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Distribution of Heavy Metals and Potential Human Health Risk in Fish Species from Komadugu River Basin, Yobe State, Nigeria

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ABSTRACT

Fish samples (*Clarias anguillaris, Synodontis budgetti* and *Heterotis niloticus*) were collected during the rainy and dry season from Komadugu river basin, Yobe State, Nigeria and identified by a fisheries scientist for the determination of some heavy metals. The concentrations of heavy metals were determined using Atomic Absorption Spectroscopy (AAS) and X-Ray Fluorescence (XRF).Fish samples of uniform size and weight were collected and dissected to remove the flesh, liver, intestine and gills and prepared according to standard method. *Heterotis niloticus* were observed to show the highest total concentration of the heavy metals studied with a value of 2.19E+03 mg/kg, while *Clarias anguillaris* shows the lowest concentration with a value of 0.03 mg/kg. The accumulation of heavy metals in the tissues of fish samples were observed to be in the order of gills>liver>intestine>flesh in both methods. The concentrations of all heavy metals were significantly higher using XRF method when compared with AAS. Fe shows the highest average daily intake (ADI) value of 1.53E+00 mg/kg/day in *Clarias anguillaris,* while *Synodontis budgetti* shows the lowest value of ADI value of 8.23E-01 mg/kg/day among all the four species of fish samples studied. From the results obtained, the hazard quotient (HQ) values of some of the heavy metals in the fish samples during the rainy season were all above one (1). The lowest HQ value of 9.00E-08 in all the fish samples study was lower than 1, while the highest HQ of 1.50E+01 is greater than one (1). The highest and lowest cancer risks chances for the studied fish species were computed as 5.10E-02 and 5.40E-07 respectively. These risk values indicate that consumption of fish from the study area would result in an excess of 5 cancer cases per 1,000,000 people.

Keywords: Fish, Heavy Metals, Komadugu, Risk Assessment, Species

INTRODUCTION

Fish, apart from being a good source of digestible protein, vitamins, minerals and polyunsaturated fatty acids are also an important source of essential heavy metals. In the future, seafood will even be a more important source of food protein than they are today and the safety for human consumption of products from aquaculture is of public health interest (WHO, 1999). Fish are often at the top of aquatic food chain and may concentrate large amounts of some metals from the water (Mansour and Sidky, 2002). Unlike organic contaminants that loose toxicity with time by biodegradation, heavy metals cannot be degraded; their concentration can be increased by bioaccumulation (Aksoy, 2008). Metal bioaccumulation by fish and subsequent distribution in organs is greatly interspecific. In addition, many factors can influence metal uptake like sex, age, size, reproductive cycle, swimming pattern, feeding behavior, and geographical location (Tawari-Fufeyin and Ekaye, 2007; Bawuro *et al.*, 2018). Generally, bioaccumulation and biomagnification occur due to longstanding anthropogenic activities within a coastal ecosystem. The accumulation of heavy metals in fish organs could also be driven by physiochemical and biological variables such as pH, temperature, hardness, exposure duration, feeding habits of species and habitat complexity (Ahmed *et al.*, 2019). Industrial development; fertilizers; livestock manure; air pollution; increases in pesticide usage and mining have led to increasing levels of heavy metals in aquatic environments (Cooper, 1993; Guerrero and Kesten, 1993).

Metal residues problems in the fish tissues are serious, as reflected by the high metal concentrations recorded in the water and sediments (Wong *et al.*, 2001). The gills are directly in contact with water. Therefore, the concentration of metals in gills reflects their concentration in water where the fish live, whereas the concentrations in liver represent storage of metals in the water (Romeo *et al.*, 1999). Studies on heavy metals in rivers, lakes, fish and sediments (Özmen *et al.*, 2004; Begüm *et al.*, 2005; Fernandes *et al.*, 2008; Öztürk *et al.*, 2008; Pote *et al.*, 2008; Praveena *et al.*, 2008) have been a major environmental focus, especially during the last decade. Sediments are important sinks for various pollutants like pesticides and heavy metals and also play a significant role in the remobilization of contaminants in aquatic systems under favorable conditions and in interactions between water and sediment. Fish samples can be considered as one of the most significant indicators in fresh water systems for the estimation of metal pollution level (Rashed, 2001).

The Komadugu-Yobe River Basin is situated in the Sudan-Sahel zone of Northeast Nigeria (85,000 $km^{2)}$) (WRECA, 1972) and Southeast Niger (63,000 km^2) (Oyebande, 2001). Fishing is an important activity in the study Basin. Fishing seasons vary between villages but the flood plain as a whole has an annual pattern of fishing activity related to the rise and fall of the rains. The intensity of fishing activity is low during the rains (June - September), highest at the end of the rainy season and the beginning of the dry season (November - February). The activity gradually declines during the course of the dry season. According to Matthes (1990), in order to maintain the economic fishing activity in the Basin, the minimum water depth of about one meter is required in the riverbed and flood plains. Water quality characteristics of aquatic environment arise from a multitude of physical, chemical and biological interactions. This work is aimed at assessing the levels of heavy metals in tissues of some fish species and their human health risk evaluation.

MATERIALS AND METHODS

Fish Sampling

Fish species namely: *Clarias anguillaris, Synodentis budgetti and Heterotis niloticus* were collected from Komadugu River Basin (Gashua and Nguru) through the employment of local fishermen. Fish samples of uniform size and weight were collected in order to avoid the possible error due to size differences. The fish samples were labelled with unique identification number and identified by an expert in the Department of Fisheries, University of Maiduguri and later dissected to remove the flesh, liver, intestine and gills of each species of fish and transferred into amber glass bottles and stored in an iced box pending further analysis. The study fish samples were prepared using method as described by Radojevic and Bashkin (1999) and adopted by Akan *et al.* (2010). Determination of Pb, Fe, Cu, Zn, Cd, Ni, Mn, As and Cr were carried out using Perkin-Elmer A Analyst 300 Atomic Absorption Spectroscopy (AAS) and EA1400 X-ray Fluorescence (XRF) Analyzer. The map of Komadugu-Yobe river basin showing the sampling points is shown in Figure 1.

