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# CONCENTRATION OF HEAVY METALS IN FISH FROM KOMADUGU RIVER BASIN, YOBE STATE, NIGERIA AND POTENTIAL HUMAN HEALTH RISK DUE TO FISH CONSUMPTION

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## ABSTRACT

In this study, Fish samples *Clarias anguillaris, Synodontis budgetti*, and *Heterotis niloticus* were collected during the rainy and dry season from Komadugu river basin, Yobe State, Nigeria for the determination of some heavy metals. The concentrations of heavy metals were determined using Perkin-Elmer Analyst 300 Atomic Absorption Spectroscopy (AAS) and X-Ray Fluoresces (XRF). The concentrations of all the heavy metals in the fish samples ranged from 1.18E+03 mg/kg. *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 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 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 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 was lower than 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 As detected in all the fish samples was higher than the HQ values of one (1). Cancer risks were computed as 5.10E-02 for highest and 5.40E-07 for lowest chances for the study fish 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:** Komadugu, heavy metals, fish, species, risk assessment.

## INTRODUCTION

Several studies reported that Fish being a source of digestible minerals, protein, vitamins, and polyunsaturated fatty acids are also combined as an important source of essential heavy metals (WHO, 1999). Many multiple factors including seasonal, physical and chemical properties of water can more often play a significant role in metal accumulation in different fish tissues (Kargin, 1996). Anthropogenic activities including Industrial development, using of agricultural fertilizers, livestock manure, increases in pesticide usage and mining have led to increasing levels of heavy metals in aquatic environments (Cooper, 1993; Guerrero and Kesten, 1993).Depuration period for various metals in different fish species and differences in uptake is largely attributed tometal bioaccumulation (Tawari-Fufeyin and Ekaye, 2007). 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 important indicators in fresh water systems, for the estimation of metal pollution level (Rashed, 2001).

Komadugu-Yobe River Basin (Fig. 1) 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). Most of the flow (80%) in the Hadejia River system, which is a tributary of the Yobe River, is controlled by the upstream Tiga Dam (completed in 1974) and Challawa Dam (completed in 1992).The confluence of the Komadugu and Yobe rivers is largely silted up. This river thus provides only a small and unreliable contribution to the Yobe River. 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

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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.

