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Spatial and Tissue-Specific Accumulation of Heavy Metals in Tilapia (*Oreochromis niloticus*) Fish from Nguru River

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ABSTRACT

The concentration of heavy metals namely, Lead, Arsenic, chromium, copper and Zinc (Pb, As, Cr, Cu, Zn) were determined in Tilapia fish samples collected from three (3) selected areas of Nguru River during raining season. The fishes were carefully dissected and the muscles, livers and gills were sampled and prepared for digestion, afterward the level of heavy metals were assessed using atomic absorption spectroscopy (AAS). The results showed that all metals identified in this study follow the same accumulation pattern, with liver having the highest concentration (As:11681µg/kg, Cu:36.87µg/kg, Cr:252.50µg/kg, Zn:11688.11µg/kg), followed by gills (As:543.39µg/kg, Cu:16.04µg/kg, Cr:499.44µg/kg, Zn:9438.93µg/kg), and muscles (As:479.58µg/kg, Cu:14.29µg/kg, Cr:252.50µg/kg, Zn:7233µg/kg). Lead was not detected in all the tissue samples. However, the concentrations of heavy metals in the muscles of fishes collected from all the sites were within the permissible levels and are safe for the human consumption and public health.

Keywords: Heavy metals, Nguru river, Tilapia fish tissue, specific accumulation.

INTRODUCTION

Fishes are among the most widely distributed organisms in aquatic environments and serve as a significant source of protein for humans. However, they are also a primary source of heavy metals in food due to their ability to bioaccumulate these substances. Heavy metals such as cadmium, zinc, mercury, chromium, and copper contribute significantly to pollution, particularly in lakes, and river systems affected by industrial effluents, sewage, and agricultural runoff. Fish, as aquatic inhabitants, are unable to escape the harmful effects of these pollutants [1]. Essential elements like zinc (Zn) and copper (Cu) tend to accumulate at higher concentrations in muscle and liver tissues compared to non-essential metals like lead (Pb) and cadmium (Cd) [2]. Different fish tissues can absorb heavy metals from their environment, making natural lakes and rivers major sources of heavy metal contamination in fish. Consequently, humans are exposed to this pollution through fish consumption.

Elevated levels of heavy metals in the environment can lead to excessive accumulation in fish, which poses serious health risks to humans, animals, and plants [3]. Fishes are considered excellent indicators of heavy metal contamination in aquatic systems because they occupy various levels in the food chain [4]. As a result, there is increasing concern and attention regarding the health effects associated with consuming food contaminated with heavy metals.

Heavy metals are elements that display metallic properties, including transition metals, lanthanides, actinides, as well as metalloids like arsenic and antimony. These metals can be found in the environment naturally and as pollutants resulting from human activities [5]. Some heavy metals, such as arsenic, lead, aluminum, and cadmium, are known for their toxicity, while others like nickel, zinc, and chromium are essential for life but can become toxic above certain thresholds [6].

This study concentrates on three specific lakes in Nguru town, with the goal of

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determining the presence and concentration of five heavy metals such as copper (Cu), selenium (Se), chromium (Cr), lead (Pb), and zinc (Zn) in Tilapia fish. The results will provide valuable insights into the level of heavy metal contamination and the potential health risks associated with consuming Tilapia from these lakes.

MATERIALS AND METHODS

Reagent/Chemicals

All reagents were of analytical grade, Deionized water was used for all dilution, 65% Nitric acid (HNO_3) and hydrogen peroxide (H_2O_2) were obtained from LobaChemie. The element standard solutions were purchased from the inorganic ventures to make the calibration standards. Distilled and deionized water were processed in the laboratory of Yobe State University.

Study Area

Nguru (or 'N') is a Local Government Area in Yobe State, Nigeria. Its head quarter is in the town of Nguru near the Hadejia river at 12° 55' 45" N 10°27'09" E/12.8791 17°N 10.45250°E. It has an area of 916km^2 and a population of 150,632 as at the 2006 census.

The town probably dates from around the 15th century. There is a variety of landscape in the area including the protected Hedejia-Nguru wetland of Nguru Lakes, and "sand Dunes" a semi-desert area. Usually, the Nguru river comes from Tiga dam (Kano State) to Hadejia dam (Jigawa State) and then to Nguru.

Sample Collection

Fresh tilapia fish samples (*Oreochromis niloticus*) were obtained from the three selected site along the Nguru River i.e. (Garbi, Yan Kwarawa and Salon Wanki). The fish is commonly consumed by the local population of Nguru town. The total size and weight of the samples were measured, fish lengths were measured in the field between 15-18 cm and the wet weight were measured in the field range between 150-200g. The fish were carefully conserved with ice in clean polyethylene bags. The ice was used to minimize the tissue decay and to maintain moisture condition during transportation. The fishes were placed in an isolated container during transportation and immediately taken to the chemistry research laboratory, Yobe State University (YSU), Nigeria.