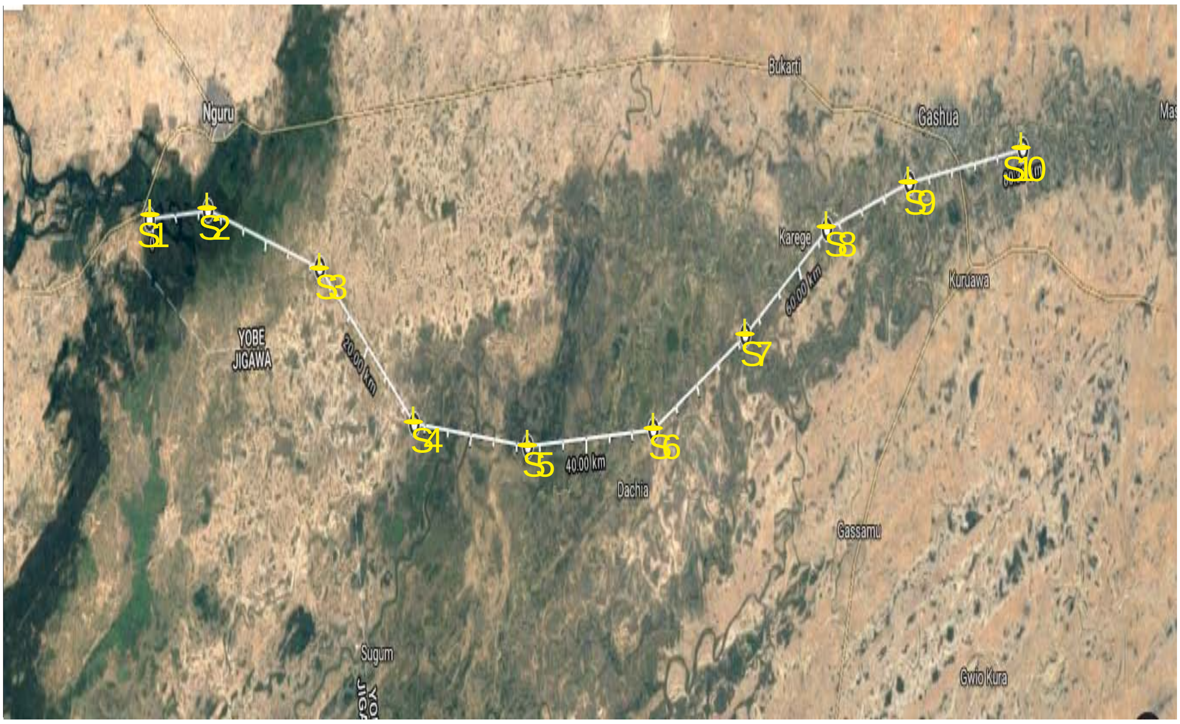

Fig. 1: Map of Komadugu-Yobe River Basin Showing Sampling Points

Risk Assessment of Some Heavy Metals in Tissues of Fish Samples

Potential cancer risks associated with exposure to a measured dose of chemical contaminant can be estimated using the incremental lifetime cancer risk (ILCR). Incremental lifetime cancer risk is obtained using the Cancer Slope Factor (CSF), which is the risk produced by a lifetime average dose of 1 $mgkg^{-1}$ body weight day^{-1} and is contaminant specific (USEPA, 2013). The associated dose is called the Lifetime Average Daily intake (ADI) or Chronic Daily Intake (CDI). It was worked out for As, Cd and Pb using equation (1).

$$ILCR=ADI \ x \ CSF \qquad (1)$$

Average daily intake upon the consumption of fish was calculated using equation (2).

$$Average\ Daily\ Intake = \frac{C \ x \ IR \ x \ EF \ x \ ED}{BW \ x \ AT} \qquad (2)$$

Where, C = Contaminant concentration in cereals (mg kg^{-1}); IR = Ingestion rate per unit time or event (kg day^{-1}); EF = Exposure frequency (days/year); ED = Exposure duration (70 years; lifetime; by convention) is the length of time that a receptor is exposed via a specific exposure pathway; BW = Body weight; AT =Pathway specific period of exposure for no carcinogenic effects (i.e., ED×365days/year) and 70-year lifetime for carcinogenic effects (70 years×365 days/year)

Hazard quotient (HQ) is defined as the ratio of the average daily intake or dose (ADI) (mg/(kg/day) to the reference dose (RfD, mg/(kg/day). The potential health risk of individual fish for heavy metal is characterized using a hazard quotient (HQ). The non-cancer hazard quotient (HQ) assumes that there is a level of exposure known as the reference dose (RfDo), which is a daily oral intake rate that is estimated to pose no appreciable risk of adverse health effects, even to sensitive populations, over a 70-year lifetime (USEPA, 2005a). The reference dose is an estimate of a daily exposure to the human population (Acceptable daily intake). If the value of HQ is less than 1, then the exposed local population (consumers) is said to be safe, if HQ is equal to or higher than 1, it is considered not safe for human health, therefore potential health risk occurs and related interventions and protective measurements should be taken (USEPA, 2013). An estimate of risk to human health (HQ) through consumption of fish was calculated using equation 3.

$$\text{Hazard Quotient (HQ)} = \text{ADI (mg/kg/day)}/RfD_{O,} \quad (3)$$

where, RfDo is the oral reference dose. RfDo is an estimate of a daily oral exposure for the human population, which does not cause deleterious effects during a lifetime (USEPA, 2013). To estimate the risk to human health through more than one heavy metal, the hazard index (HI) was developed by USEPA, (2013). The hazard index is the sum of the hazard quotients for all heavy metals, which was calculated using equation (4) (Guerra *et al.* 2010).

$$\text{Total Chronic Hazard Index (THI)} = \sum HQ \quad (4)$$

RESULTS AND DISCUSSION

Distribution of Heavy Metals in Fish Samples

The results of this study showed that the highest heavy metal concentrations were found in the livers and intestine of all sampled fishes. These results are similar to other studies that showed the bioaccumulation of heavy metals in the livers and intestine of fishes was higher than the concentrations of heavy metals in the muscles or flesh of fishes (Mensoor and Said, 2018). The distribution of heavy metals in all the fish tissues studied are in the order of liver>intestine >gills>flesh**.** The levels of copper in the different tissues of the three species of fish ranged between 2.00E-02 and 8.46E+02 mg/kg (Tables 1 - 3).

Table 1: Mean Concentrations of Some Heavy Metals (mg/kg) in Different Tissues of *Heterotis niloticus* of Komadugu River Basin

Rainy Season										
Method	**Tissues**	**Fe**	**Pb**	**Cu**	**Zn**	**Cd**	**Ni**	**Mn**	**As**	**Cr**
	Flesh	3.76E+01	1.81E+00	2.00E-02	1.76E+01	2.00E-03	6.00E-02	6.86E+00	1.00E-04	5.00E-01
	Gill	1.95E+02	3.45E+00	2.06E+01	7.65E+01	1.70E-01	3.92E+00	1.17E+01	1.00E-04	6.00E-03
	Intestine	5.86E+01	1.66E+00	9.30E-01	6.18E+01	1.80E-01	6.00E-02	5.35E+01	1.00E-04	6.00E-03
AAS	**Liver**	9.71E+01	2.31E+00	2.00E-02	5.20E+01	2.00E-03	6.00E-02	2.40E+01	1.00E-04	6.00E-03
	Total	**3.88E+02**	**9.23E+00**	**2.16E+01**	**2.08E+02**	**3.54E-01**	**4.10E+00**	**9.61E+01**	**4.00E-04**	**5.18E-01**
	Flesh	1.34E+02	1.00E+00	3.20E+00	4.29E+01	2.00E+00	5.10E+00	6.00E+00	5.00E-01	6.40E+00
	Gill	1.28E+02	1.00E+00	3.10E+00	2.10E+02	2.00E+00	4.10E+00	1.84E+01	5.00E-01	5.00E+00
	Intestine	2.44E+02	1.00E+00	4.50E+00	1.30E+02	2.00E+00	6.80E+00	8.17E+01	5.00E-01	3.10E+00
XRF	**Liver**	2.22E+02	1.00E+00	1.43E+01	3.84E+02	2.00E+00	3.90E+00	1.75E+01	5.00E-01	8.60E+00
	Total	**7.28E+02**	**4.00E+00**	**2.51E+01**	**7.67E+02**	**8.00E+00**	**1.99E+01**	**1.24E+02**	**2.00E+00**	**2.31E+01**

Dry Season										
Method	**Tissues**	**Fe**	**Pb**	**Cu**	**Zn**	**Cd**	**Ni**	**Mn**	**As**	**Cr**
	Flesh	5.23E+01	8.00E-03	7.37E+01	1.11E+01	2.11E+00	1.02E+01	4.18E+00	5.00E-02	6.00E-03
	Gill	1.19E+02	8.00E-03	2.87E+02	3.88E+01	1.33E+01	1.23E+01	6.63E+00	1.00E-01	6.00E-03
	Intestine	5.31E+02	8.00E-03	1.66E+02	2.84E+01	6.36E+00	1.34E+01	5.16E+00	7.00E-02	6.00E-03
AAS	**Liver**	4.33E+02	8.00E-03	5.29E+01	1.69E+02	7.78E+00	4.10E+00	7.99E+00	8.00E-02	6.00E-03
	Total	**1.14E+03**	**3.20E-02**	**5.80E+02**	**2.47E+02**	**2.96E+01**	**4.00E+01**	**2.40E+01**	**3.00E-01**	**2.40E-02**
	Flesh	1.20E+02	1.00E+00	6.10E+00	7.45E+01	2.10E+00	1.13E+01	1.48E+01	5.00E-01	2.03E+01
	Gill	1.40E+03	1.00E+00	7.99E+01	1.72E+02	2.80E+00	1.94E+01	2.22E+01	5.00E-01	1.68E+01
	Intestine	1.03E+03	1.00E+00	6.30E+01	1.00E+02	3.00E+00	1.03E+01	1.40E+01	5.00E-01	1.41E+01
XRF	**Liver**	1.19E+03	1.00E+00	6.00E+00	3.99E+01	1.10E+00	1.23E+01	6.40E+01	4.70E+00	2.50E+01
	Total	**3.74E+03**	**4.00E+00**	**1.55E+02**	**3.86E+02**	**9.00E+00**	**5.33E+01**	**1.15E+02**	**6.20E+00**	**7.62E+01**