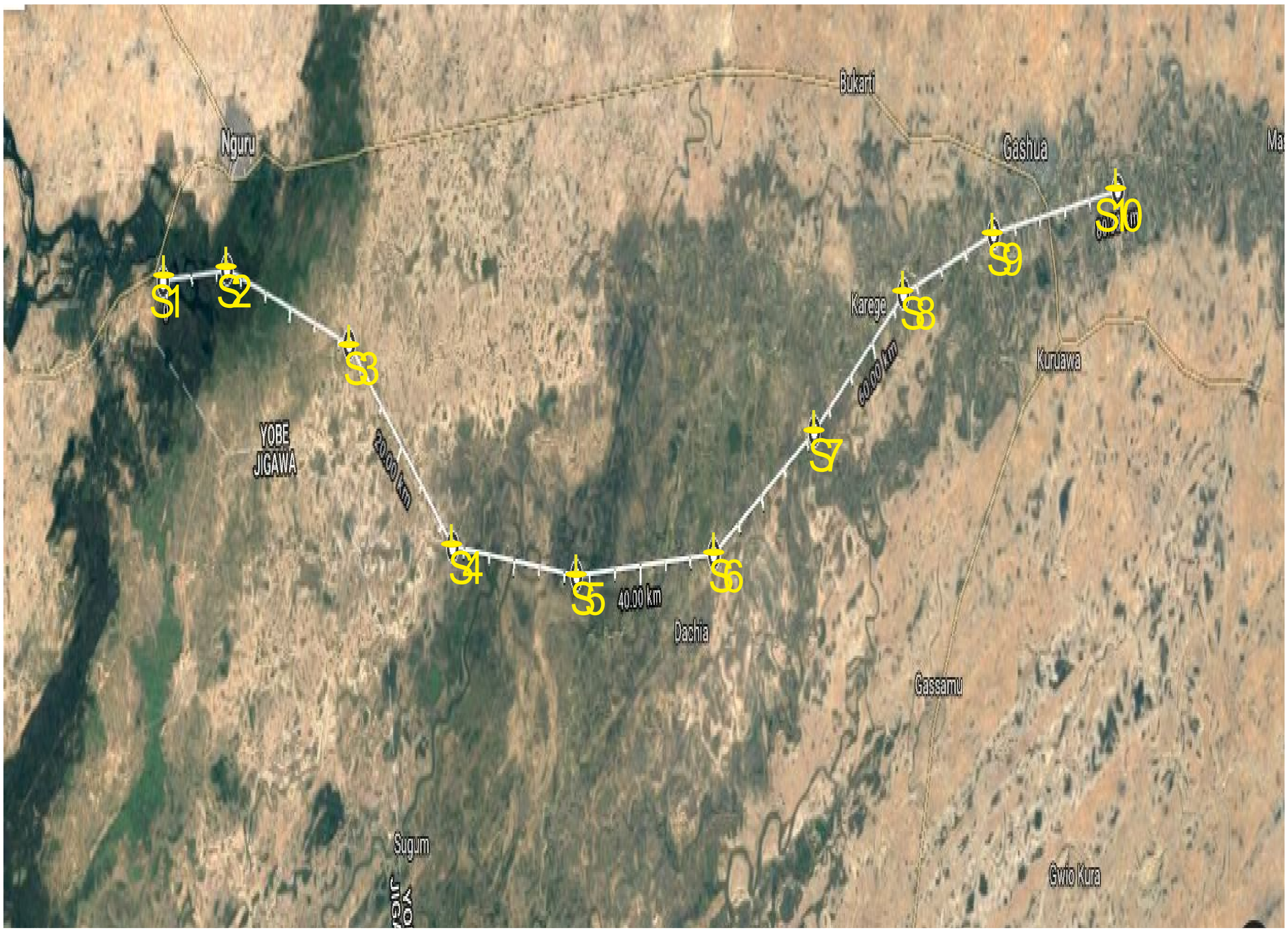


Fig. 1.Map of Komadugu-Yobe River Basin Showing Sampling Points.

## MATERIALS AND METHODS

### Fish Sampling

Three fish species *Clarias anguillaris, Synodontis budgetti* and *Heterotis niloticus* were caught from Komadugu River Basin (Gashua and Nguru) through 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 carried out using Perkin-Elmer A Analyst 300 Atomic Absorption Spectroscopy (AAS) and XRF.

### 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 $mgkg^{-1}$ $BWday^{-1}$ 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 the equation belowILCR=ADI X CSF.

Average daily intake upon the consumption of fish was carried out using the equation below

$$\text{Average Daily intake} = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

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 by the following equation: Hazard Quotient (HQ) = ADI (mg/kg/day)/$RfD_O$, 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 by the equation below (Guerra *et al*., 2010). Total Chronic Hazard Index (THI) = $\sum HQ$

## RESULTS

### Mean Concentrations of Heavy Metals Fish Samples

The mean concentrations of the studied metals using AAS and XRF methods in the flesh, gill, intestine and liver of *Heterotis niloticus* from Komadugu river basin within the rainy and dry season is as presented in Table 1. Fe ranged from 3.76E+01 to 1.40E+03 mg/kg; 8.00E-03 to 3.45E+00 mg/kg Pb; 2.00E-02 to 2.87E+02 mg/kg Cu;1.11E+01 to 3.84E+02 mg/kg Zn; 2.00E-03 to 7.78E+00 mg/kg Cd; 6.00E-02 to 1.94E+01 mg/kg Ni; 4.18E+00 to 8.17E+01 mg/kg Mn; 1.00E-04 to 4.70E+00 mg/kg As and 6.00E-03 to 2.50E+01 mg/kg Cr. The results revealed that Fe shows the highest total concentrations with a value of 3.74E+03 mg/kg during the dry season, while As shows the lowest total concentrations with a value of 2.00E+00 mg/kg during the dry season. For *Synodontis budgetti,* the concentration of Fe ranged from 2.79E+01 to 1.03E+03mg/kg; 8.00E-03 to 3.11E+00 mg/kg Pb; 2.00E-02 to 3.03E+01 mg/kg Cu;7.93E+00 to 2.10E+02 mg/kg Zn; 2.00E-03 to 2.00E+00 mg/kg Cd; 6.00E-02 to 9.79E+00 mg/kg Ni; 1.63E+00 to 7.71E+01 Mn; 1.00E-04 to 5.00E-01 mg/kg As and 6.00E-03 to 7.10E+00 mg/kg Cr Table 2. The result revealed that Fe shows the highest total concentration with a value of 2.20E+03 mg/kg during the dry season, while As shows the lowest total concentration with a value of 2.00E+00 during the dry season. The mean concentrations of the studied metals using AAS and XRF methods in the flesh, gill, intestine and liver of *Clarias anguillaris* from Komadugu River basin are as presented in Table 3. The concentration of Fe ranged from 4.09E+01 to 1.70E+03 mg/kg; 8.00E-03 to 1.31E+00 mg/kg Pb; 2.00E-02 to 8.46E+02 mg/kg Cu;7.17E+00 to 1.32E+02 mg/kg Zn; 2.00E-03 to 2.50E+00 mg/kg Cd; 6.00E-02 to 4.58E+02 mg/kg Ni; 5.00E-02 to 7.52E+01 mg/kg Mn; 1.00E-04 to 5.00E-01 mg/kg As and 6.00E-03 to 3.80E+02 mg/kg Cr. The results revealed that Fe shows the highest total concentrations with a value of 3.55E+03 mg/kg during the dry season, while AS shows the lowest total concentration with a value of 2.00E+00 mg/kg during the same season.