Sample Pre-Treatment

The frozen fresh samples were thawed, only boneless tissues were taken for metal analysis (Liver, gills and Muscles). The fish organs were removed with a stainless-steel knife and the samples were allowed to dry using hot oven (Model 30GC) at temperature of 40^{o}C. After drying, the sample was ground in to fine powder using a porcelain pestle and mortar.100mg of each grounded tissue sample was weighed in to thoroughly cleaned plastic container (microwave tube) and 2mL of 65% HNO_3 and 1mL of hydrogen peroxide 3:1 was chambered and allowed to stand for 30min. The plastic containers (microwave tubes) were then covered and placed in to Microwave digester (Master 40G106M). The digestion was carried out at a temperature of (95°C) for 30mins, followed by cooling at room temperature in the microwave.

Heavy Metal Analysis

Potential presence of heavy metals in reagents used in the digestion was determined. Blanks were used simultaneously in each batch of the analysis to authenticate the analytical quality. The digested samples were diluted with deionized water to a total volume of 25mL. The analysis was performed using atomic absorption spectroscopy (AAS) (Buck scientific Model 210VGP). The Concentration of the following heavy metals cadmium (Cd), Zinc (Zn), Lead (Pb), Nickel (Ni) and cobalt (Co) were determined in the fish samples. All the glassware and plastic were soaked overnight in 10 %(V/V) nitric

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acid rinsed with distilled and deionized water and dried before being used.

Statistical Analysis

Statistical analysis was done using a computer program SPSS version 15 and two-way ANOVA, and the significance was reported at $P < 0.05$ levels.

RESULTS AND DISCUSSION

The results for the determination of heavy metals (Cu, Pb, As, Zn, and Cr) in fish caught from the three selected areas of the Nguru River are presented in Table I. The limits of detection (LODs) represent the lowest concentrations that the instrument could reliably detect, calculated as three times the standard deviation of the blanks for each heavy metal. The limits of quantification (LOQs) represent the lowest concentrations that the instrument could detect and accurately quantify, calculated as ten times the standard deviation of the blanks. The LODs and LOQs for all heavy metals ranged from 0.0005 to 0.0020 µg/kg and 0.001 to 0.005 µg/kg, respectively.

Table 1: Mean concentration ± SD (µg/kg) of heavy metal in all samples (n=3)

Sample	Copper	Lead	Arsenic	Zinc	Chromium
M A	14.1 2± 0.25^{a}	ND	358.98 ± 0.34^{b}	1800.04 ± 0.32^{d}	ND
M B	14.29 ± 0.34^{a}	ND	479.58 ± 0.24c	7233.18 ± 0.43^{c}	ND
M C	0.14 ± 0.05^{c}	ND	383.38 ± 0.43^{b}	6188.25 ± 0.38^{c}	252.50 ± 0.07^{d}
G A	11.69 ± 0.37^{a}	ND	320.56 ± 0.45^{b}	6584.45 ± 0.09^{c}	105.60 ± 0.51^{d}
G B	13.10 ± 0.34^{a}	ND	442.22 ± 0.33^{c}	6978.9 3± 0.21^{c}	488.98 ± 0.64^{d}
G C	16.04 ± 0.35^{c}	ND	543.39 ± 0.51^{c}	9438.9 3 ±0.18^{d}	499.44 ± 0.05^{d}
L A	34.27 ± 5.40^{d}	ND	11616.00 ± 23.43^{d}	11063.85 ± 0.66^{d}	668.20 ± 0.42^{d}
L B	36.87 ± 0.21^{c}	ND	1211.02 ± 0.45^{d}	11688.11 ± 0.96^{d}	698.66 ± 0.01^{d}
L C	173.56 ± 0.74	ND	1172.73 ± 0.56^{d}	7669.64 ± 0.39^{d}	422.18 ± 0.56^{d}

Key: M=muscles, G=gills, L=liver, A=Salon wanki, B= Garbi, C= ýan kwarawa, ND = Not detected.

Results show mean ± SD. Values in each row marked by the same superscript letter are not significantly different at P<0.05.

The concentrations of Pb were below the limit of detection in all the samples. The highest concentration of Cu was found in the liver as compare to any other organ of the Sample. The accumulation pattern is as follows, liver > gill > muscles are shown in figure 1.