Table 2: Mean Concentrations of Some Heavy Metals (mg/kg) in different Tissues of *Synodontis budgetti* from of Komadugu River Basin

Rainy Season										
Method		Fe	Pb	Cu	Zn	Cd	Ni	Mn	As	Cr
	Flesh	8.17E+01	8.00E-03	9.15E+01	2.11E+01	1.48E+01	1.23E+01	7.08E+00	2.00E-02	6.00E-03
	Gill	5.05E+01	8.00E-03	5.60E+01	2.72E+01	2.00E-03	1.95E+01	1.63E+00	7.00E-02	6.00E-03
	Intestine	6.85E+02	8.00E-03	2.23E+01	9.31E+01	2.00E-03	6.37E+00	8.57E+00	1.00E-02	6.00E-03
AAS	**Liver**	7.02E+02	8.00E-03	1.27E+02	3.63E+01	2.00E-03	3.17E+01	2.26E+01	8.00E-02	6.00E-03
	Total	**1.52E+03**	**3.20E-02**	**2.97E+02**	**1.78E+02**	**1.48E+01**	**6.99E+01**	**3.99E+01**	**1.80E-01**	**2.40E-02**
	Flesh	9.55E+01	1.00E+00	4.70E+00	9.57E+01	3.20E+00	9.90E+00	1.20E+01	5.00E-01	1.43E+01
	Gill	1.03E+03	1.00E+00	1.27E+01	9.19E+01	2.00E+00	1.33E+01	7.41E+01	5.00E-01	1.94E+01
	Intestine	1.61E+02	1.00E+00	1.56E+01	1.17E+02	2.00E+00	1.45E+01	3.13E+01	5.00E-01	1.00E+00
XRF	**Liver**	9.14E+02	1.00E+00	1.02E+01	1.17E+02	2.00E+00	1.16E+01	6.97E+01	5.00E-01	5.60E+00
	Total	**2.20E+03**	**4.00E+00**	**4.32E+01**	**4.22E+02**	**9.20E+00**	**4.93E+01**	**1.87E+02**	**2.00E+00**	**4.03E+01**

Dry Season										
Method	**Tissues**	**Fe**	**Pb**	**Cu**	**Zn**	**Cd**	**Ni**	**Mn**	**As**	**Cr**
	Flesh	2.79E+01	2.76E+00	8.00E-02	2.01E+01	1.20E-01	6.00E-02	7.74E+00	1.00E-04	9.50E-01
	Gill	1.80E+02	4.00E-02	2.00E-02	6.18E+01	2.00E-03	6.00E-02	1.23E+01	1.00E-04	6.00E-03
	Intestine	2.44E+02	1.85E+00	3.03E+01	3.75E+01	2.90E-01	9.78E+00	2.13E+01	1.00E-04	5.00E-01
AAS	**Liver**	5.84E+01	3.11E+00	2.00E-02	7.93E+00	1.40E-01	6.00E-02	3.14E+00	1.00E-04	1.37E+00
	Total	**5.10E+02**	**7.76E+00**	**3.04E+01**	**1.27E+02**	**5.52E-01**	**9.96E+00**	**4.45E+01**	**4.00E-04**	**2.83E+00**
	Flesh	1.95E+02	1.00E+00	1.30E+00	5.01E+01	2.00E+00	5.30E+00	7.00E+00	5.00E-01	7.10E+00
	Gill	3.73E+02	1.00E+00	4.80E+00	1.04E+02	2.00E+00	6.60E+00	1.59E+01	5.00E-01	2.97E+00
	Intestine	2.28E+02	1.00E+00	6.10E+00	2.10E+02	2.00E+00	7.70E+00	7.71E+01	5.00E-01	5.10E+00
XRF	**Liver**	1.23E+02	1.00E+00	1.06E+01	1.38E+02	2.00E+00	8.20E+00	3.01E+01	5.00E-01	3.40E+00
	Total	**9.19E+02**	**4.00E+00**	**2.28E+01**	**5.02E+02**	**8.00E+00**	**2.78E+01**	**1.30E+02**	**2.00E+00**	**1.86E+01**

Table 3: Mean Concentrations of Some Heavy Metals (mg/kg) in different tissues of *Clarias anguillaris* from of Komadugu River Basin

Rainy Season										
Method	**Tissues**	**Fe**	**Pb**	**Cu**	**Zn**	**Cd**	**Ni**	**Mn**	**As**	**Cr**
	Flesh	6.21E+01	8.00E-03	5.68E+01	1.16E+01	2.00E-03	4.58E+02	2.04E+00	2.00E-02	6.00E-03
	Gill	7.47E+02	8.00E-03	6.55E+02	7.62E+00	2.00E-03	1.09E+02	9.48E+00	1.00E-04	2.04E+00
	Intestine	9.25E+02	8.00E-03	8.46E+02	9.91E+00	2.00E-03	2.31E+02	2.40E+01	1.00E-04	6.00E-03
AAS	**Liver**	4.59E+02	8.00E-03	1.85E+01	7.17E+00	2.00E-03	2.40E+00	5.00E-02	1.00E-02	6.00E-03
	Total	**2.19E+03**	**3.20E-02**	**1.58E+03**	**3.63E+01**	**8.00E-03**	**8.00E+02**	**3.56E+01**	**3.02E-02**	**2.06E+00**
	Flesh	2.04E+02	1.00E+00	4.10E+00	1.23E+02	2.50E+00	1.00E+01	2.10E+01	5.00E-01	1.35E+01
	Gill	1.05E+02	1.00E+00	1.02E+01	8.44E+01	2.20E+00	1.12E+01	2.97E+01	5.00E-01	1.74E+01
	Intestine	4.36E+02	1.00E+00	5.80E+00	1.32E+02	2.00E+00	1.25E+01	3.35E+01	5.00E-01	1.56E+01
XRF	**Liver**	1.73E+02	1.00E+00	8.30E+00	6.53E+01	2.00E+00	1.12E+01	1.62E+01	5.00E-01	1.45E+01
	Total	**9.18E+02**	**4.00E+00**	**2.84E+01**	**4.05E+02**	**8.70E+00**	**4.49E+01**	**1.00E+02**	**2.00E+00**	**6.10E+01**