### Risk Assessment of Heavy Metals in Fish Samples

### The Average Dietary Intake

The average dietary intake of some heavy metals in different tissues of *Heterotis niloticus* for both AAS and XRF methods from Komadugu River Basin, Yobe State during the rainy and dry seasons are as presented in Table 4. The average dietary intake of Fe ranged from 3.38E-02 to 1.26E+00 mg/kg $day^{-1}$;7.20E-06 to 3.11E-03 mg/kg $day^{-1}$ Pb; 1.80E-05 to 2.58E-01 mg/kg $day^{-1}$ Cu;9.99E-03 to 3.46E-01 mg/kg $day^{-1}$ Zn; 1.53E-04 to 1.20E-02 mg/kg $day^{-1}$ Cd; 9.00E-08 to 4.23E-03 mg/kg $day^{-1}$ As and 5.40E-06 to 2.25E-02 mg/kg $day^{-1}$Cr. The results revealed that Fe shows the highest total average dietary intake with a value of 3.37E+00 mg/kg $day^{-1}$ during the rainy season, while Cr shows the lowest total average dietary with a value of 2.16E-05 mg/kg $day^{-1}$ during the dry season. For *Synodontis budgetti* the average dietary intake of Fe ranged from 2.51E-02 to 9.29E-01 mg/kg $day^{-1}$;7.20E-06 to 2.48E-03 mg/kg $day^{-1}$ Pb; 1.80E-05 to 1.14E-01 mg/kg $day^{-1}$ Cu;7.14E-03 to 1.89E-01 mg/kg $day^{-1}$ Zn; 1.80E-06 to 1.33E-02 mg/kg $day^{-1}$ Cd; 9.00E-08 to 4.50E-04 mg/kg $day^{-1}$ As and 5.40E-06 to 1.75E-02 mg/kg $day^{-1}$ Cr Table 5. The result revealed that Fe shows the highest total concentrations with a value of 1.98E+00 mg/kg day$^{-1}$ during the rainy season, while Cr shows the lowest total concentrations with a value of 3.60E-07 mg/kg day$^{-1}$ during the dry season. For *Clarias anguillaris,* the average dietary intake of Fe ranged from 3.68E-02 to 1.53E+00 mg/kg day$^{-1}$;7.20E-06 to 1.18E-03 mg/kg day$^{-1}$ Pb; 1.80E-05 to 5.90E-01 mg/kg day$^{-1}$ Cu;6.45E-03 to 1.19E-01 mg/kg day$^{-1}$ Zn; 1.80E-06 to 2.25E-03 mg/kg day$^{-1}$ Cd; 9.00E-08 to 4.50E-04 mg/kg day$^{-1}$ As and 5.40E-06 to 3.42E-02 mg/kg day$^{-1}$ Cr Table 6. The results revealed that Fe shows the highest total concentrations with a value of 3.19E+00 mg/kg day$^{-1}$ during the dry season, while As shows the lowest total concentrations with a value of 1.80E-07 mg/kg day$^{-1}$ during the same season.

**Hazard Quotient and Hazard Index of Some Heavy Metals in Fish**

The hazard quotient of some heavy metals in *Heterotis niloticus* from Komadugu River basin, Yobe state, Nigeria during the rainy and the dry seasons for AAS and XRF methods are as presented in Table 7. The Hazard Quotient of Fe ranged from 3.38E-02 to 1.81E+02mg/kgday-$^{1}$; 9.00E-04 to 2.25E-01mg/kgday-$^{1}$ Pb; 1.80E-05to 6.46E+02 mg/kgday-$^{1}$ Cu; 1.58E-02 to 5.16E-01 mg/kgday-$^{1}$ Zn; 1.80E-06 to 11.97E+02 mg/kgday-$^{1}$ Cd; 9.00E-08 to 1.410E+02 mg/kgday-$^{1}$ As; 3.60E-06 to 1.50E-02 mg/kgday-$^{1}$ Cr. As shows the highest Hazard index with a value of 26.59E+02 mg/kgday-$^{1}$ during the rainy season, while As show the lowest hazard index with a value of 1.80E-07 mg/kgday-$^{1}$ during the dry season. The hazard quotient of some heavy metals in *Synodontis budgetti* fish samples from Komadugu River basin of Yobe State, Nigeria during the rainy and the dry seasons for AAS and XRF methods are as presented in Table 8. The Hazard Quotient of Fe ranged from 2.51E-02 to 1.33E+02mg/kgday-$^{1}$; 3.60E-05 to 2.25E-01mg/kgday-$^{1}$ Pb; 1.80E-05to 2.85E+02 mg/kgday-$^{1}$ Cu; 7.14E-03 to 8.16E-01 mg/kgday-$^{1}$ Zn; 1.80E-06 to 1.33E+03 mg/kgday-$^{1}$ Cd; 9.00E-08 to 1.50E+02 mg/kgday-$^{1}$ As and 3.60E-06 to 8.58E-03 mg/kgday-$^{1}$ Cr. Cd shows the highest Hazard index with a value of 8.28E+02 mg/kgday-$^{1}$ during the rainy season, while As show the lowest hazard indesx with a value of 3.60E-07 mg/kgday-$^{1}$ during the dry season. For *Clarias anguillaris.* Samples from Komadugu River basin of Yobe State, Nigeria during the rainy and the dry seasons for AAS and XRF methods are as presented in Table 9. The Hazard Quotient of Fe ranged from 3.68E-02 to1.53E+00 mg/kgday-$^{1}$; 9.00E-04 to 2.25E-01mg/kgday-$^{1}$ Pb; 1.80E-05to 7.61E-01 mg/kgday-$^{1}$ Cu; 1.94E-02 to 3.69E-01 mg/kgday-$^{1}$ Zn; 1.80E-06 to 2.25E+02 mg/kgday-$^{1}$ Cd; 9.00E-08 to 1.50E+02 mg/kgday-$^{1}$ As and 3.60E-06 to 3.42E-01 mg/kgday-$^{1}$ Cr. Cd shows the highest Hazard index with a value of 8.01E+02 mg/kgday-$^{1}$ during the rainy season, while As show the lowest hazard indesx with a value of 3.60E-07 mg/kgday-$^{1}$ during the dry season.

**Incremental Life Cancer Risk of Some Heavy Metals in Different Tissues of Fish**

The incremental life cancer risk (CR) of the studied metals using AAS and XRF methods in the flesh, gill, intestine and liver of *Heterotis niloticus* from Komadugu River basin, Yobe State Nigeria during the rainy and dry seasons are as presented in Table 10. The incremental life cancer risk of As ranged from 1.35E-07 to 6.30E-03 mg/kgday-$^{1}$; 1.13E-05 to 7.54E-02 mg/kgday-$^{1}$ Cd; 6.40E-07 to 2.75E-04 mg/kgday-$^{1}$ Pb. The highest total CR value of 5.10E-02 mg/kgday-$^{1}$ was observed during the rainy season using XRF method, while the lowest total CR value of 5.40E-07 mg/kgday-$^{1}$were observed during the dry season using AAS method.