Dry season										
Method	**Tissues**	**Fe**	**Pb**	**Cu**	**Zn**	**Cd**	**Ni**	**Mn**	**As**	**Cr**
	Flesh	4.09E+01	1.31E+00	2.00E-02	2.16E+01	2.60E-01	6.00E-02	7.70E+00	1.00E-04	9.90E-01
	Gill	1.47E+02	8.00E-03	7.29E+00	3.90E+01	2.90E-01	1.03E+00	1.34E+01	1.00E-04	2.50E+00
	Intestine	2.64E+02	7.70E-01	2.00E-02	5.76E+01	2.00E-03	6.00E-02	5.02E+01	1.00E-04	3.27E+00
AAS	**Liver**	7.54E+02	3.80E-01	1.64E+01	5.19E+01	1.40E-01	6.00E-02	6.59E+00	1.00E-04	2.58E+00
	Total	**1.21E+03**	**2.47E+00**	**2.37E+01**	**1.70E+02**	**6.92E-01**	**1.21E+00**	**7.79E+01**	**4.00E-04**	**9.34E+00**
	Flesh	1.22E+02	1.00E+00	3.30E+00	4.33E+01	2.00E+00	4.00E+00	6.20E+00	5.00E-01	6.00E+00
	Gill	1.13E+02	1.00E+00	2.90E+00	6.00E+01	2.00E+00	5.15E+00	1.86E+01	5.00E-01	4.00E+00
	Intestine	1.70E+03	1.00E+00	5.50E+02	1.17E+02	2.00E+00	1.05E+01	7.52E+01	5.00E-01	3.80E+02
XRF	**Liver**	1.61E+03	1.00E+00	4.66E+01	1.09E+02	2.00E+00	4.10E+00	9.60E+00	5.00E-01	4.60E+00
	Total	**3.55E+03**	**4.00E+00**	**6.03E+02**	**3.29E+02**	**8.00E+00**	**2.38E+01**	**1.10E+02**	**2.00E+00**	**3.95E+02**

The highest concentration of copper (8.46E+02 mg/kg) was detected in the intestine of *Clarias anguillaria*, while the lowest detected limit (2.00E-02 mg/kg) was found in the flesh of *Heterotis niloticus*. The liver and the gills also concentrate higher levels of copper in *Heterotis niloticus* and *Synodontis budgetti*. This high level of copper in the liver tissues of the two fishes might be due to the fact that, the liver is a target organ for the accumulation of this element. For the gills, it may be due to the fact that freshwater fish gills might be expected to be the primary route for the uptake of water borne pollutants (Allen and Wilson, 1991). WHO (1989) reported that copper toxicity in fish may be due to the fact that the copper is taken up directly from the water via the gills and stored in the liver. The present study showed a similar accumulation of copper in the gills and livers. The high concentration of heavy metals in the gills was due to the fact that the gills in fresh waterfishes are the main entry point for any dissolved heavy metals (Mensoor and Said, 2018). The effects of high concentrations of copper in fish are not well established; however, there is evidence that high concentrations in fish can lead to toxicity (Woodward *et al.*, 1994). Copper can combine with other contaminants such as ammonia, mercury and zinc to produce an additive toxic effect on fish (Agbugui and Abe, 2022). However, the mean concentrations of copper levels in liver, intestine, gills and flesh of *Heterotis niloticus, Clarias anguillaris and Synodentis budgetti* from the study area were above the maximum level of 1.0 mg/kg.

Lead accumulates significantly in the liver, intestine, gills and flesh of *Heterotis niloticus, Clarias anguillaris and Synodontis budgetti*. The highest levels of lead (3.45E+00) was observed in the live tissue of *Synodentis niloticus*, while the lowest limit (8.00E-03 mg/kg) was detected in the flesh of all the fish samples. The concentrations of lead were higher in the following order liver>gills>intestine>flesh. Similar findings were reported by Buhler *et al.,* (1977) that the highest concentrations were in the gills of rainbow trout. Oladimeji and Offem, (1989) noticed in *Oreochromis niloticus*, that the gills consistently accumulated higher amount of lead as lead nitrate. Lead is highly toxic to aquatic organisms, especially fish (Agbugui and Abe, 2022). The biological effects of sublethal concentrations of lead include delayed embryonic development, suppressed reproduction and inhibition of growth, increased mucous formation, neurological problems, enzyme inhalation and kidney dysfunction (Agbugui and Abe, 2022;Leland andKuwabara, 1985). The levels of lead in the liver, intestine and gills of *Heterotis niloticus, Clarias anguillaris and Synodentis budgetti* were above the 0.5 mg/kg limit (Walsh *et al.*, 1977) with the exception of the flesh which was lower than the said limit.

It was observed that the concentrations of chromium in the different tissues of the three fish species from the study area varied from one tissue to another. The maximum concentration of chromium (3.80E+02 mg/kg) was detected in the liver of *Clarias anguillaris*, while the minimum was observed in the flesh of *Heterotis niloticus*. Optimum Cr concentration in the diet has an important role in lipid and glucose metabolism. However, the excess Cr consumption may lead to acute pulmonary disorders and organ damage like lungs, kidney, and liver. The recommended maximum permissible concentration for Cr is 50 mg/kg from the WHO (Hossain *et al.*, 2022). In view of other sanctions, the present chromium concentrations in the tissues of *Heterotis niloticus, Clarias anguillaris and Synodentis budgetti* were well above the levels validated by USEPA (1987) (0.001mg/kg) for fish tissue (Pastorok,1987). However, surveys of contaminants in edible shellfish conducted by the FDA and the National Marine Fisheries Service reported chromium levels from 0.1 up to 0.9 mg/kg (Adams *et al*., 1993) which is in line with the above threshold. The present chromium tissues concentration for this study was above 4.0 mg/kg levels suggested by Eisler, (1986) as indicative of Cr contamination, with the exception of flesh which were above the said limit.

Mn tends to reside in the gills in all the fish samples studied, while the flesh showed the lowest accumulated tissue. Hence, Mn concentrations in the entire species of fish were above the limit of 0.7 mg/kg set by Charbonneau and Nash (1993) thus constituting a threat upon consumption of these species of fish, with the exception of the liver in *Clariias anguilaris*.

In contrast to earlier reports showing iron (Fe) to be highest in the gills and the liver (Mensoor and Said, 2018). The Fe concentration was the maximum obtained compared to all other elements analyzed in the different species offishes (Hossain*et al.*, 2022). This higher concentration could also be attributed to the fact that iron is naturally abundant in soil in Nigeria since the sources of iron depositories are the aquatic system (Elinge *et al.*, 2019). The present study showed intestine and gills containing the highest Fe concentrations. The concentration of iron in the three species of fish varied from 3.76E+01 to 1.70E+03 mg/kg. The concentrations were below the high residue of Fe (34-107 ppm) in fish samples on MNW Refuge as reported by Charbonneau and Nash (1993). The highest level of iron was observed in the intestine of *Clarias anguilaria,* while the flesh of *Heterotis niloticus* shows the least concentration.

The concentration of nickel in the fish tissues are in the order liver> gill>intestine>flesh. Nickel level of 0.7 mg/kg is considered potentially lethal to fish and aquatic birds that consume them (Lemly, 1993). Nickel concentration of 2.3 mg/kg or greater, may cause reproductive impairment and lack of recruitment in fishes (Baumann and May, 1984). With the exception of the flesh, all the other tissues of the studied fish species contain higher Ni levels. Hence, nickel concentration in the entire species of fish constitute a threat upon its consumption. The highest concentrationof cadmium (1.48E+01 mg/kg) was observed in the flesh of *Synodontis budgetti*, while the lowest concentration (2.00E-03 mg/kg) was detected in the intestine.

Cadmium is a nonessential trace metal that is potentially toxic to most fish and wildlife, particularly freshwater organisms causing reduction in calcium availability, endocrine disruption, and infertility (Ehiemere *et al.,* 2022). The highest concentration of 1.48E+01 mg/kg was above the 0.5 mg/kg threshold considered harmful to fish and predators (Walsh *et al.*, 1977). Zinc was detected in all the fish samples, and the highest concentration was observed in the intestine followed by the liver, while the flesh showed the least concentrations. The concentrations of Zn in the liver, intestine and gills of *Heterotis niloticus, Clarias anguillaris* and *Synodentis budgetti* were below the NCBP 34.2 mg/kg. Fish can accumulate zinc from both the surrounding water and from their diet (Bawuro *et al.*, 2018). Although zinc is an essential element, at high concentrations, it can be toxic to fish, cause mortality, growth retardation and reproductive impairment (Sorenson, 1991). Zinc is capable of interacting with other elements and producing antagonistic, additive, or synergistic effects (Bawuro *et al.*, 2018). Based on the results, Zn appears to be hazardous to the fish.