For *Synodontis budgetti*, the Incremental Life Cancer Risk of the studied metals using AAS and XRF methods in the flesh, gill, intestine and liver from Komadugu River basin, Yobe State Nigeria during the rainy and dry seasons are as presented in Table 11. The incremental life cancer risk of As ranged from 1.35E-07 to 1.10E-04 mg/kgday-$^{1}$; 1.10E-05 to 1.13E-02 mg/kgday-$^{1}$ Cd; 6.40E-07 to 1.47E-04 mg/kgday-$^{1}$ Pb. The highest total CR value of 8.40E-02 mg/kgday-$^{1}$ was observed during the rainy season in XRF method, while the lowest total CR value of 5.40E-07 mg/kgday-$^{1}$were observed during the dry season in AAS method. The incremental life cancer risk of the studied metals using AAS and XRF methods in the flesh, gill, intestine and liver of *Clarias anguillaris* from Komadugu River basin, Yobe State Nigeria during the rainy and dry seasons are as presented in Table 12.The Incremental Life Cancer Risk of As ranged from 1.40E-07 to 6.75E-04 mg/kgday-$^{1}$; 1.10E-05 to1.13E-02 mg/kgday-$^{1}$ Cd; 6.40E-07 to 8.00E-05 mg/kgday-$^{1}$ Pb. The highest total CR value of 5.05E-02 mg/kgday-$^{1}$ was observed during the rainy season in XRF method, while the lowest total CR value of 5.40E-07 mg/kgday-$^{1}$ was observed during the dry season in AAS method.

## DISCUSSION

**Distribution of Heavy Metals in Fish Samples**

The distribution of heavy metals in all thestudied fish tissues for this research work are in the order of liver<intestine <gills<flesh**.** The levels of copper in the different tissues of the three species of fish studied ranged between 2.00E-02 and 8.46E+02 mgkg$^{-1}$ (Tables 1 to 3). The highest concentration of copper (8.46E+02 mgkg$^{-1}$) was detected in the intestine of *Clarias anguillaris*, while the lowestdetected limit (2.00E-02 mg/kg) was found in the flesh of fish species *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 as reported by other recent research results. 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 which agrees with the WHO report. 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 and other aquatics (Herbert and Vandyke 1964; Rompala*et al*., 1984). However, the mean concentrations of copper levels in liver, intestine, gills and flesh of *Heterotis niloticus*, *Clarias anguillaris*, and *Synodontis budgetti* from the study area were above the maximum level of 1.0 mgkg$^{-1}$indicating a potential health risk.

Lead (Pb) was found to 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 mgkg$^{-1}$) was detected in the flesh of all the fish samples. The concentrations of lead were higher in the following order liver<gills<mintestine<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 as reported by (Rompala*et al*., 1984). 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 (Rompala*et al*., 1984; Leland andKuwabara, 1985). The levels of lead in the liver, intestine and gills of *Heterotis niloticus, Clarias anguillaris* and *Synodontis budgetti* were above the 0.5 mgkg$^{-1}$ 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 threestudied fish species from the study area varied from one tissue to another. The maximum concentration of chromium (3.80E+02 mgkg$^{-1}$) was detected in the liver of *Clarias anguillaris*, while the minimum was observed in the flesh of *Heterotis niloticus*. Chromium is an essential trace element in humans and some laboratory animals (Lee and Schultz, 1994) but in excess, it could have lethal and sublethal effects on fish and wildlife (Robertson *et al*., 1991). No guideline documents are available for chromium in the edible part of fish; neither was it assessed by NCBP or FEPA. In view of other sanctions, the present chromium concentrations in the tissues of *Heterotis niloticus, Clarias anguillaris* and *Synodontis budgetti* were well above the levels validated by USEPA (1987) (0.001mgkg$^{-1}$) 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 mgkg$^{-1}$ (Adams *et al*., 1993) which is in line with the above threshold. The present chromium tissues concentration for this study was above 4.0 mgkg$^{-1}$ 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 mgkg$^{-1}$ set by Charbonneau and Nash (1993) thus constituting a threat upon consumption of these species of fish, with the exception of the liver in *Clarias anguillaris*.