Arsenic was detected in all the fish tissues sampled, with concentrations ranging from 1.00E-04 to 4.70E+00 mg/kg. The highest concentration of arsenic was observed in liver, while the flesh showed the least concentration. Arsenic in the liver of *Heterotis niloticus* was above NCBP 0.27 mg/kg value (Schmitt and Brumbaugh 1990). Walsh *et al.* (1977) considered that arsenic concentrations >0.5 mg/kg could harm fish. Based on the above level, the study area contained fish with arsenic concentration relatively above this potentially harmful threshold.

Average Daily Intake of Heavy Metals in Fish

The degree of toxicity of heavy metal to human being depends upon their daily intake (Singh *et al.*, 2010). Average daily intake is a function of body weight and intake. In the present study, the highest ADI value for Fe in all the fish was 1.53E+00 mg/kg per day in *Clarias anguillaria*; 1.26E+00 mg/kg per day in *Heterotis niloticus* and 9.29E-01 in *Synodentis budgetti*. The highest daily dose of Cd was estimated as 1.20E-02 mg/kg per day in *Heterotis niloticus*, while the lowest daily dose of Cd was estimated as 1.80E-06 mg/kg per day in all the four species of fish samples. The lower ADI values in all the fish samples studied were lower than 0.008 and 0.052 mg/kg per day(Santos *et al.*, 2004; Tripathi *et al.*,1997). Sridhara-Chary *et al.* (2008) recorded higher ADI values for heavy metals than tolerable daily intake limits. In all fish samples studied, the estimated average daily intake of heavy metals through the consumption of fish was lower than the tolerable daily intake limit set by the USEPA, (2013). With exception of Fe which was higher than the set limit. The observed results show that, there is probably no risk upon the consumption of the fish samples studied (Tables 4 – 6).

Table 4: Average Dietary Intake of Some Heavy Metals in Different Tissues of *Heterotis niloticus*

Rainy season								
Method	**Tissues**	**Fe**	**Pb**	**Cu**	**Zn**	**Cd**	**As**	**Cr**
	Flesh	4.68E-02	7.20E-06	6.63E-02	9.99E-03	1.90E-03	4.50E-05	5.40E-06
	Gill	1.07E-01	7.20E-06	2.58E-01	3.49E-02	1.20E-02	9.00E-05	5.40E-06
	Intestine	4.78E-01	8.10E-06	1.49E-01	2.56E-02	5.72E-03	6.30E-05	5.40E-06
AAS	**Liver**	3.90E-01	7.20E-06	4.76E-02	1.52E-01	7.00E-03	7.20E-05	5.40E-06
	Total	**1.02E+00**	**2.97E-05**	**5.22E-01**	**2.23E-01**	**2.66E-02**	**2.70E-04**	**2.16E-05**
	Flesh	1.08E-01	9.00E-04	5.49E-03	6.71E-02	1.89E-03	4.50E-04	1.83E-02
	Gill	1.26E+00	9.00E-04	7.19E-02	1.55E-01	2.52E-03	4.50E-04	1.51E-02
	Intestine	9.24E-01	9.00E-04	5.67E-02	9.00E-02	2.70E-03	4.50E-04	1.27E-02
XRF	**Liver**	1.07E+00	9.00E-04	5.40E-03	3.59E-02	9.90E-04	4.23E-03	2.25E-02
	Total	**3.37E+00**	**3.60E-03**	**1.40E-01**	**3.48E-01**	**8.10E-03**	**5.58E-03**	**6.86E-02**

Dry season								
Method	**Tissues**	**Fe**	**Pb**	**Cu**	**Zn**	**Cd**	**As**	**Cr**
	Flesh	3.38E-02	1.63E-03	1.80E-05	1.58E-02	1.80E-06	9.00E-08	4.50E-04
	Gill	1.76E-01	3.11E-03	1.85E-02	6.89E-02	1.53E-04	9.00E-08	5.40E-06
	Intestine	5.27E-02	1.49E-03	8.37E-04	5.56E-02	1.62E-04	9.00E-08	5.40E-06
AAS	**Liver**	8.74E-02	2.08E-03	1.80E-05	4.68E-02	1.80E-06	9.00E-08	5.40E-06
	Total	**3.49E-01**	**8.31E-03**	**1.94E-02**	**1.87E-01**	**3.19E-04**	**3.60E-07**	**4.66E-04**
	Flesh	1.21E-01	9.00E-04	2.88E-03	3.86E-02	1.80E-03	4.50E-04	5.76E-03
	Gill	1.15E-01	9.00E-04	2.79E-03	1.89E-01	1.80E-03	4.50E-04	4.50E-03
	Intestine	2.20E-01	9.00E-04	4.05E-03	1.17E-01	1.80E-03	4.50E-04	2.79E-03
XRF	**Liver**	2.00E-01	9.00E-04	1.29E-02	3.46E-01	1.80E-03	4.50E-04	7.74E-03
	Total	**6.55E-01**	**3.60E-03**	**2.26E-02**	**6.90E-01**	**7.20E-03**	**1.80E-03**	**2.08E-02**

Table 5: Average Dietary Intake of Some Heavy Metals in Different Tissues of *Synodontis budgetti*

Rainy season								
Method	**Tissues**	**Fe**	**Pb**	**Cu**	**Zn**	**Cd**	**As**	**Cr**
	Flesh	7.35E-02	7.20E-06	8.24E-02	1.90E-02	1.33E-02	1.80E-05	5.40E-06
	Gill	4.55E-02	7.20E-06	5.04E-02	2.45E-02	1.80E-06	6.30E-05	5.40E-06
	Intestine	6.17E-01	7.20E-06	2.01E-02	8.38E-02	1.80E-06	9.00E-06	5.40E-06
AAS	**Liver**	6.32E-01	7.20E-06	1.14E-01	3.27E-02	1.80E-06	7.20E-05	5.40E-06
	Total	**1.37E+00**	**2.88E-05**	**2.67E-01**	**1.60E-01**	**1.33E-02**	**1.62E-04**	**2.16E-05**
	Flesh	8.60E-02	9.00E-04	4.23E-03	8.61E-02	2.88E-03	4.50E-04	1.29E-02
	Gill	9.29E-01	9.00E-04	1.14E-02	8.27E-02	1.80E-03	4.50E-04	1.75E-02
	Intestine	1.45E-01	9.00E-04	1.40E-02	1.05E-01	1.80E-03	4.50E-04	9.00E-04
XRF	**Liver**	8.23E-01	9.00E-04	9.18E-03	1.05E-01	1.80E-03	4.50E-04	5.04E-03
	Total	**1.98E+00**	**3.60E-03**	**3.89E-02**	**3.79E-01**	**8.28E-03**	**1.80E-03**	**3.63E-02**

Dry season								
Method	**Tissues**	**Fe**	**Pb**	**Cu**	**Zn**	**Cd**	**As**	**Cr**
	Flesh	2.51E-02	2.48E-03	7.20E-05	1.81E-02	1.08E-04	9.00E-08	8.55E-04
	Gill	1.62E-01	3.60E-05	1.80E-05	5.56E-02	1.80E-06	9.00E-08	5.40E-06
	Intestine	2.20E-01	1.67E-03	2.73E-02	3.38E-02	2.61E-04	9.00E-08	4.50E-04
AAS	**Liver**	5.26E-02	2.80E-03	1.80E-05	7.14E-03	1.26E-04	9.00E-08	1.23E-03
	Total	**4.59E-01**	**6.98E-03**	**2.74E-02**	**1.15E-01**	**4.97E-04**	**3.60E-07**	**2.54E-03**
	Flesh	1.76E-01	9.00E-04	1.17E-03	4.51E-02	1.80E-03	4.50E-04	6.39E-03
	Gill	3.36E-01	9.00E-04	4.32E-03	9.36E-02	1.80E-03	4.50E-04	2.67E-03
	Intestine	2.05E-01	9.00E-04	5.49E-03	1.89E-01	1.80E-03	4.50E-04	4.59E-03
XRF	**Liver**	1.11E-01	9.00E-04	9.54E-03	1.24E-01	1.80E-03	4.50E-04	3.06E-03
	Total	**8.27E-01**	**3.60E-03**	**2.05E-02**	**4.52E-01**	**7.20E-03**	**1.80E-03**	**1.67E-02**

Table 6: Average Dietary Intake of Some Heavy Metals in Different Tissues of *Clarias anguillaris*

Rainy season								
Method	**Tissues**	**Fe**	**Pb**	**Cu**	**Zn**	**Cd**	**As**	**Cr**
	Flesh	5.59E-02	7.20E-06	5.11E-02	1.04E-02	1.80E-06	1.80E-05	5.40E-06
	Gill	6.72E-01	7.20E-06	5.90E-01	6.86E-03	1.80E-06	9.00E-08	1.84E-03
	Intestine	8.33E-01	7.20E-06	7.61E-01	8.92E-03	1.80E-06	9.00E-08	5.40E-06
AAS	**Liver**	4.13E-01	7.20E-06	1.67E-02	6.45E-03	1.80E-06	9.00E-06	5.40E-06
	Total	**1.97E+00**	**2.88E-05**	**1.42E+00**	**3.27E-02**	**7.20E-06**	**2.72E-05**	**1.85E-03**
	Flesh	1.84E-01	9.00E-04	3.69E-03	1.11E-01	2.25E-03	4.50E-04	1.22E-02
	Gill	9.45E-02	9.00E-04	9.18E-03	7.60E-02	1.98E-03	4.50E-04	1.57E-02
	Intestine	3.92E-01	9.00E-04	5.22E-03	1.19E-01	1.98E-03	4.50E-04	1.57E-02
XRF	**Liver**	1.56E-01	9.00E-04	7.47E-03	5.88E-02	1.80E-03	4.50E-04	1.31E-02
	Total	**8.26E-01**	**3.60E-03**	**2.56E-02**	**3.64E-01**	**8.01E-03**	**1.80E-03**	**5.65E-02**

Dry season								
Method	**Tissues**	**Fe**	**Pb**	**Cu**	**Zn**	**Cd**	**As**	**Cr**
	Flesh	3.68E-02	1.18E-03	1.80E-05	1.94E-02	2.34E-04	9.00E-08	8.91E-04
	Gill	1.32E-01	7.20E-06	6.56E-03	3.51E-02	2.61E-04	9.00E-08	2.25E-03
	Intestine	2.38E-01	6.93E-04	1.80E-05	5.18E-02	1.80E-06	9.00E-08	2.94E-03
AAS	**Liver**	6.79E-01	3.42E-04	1.48E-02	4.67E-02	1.26E-04	9.00E-08	2.32E-03
	Total	**1.09E+00**	**2.22E-03**	**2.14E-02**	**1.53E-01**	**6.23E-04**	**3.60E-07**	**8.41E-03**
	Flesh	1.10E-01	9.00E-04	2.97E-03	3.90E-02	1.80E-03	4.50E-04	5.40E-03
	Gill	1.02E-01	9.00E-04	2.61E-03	5.40E-02	1.80E-03	4.50E-04	3.60E-03
	Intestine	1.53E+00	9.00E-04	4.95E-01	1.05E-01	1.80E-03	4.50E-04	3.42E-01
XRF	**Liver**	1.45E+00	9.00E-04	4.19E-02	9.81E-02	1.80E-03	4.50E-04	4.14E-03
	Total	**3.19E+00**	**3.60E-03**	**5.43E-01**	**2.96E-01**	**7.20E-03**	**1.80E-03**	**3.55E-01**

Hazard Quotient (HQ)

The hazard quotient and hazard index (HQ) values were calculated on the basis of the oral reference dose. Oral reference doses (RfDo) for heavy metals (Tables 7 – 9)).From the results obtained, the HQ values of some of the heavy metals in the fish samples during the rainy season were all above one (1), with the exception of HQ value during the dry season which was lower than 1. When HQ exceeds one (1), there is concern for health effect (Huang *et al.*, 2008). The lowest HQ value of 9.00E-08 Pb in all the fish samples study was lower than 1, while the highest HQ of 1.50E+01 As detected in all the fish samples was higher than the HQ values of one (1). The high HQ values for all the metals studied in the fish samples had greatest potential to pose a health risk to the consumers within the rainy season. The results further indicated that the population might be probably exposed to some potential health risk through the intake of heavy metals via consuming fish during the rainy season. In the present study, some heavy metals during the rainy season might be responsible for causing risk to the population that consumed the fish as the value of HQ was above 1 for some of the fish samples from the study area.

Table 7: Hazard Quotient and Hazard Index of Some Heavy Metals (mg/kg) in *Heterotis niloticus* from Komadugu River Basin

				Rainy Season				
Methods	**Tissues**	Fe	Pb	Cu	Zn	Cd	As	Cr
AAS	Flesh	6.69E-02	1.80E-03	1.66E+02	3.33E-02	1.90E+02	1.50E-01	3.60E-06
	Gill	1.53E-01	1.80E-03	6.46E+02	1.16E-01	11.97E+02	3.00E-01	3.60E-06
	Intestine	6.83E-01	2.02E-03	3.74E+02	8.52E-02	5.72E+02	2.10E-01	3.60E-06
	Liver	5.57E-01	1.80E-03	1.19E+02	5.07E-01	7.00E+02	2.40E-01	3.60E-06
	HI	**1.46E+02**	**7.43E-03**	**1.30E+03**	**7.42E-01**	**2.70E+03**	**9.00E-01**	**1.44E-05**
XRF	Flesh	1.54E-01	2.25E-01	1.37E-01	2.24E-01	1.89E+02	1.50E+02	1.22E-02
	Gill	1.81E+02	2.25E-01	1.79E+02	5.16E-01	2.52E+02	1.50E+02	1.01E-02
	Intestine	1.32E+02	2.25E-01	1.42E+02	3.00E-01	2.70E+02	1.50E+02	8.46E-03
	Liver	1.53E+02	2.25E-01	1.35E-01	1.19E-01	9.90E-01	1.41E+02	1.50E-02
	HI	**4.81E+02**	**9.00E-01**	**3.48E+02**	**1.16E+02**	**8.10E+02**	**5.90E+02**	**4.57E-02**
				Dry Season				
Method	**Tissues**	**Fe**	**Pb**	**Cu**	**Zn**	**Cd**	**As**	**Cr**
	Flesh	3.38E-02	1.63E-03	1.80E-05	1.58E-02	1.80E-06	9.00E-08	4.50E-04
	Gill	1.76E-01	3.11E-03	1.85E-02	6.89E-02	1.53E-04	9.00E-08	5.40E-06
	Intestine	5.27E-02	1.49E-03	8.37E-04	5.56E-02	1.62E-04	9.00E-08	5.40E-06
AAS	**Liver**	8.74E-02	2.08E-03	1.80E-05	4.68E-02	1.80E-06	9.00E-08	5.40E-06
	HI	**3.49E-01**	**8.31E-03**	**1.94E-02**	**1.87E-01**	**3.19E-04**	**3.60E-07**	**4.66E-04**
	Flesh	1.21E-01	9.00E-04	2.88E-03	3.86E-02	1.80E-03	4.50E-04	5.76E-03
	Gill	1.15E-01	9.00E-04	2.79E-03	1.89E-01	1.80E-03	4.50E-04	4.50E-03
	Intestine	2.20E-01	9.00E-04	4.05E-03	1.17E-01	1.80E-03	4.50E-04	2.79E-03
	Liver	2.00E-01	9.00E-04	1.29E-02	3.46E-01	1.80E-03	4.50E-04	7.74E-03
XRF	**HI**	**6.55E-01**	**3.60E-03**	**2.26E-02**	**6.90E-01**	**7.20E-03**	**1.80E-03**	**2.08E-02**