In contrast to earlier reports showing Iron (Fe) to be normally highest in the gills (Philips, 1976) and in the liver (Charbonneau and Nash, 1993). 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 mgkg$^{-1}$. The concentrations were below the high residue of Fe (34-107 ppm) in fish samples on MNW Refuge Charbonneau and Nash (1993). The highest level of iron was observed in the intestine of *Clarias anguillaris* Table 4.13, while the flesh of *Heterotis niloticus* shows the least concentration.The concentration of nickel in the fish tissues are in the order of liver> gill>intestine>flesh. Nickel level of 0.7 mgkg$^{-1}$ is considered potentially lethal to fish and aquatic birds that consume them (Lemly, 1993). Nickel concentrations of 2.3 mgkg$^{-1}$ or greater, may cause reproductive impairment and lack of recruitment in fishes (Baumann and May, 1984). All the tissues of the fish samples in this study were more than these levels of concern with respect to Ni, with the exception of flesh. Hence, nickel concentrations in the entire species of fish constitute a threat upon its consumption. The highest concentrations of cadmium (1.48E+01 mgkg$^{-1}$) were observed in the flesh of *Synodontis budgetti*, while the lowest concentration of (2.00E-03 mgkg$^{-1}$) was detected in the intestine. Cadmium is a nonessential trace metal that is potentially toxic to most fish and wildlife, particularly freshwater organisms (Robertson *et al*., 1991).

The highest concentration of 1.48E+01 $mgkg^{-1}$ 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 *Synodontis budgetti* was below the NCBP 34.2 $mgkg^{-1}$. Fish can accumulate zinc from both the surrounding water and from their diet (Eisher, 1993). 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 (Eisher, 1993). Based on the above results, Zn appears to be a hazard to the fish within this portion of the study area.

Arsenic was detected in all the fish tissues sampled, with concentrations ranging from 1.00E-04 to 4.70E+00 $mgkg^{-1}$. 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 $mgkg^{-1}$ value (Schmitt and Brumbaugh, 1990). Walsh *et al.* (1977) considered that arsenic concentrations >0.5 $mgkg^{-1}$ 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 anguillaris*; 1.26E+00 mg/kg per day in *Heterotis niloticus* and 9.29E-01 in *Synodontis 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 was lower than that of 0.008 and 0.052 mg/kg per day reported by 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). Apendix 1, 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.

**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 (Apendix 2). From the result 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.

**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); 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 study fish respectively. 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 ($1.00E^{-06}$) to be so small as to be negligible, and risks above 1 in 10,000 ($1\times10^{-4}$) 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*., 2011). Chronic exposure to low doses of As, Cd and Pb could therefore result into many cancers (Jarup, 2003).

## CONCLUSION

The obtained results demonstrate that there was fluctuation 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 anguillaris*, while *Synodontis budgetti* had the lowest ADI value of 8.23E-01 mg/kg/day. From the result 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 As detected 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.

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

| | | | | | 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** |
| | | | | | **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** |

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

| | | Dry Season | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 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** |

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-0-06 |
| | **Gill** | 4.55E-02 | 7.20E-06 | 5.04E-02 | 2.45E-02 | 1.80E-06 | 6.30E-05 | 5.40E-0-06 |
| | **Intestine** | 6.17E-01 | 7.20E-06 | 2.01E-02 | 8.38E-02 | 1.80E-06 | 9.00E-06 | 5.40E-0-06 |
| **AAS** | **Liver** | 6.32E-01 | 7.20E-06 | 1.14E-01 | 3.27E-02 | 1.80E-06 | 7.20E-05 | 5.40E-0-06 |
| | **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** |

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 |
| **XRF** | **Liver** | 2.00E-01 | 9.00E-04 | 1.29E-02 | 3.46E-01 | 1.80E-03 | 4.50E-04 | 7.74E-03 |
| | **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.

| | | Rainy Season | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Methods** | **Tissues** | **Fe** | **Pb** | **Cu** | **Zn** | **Cd** | **As** | **Cr** |
| **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** |
| | **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 |
| | **HI** | **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 |
| | **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.

| | Tissues | Fe | Pb | Cu | Zn | Cd | As | Cr |
|---|---|---|---|---|---|---|---|---|
| **Rainy Season** | | | | | | | | |
| 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 | **6.00E**+02 | **3.77E-02** |
| **Dry Season** | | | | | | | | |
| | **Tissues** | **Fe** | **Pb** | **Cu** | **Zn** | **Cd** | **As** | **Cr** |
| AAS | 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 |
| | 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** |
| XRF | 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 |
| | 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** |

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** | **Tissues** | **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** |

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