Table 8: Hazard Quotient and Hazard Index of Some Heavy Metals (mg/kg) in *Synodontis budgetti* from Komadugu River Basin

Method	Tissues	Fe	Pb	Cu	Zn	Cd	As	Cr
				Rainy Season				
AAS	Flesh	1.05E-01	1.80E-03	2.06E+02	6.33E-02	1.32E+03	6.00E-02	3.60E-06
	Gill	6.49E-02	1.80E-03	1.26 E+02	8.16E-01	1.80E-03	2.10E-01	3.60E-06
	Intestine	8.81E-01	1.80E-03	5.01E-01	2.79E-01	1.80E-03	3.00E-02	3.60E-06
	Liver	9.02E-01	1.80E-03	2.85E+02	1.10E-01	1.80E-03	2.40E-01	3.60E-06
	HI	**1.95E+02**	**7.20E-03**	**6.67**E+02	**5.33E-01**	**1.33E+03**	**5.40E-01**	**1.44E-05**
XRF	Flesh	1.23E-01	2.25E-01	1.05E-01	2.87E-01	2.88E+02	1.50E+02	8.58E-03
	Gill	1.33E+02	2.25E-01	8.50E-01	2.76E-01	1.80E+02	1.50E+02	1.64E-03
	Intestine	2.07E-01	2.25E-01	3.51E-01	3.51E-01	1.80E+02	1.50E+02	6.00E-04
	Liver	1.17E+02	2.25E-01	2.29E-01	3.51E-01	1.80E+02	1.50E+02	3.36E-03
	HI	**2.83E+02**	**9.00E-01**	**9.72E-01**	**1.26E+02**	**8.28** E+02	**6.00E+02**	**2.42E-02**
				Dry Season				
Method	**Tissues**	**Fe**	**Pb**	**Cu**	**Zn**	**Cd**	**As**	**Cr**
AAS	**Flesh**	2.51E-02	2.48E-03	7.20E-05	1.81E-02	1.08E-04	9.00E-08	8.55E-04
	Gill	1.62E-01	3.60E-05	1.80E-05	5.56E-02	1.80E-06	9.00E-08	5.40E-06
	Intestine	2.20E-01	1.67E-03	2.73E-02	3.38E-02	2.61E-04	9.00E-08	4.50E-04
	Liver	5.26E-02	2.80E-03	1.80E-05	7.14E-03	1.26E-04	9.00E-08	1.23E-03
	HI	**4.59E-01**	**6.98E-03**	**2.74E-02**	**1.15E-01**	**4.97E-04**	**3.60E-07**	**2.54E-03**
XRF	**Flesh**	1.76E-01	9.00E-04	1.17E-03	4.51E-02	1.80E-03	4.50E-04	6.39E-03
	Gill	3.36E-01	9.00E-04	4.32E-03	9.36E-02	1.80E-03	4.50E-04	2.67E-03
	Intestine	2.05E-01	9.00E-04	5.49E-03	1.89E-01	1.80E-03	4.50E-04	4.59E-03
	Liver	1.11E-01	9.00E-04	9.54E-03	1.24E-01	1.80E-03	4.50E-04	3.06E-03
	HI	**8.27E-01**	**3.60E-03**	**2.05E-02**	**4.52E-01**	**7.20E-03**	**1.80E-03**	**1.67E-02**

Table 9: Hazard Quotient and Hazard Index of Some Heavy Metals in *Clarias anguillaris* from Komadugu River Basin

				Rainy Season				
Method	**Tissues**	**Fe**	**Pb**	**Cu**	**Zn**	**Cd**	**As**	**Cr**
AAS	**Flesh**	7.98E-02	1.80E-03	5.11E-02	3.48E-02	1.80E-03	6.00E-02	3.60E-06
	Gill	9.60E-01	1.80E-03	5.89E-01	2.28E-02	1.80E-03	3.00E-03	1.22E-03
	Intestine	1.20E+02	1.80E-03	7.61E-01	2.97E-02	1.80E-03	3.00E-04	3.06E-06
	Liver	5.90E-01	1.80E-03	1.67E-02	2.15E-02	1.80E-03	3.00E-02	3.60E-06
	HI	**2.82E+02**	**7.20E-03**	**1.42E+02**	**1.10E-01**	**7.20E-03**	**9.06E-02**	**1.24E-03**
XRF	**Flesh**	2.62E-01	2.25E-01	3.69E-03	3.69E-01	2.25E+02	1.50E+02	8.10E-03
	Gill	1.35E-01	2.25E-01	9.18E-03	2.53E-01	1.98 E+02	1.50E+02	1.04E-02
	Intestine	5.61E-01	2.25E-01	5.22E-03	3.96E-01	1.98 E+02	1.50E+02	1.04E-02
	Liver	2.22E-01	2.25E-01	7.47E-03	1.96E-01	1.80E+02	1.50E+02	8.70E-03
	HI	**1.18E+01**	**9.00E-01**	**2.56E-02**	**1.21E+02**	**8.01** E+02	**6.00**E+02	**3.77E-02**
				Dry Season				
Method	**Tissues**	**Fe**	**Pb**	**Cu**	**Zn**	**Cd**	**As**	**Cr**
	Flesh	3.68E-02	1.18E-03	1.80E-05	1.94E-02	2.34E-04	9.00E-08	8.91E-04
	Gill	1.32E-01	7.20E-06	6.56E-03	3.51E-02	2.61E-04	9.00E-08	2.25E-03
	Intestine	2.38E-01	6.93E-04	1.80E-05	5.18E-02	1.80E-06	9.00E-08	2.94E-03
AAS	**Liver**	6.79E-01	3.42E-04	1.48E-02	4.67E-02	1.26E-04	9.00E-08	2.32E-03
	HI	**1.09E+00**	**2.22E-03**	**2.14E-02**	**1.53E-01**	**6.23E-04**	**3.60E-07**	**8.41E-03**
	Flesh	1.10E-01	9.00E-04	2.97E-03	3.90E-02	1.80E-03	4.50E-04	5.40E-03
	Gill	1.02E-01	9.00E-04	2.61E-03	5.40E-02	1.80E-03	4.50E-04	3.60E-03
	Intestine	1.53E+00	9.00E-04	4.95E-01	1.05E-01	1.80E-03	4.50E-04	3.42E-01
XRF	**Liver**	1.45E+00	9.00E-04	4.19E-02	9.81E-02	1.80E-03	4.50E-04	4.14E-03
	HI	**3.19E+00**	**3.60E-03**	**5.43E-01**	**2.96E-01**	**7.20E-03**	**1.80E-03**	**3.55E-01**

Hazard Index (HI)

An index of risk called hazard index (HI) for residents of ingesting of heavy metals by consuming fish in the study areas were calculated by summation of HQ of all heavy metals for each fish. In the present study, the highest HI of heavy metals was found in *Synodontis budgetti* with a value of 8.28E+02 Cd, whereas the lowest HI was found in *Heterotis niloticus* with a value of 3.60E-07 As. HI values of the heavy metals for all the fish samples were between 3.60E-07 and 8.28E+02. The values of all the metals within the rainy season were found to be more than one (1), indicating that there is a risk from the consumption of these fish, while that of the dry season were lower than 1 indicating that there is no risk of consumption of fish during the dry season. Huang *et al.*(2008) and Wang *et al.* (2005) also recorded a minimal contribution of heavy metals to aggregated risk via consumption of vegetables in Kunshan and Tianjin, China.

Cancer Risk

Cancer risks were computed as 5.10E-02 for highest and 5.40E-07 for lowest chances for the studied fish respectively (Tables 10 – 12). These cancer risk values indicate that consumption of fish from the study area would result in an excess of 5 cancer cases per 1,000,000 people while a previous study showed consumption of fish could result in 5 cancer cases per 100 people (Molina, 2011). The risk of developing cancer as a result of consuming the four fish samples showed significant difference ($p > 0.05$). Compared to all the metals studied, As and Cd were predominant contaminants contributing more of the ILCR in all the fish samples. In general, EPA considers excess cancer risks that are below about 1chance in 1,000,000 (1.00E06) to be so small as to be negligible, and risks above 1 in 10,000 (1×10^{-4}) to be sufficiently large that some sort of remediation is desirable. An ILCR greater than one in ten thousand (ILCR > 10^{-4}) is a benchmark for gathering additional information whereas 1/1000 or greater (ILCR > 10^{-3}) is a moderate increased risk and should be given high priority as a public health concern (USEPA, 2005a). As, Cd and Pb are classified by the International Agency for Research on Cancer (IARC) as being carcinogenic (Hague *et al.*, 2008). Chronic exposure to low doses of As, Cd and Pb could therefore result into many cancers (Jarup, 2003).

Table 10: Incremental Life Cancer Risk of Some Heavy Metals in Different Tissues of *Heterotis niloticus*

Rainy Season				
Method	**Tissues**	**As**	**Cd**	**Pb**
AAS	**Flesh**	7.00E-05	1.20E-02	6.40E-07
	Gill	1.00E-04	7.54E-02	6.40E-07
	Intestine	9.00E-05	3.60E-02	7.20E-07
	Liver	1.00E-04	4.41E-02	6.40E-07
	ΣILCR	**4.00E-04**	**1.67E-02**	**2.60E-06**
	Flesh	7.00E-04	1.19E-02	8.00E-05
	Gill	7.00E-04	1.59E-02	8.00E-05
	Intestine	7.00E-04	1.70E-02	8.00E-05
XRF	**Liver**	6.30E-03	6.24E-03	8.00E-05
	ΣILCR	**8.40E-03**	**5.10E-02**	**3.20E-04**

Dry Season				
Method	**Tissue**	**As**	**Cd**	**Pb**
	Flesh	1.35E-07	1.13E-05	1.44E-04
	Gill	1.35E-07	9.64E-04	2.75E-04
	Intestine	1.35E-07	1.02E-02	1.32E-04
AAS	**Liver**	1.35E-07	1.13E-05	1.84E-04
	ΣILCR	**5.40E-07**	**1.20E-02**	**7.35E-04**
	Flesh	6.75E-04	1.13E-02	8.00E-05
	Gill	6.75E-04	1.13E-02	8.00E-05
	Intestine	6.75E-04	1.13E-02	8.00E-05
XRF	**Liver**	6.75E-04	1.13E-02	8.00E-05
	ΣILCR	**2.70E-03**	**4.52E-02**	**1.79E-03**

Table 11: Incremental Life Cancer Risk of Some Heavy Metals in Different Tissues of *Synodontis Budgetti*

Rainy Season

Method	Tissues	As	Cd	Pb
AAS	**Flesh**	2.70E-05	8.40E-02	6.40E-07
	Gill	9.50E-05	1.10E-05	6.40E-07
	Intestine	1.40E-05	1.10E-05	6.40E-07
	Liver	1.10E-04	1.10E-05	6.40E-07
	ΣILCR	**2.40E-04**	**8.40E-02**	**2.50E-06**
XRF	**Flesh**	6.80E-04	1.80E-02	8.00E-05
	Gill	6.80E-04	1.13E-02	8.00E-05
	Intestine	6.80E-04	1.13E-02	8.00E-05
	Liver	6.80E-04	1.13E-02	8.00E-05
	ΣILCR	**2.70E-03**	**5.21E-02**	**3.20E-04**

Dry Season

Method	Tissue	As	Cd	Pb
	Flesh	1.35E-07	6.80E-04	2.20E-04
	Gill	1.35E-07	1.13E-05	3.186E-06
	Intestine	1.35E-07	1.64E-03	1.47E-04
AAS	**Liver**	1.35E-07	7.94E-04	2.48E-04
	ΣILCR	**5.40E-07**	**3.13E-03**	**6.18E-04**
	Flesh	6.75E-04	6.75E-04	7.97E-05
	Gill	6.75E-04	1.13E-02	7.97E-05
	Intestine	6.80E-04	1.13E-02	7.97E-05
XRF	**Liver**	6.80E-04	1.13E-02	7.97E-05
	ΣILCR	**2.71E-03**	**3.39E-02**	**3.19E-04**

Table 12: Incremental Life Cancer Risk of Some Heavy Metals in Different Tissues of *Clarias anguillaris*

Rainy Season

Method	Tissues	As	Cd	Pb
AAS	**Flesh**	2.70E-05	1.10E-05	6.40E-07
	Gill	1.40E-07	1.10E-05	6.40E-07
	Intestine	1.40E-07	1.10E-05	6.40E-07
	Liver	1.40E-05	1.10E-05	6.40E-07
	ΣILCR	**4.10E-05**	**4.50E-05**	**2.50E-06**
XRF	**Flesh**	6.80E-04	1.42E-02	8.00E-05
	Gill	6.80E-04	1.42E-02	8.00E-05
	Intestine	6.80E-04	1.42E-02	8.00E-05
	Liver	6.80E-04	1.13E-02	8.00E-05
	ΣILCR	**2.70E-03**	**5.05E-02**	**3.20E-04**

Dry Season

Method	Tissue	As	Cd	Pb
	Flesh	1.35E-07	1.50E-03	1.04E-04
	Gill	1.35E-07	1.64E-03	6.37E-07
	Intestine	1.35E-07	1.13E-05	6.13E-05
AAS	**Liver**	1.35E-07	8.00E-04	3.03E-05
	ΣILCR	**5.40E-07**	**4.00E-03**	**1.96E-04**
	Flesh	6.75E-04	1.13E-02	7.97E-05
	Gill	6.75E-04	1.13E-02	7.97E-05
	Intestine	6.75E-04	1.13E-02	7.97E-05
XRF	**Liver**	6.75E-04	1.13E-02	7.97E-05
	ΣILCR	**2.70E-03**	**4.52E-02**	**3.19E-04**

CONCLUSION

The results obtained demonstrated that there was variation in the concentrations of heavy metals between tissues of fish samples studied. Among the heavy metals studied, Fe was observed to show the highest total concentrations, while Pb showed the lowest total concentrations. The concentrations of all the studied heavy metals in fish were observed to be above the WHO recommended standard limit with exception of Pb, As and Cr.Heavy metals concentrations in tissues of fish samples were in the order of gills>liver>intestine>flesh.Fe showed the highest ADI value of 1.53E+00 mg/kg/day in *Clarias anguillaria*, while *Synodontis budgetti* had the lowest ADI value of 8.23E-01 mg/kg/day. From the results obtained, the HQ values of some of the heavy metals in the fish samples during the rainy season were all above one (1), with the exception of HQ values during the dry season which were lower than 1. The lowest HQ value of 9.00E-08 in all the fish samples studied was lower than 1, while the highest HQ value was 1.50E+01. The detected level of As in all the fish samples was higher than the HQ values of one (1). The cancer risk (CR) values of all the metals within the rainy season were found to be more than one (1), indicating that there is a risk upon the consumption of these fish during the rainy season, while that of the dry season were lower than 1 indicating that there is no risk of consumption of fish during the dry season.

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