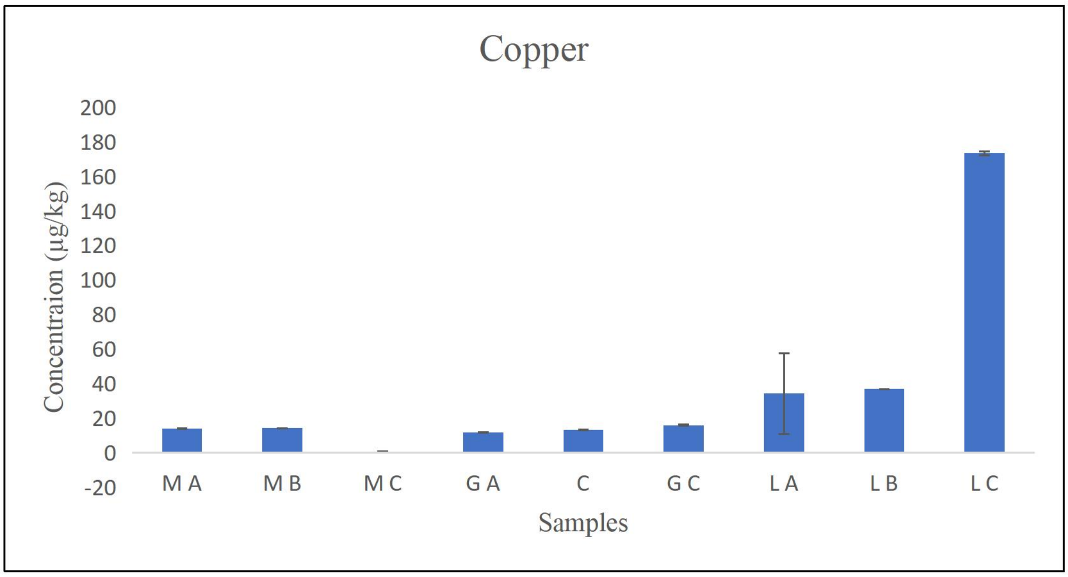

Figure 1: Mean Copper concentration ± SD (µg/kg) in Tilapia tissue

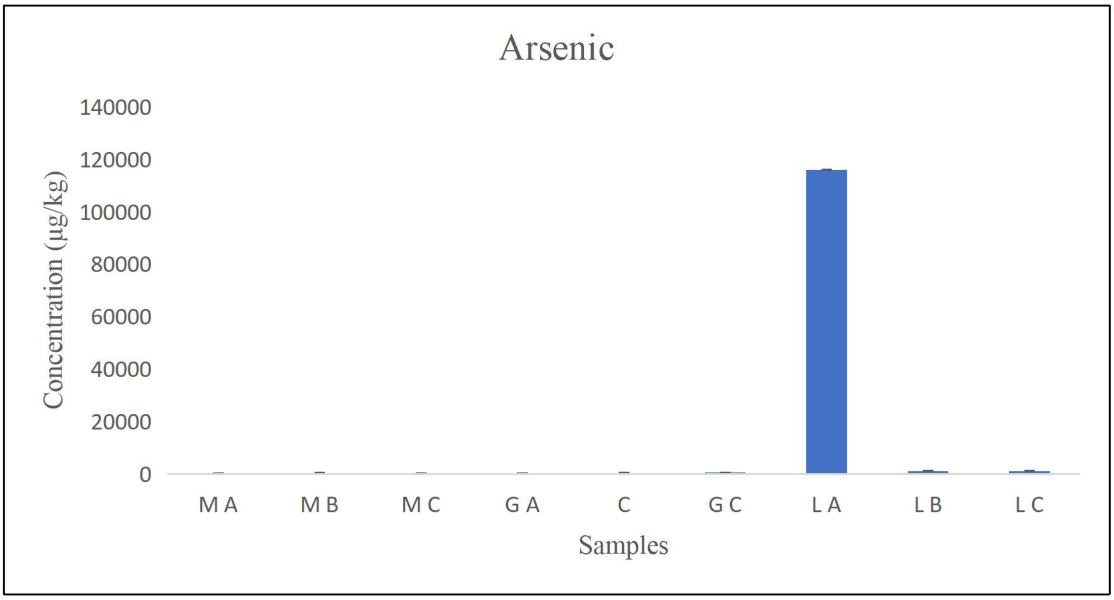

Figure 2: Mean Arsenic concentration ± SD (µg/kg) in Tilapia tissue

Figure 2 shows the concentration of As were found in all the samples, the highest concentration was found in the liver. The results of this study indicate that the level of As in all the samples are higher than the WHO acceptable level of (50-100 ug/L in drinking water) and 1000 times higher in the fish liver which is in agreement with the findings reported by Karadede-akin and Unlu [4] and Amal *et al.,*[16]. These levels of As if substantiated with further research finding in the sampling area may pose greater health risk to the consumer of these fish species in the studied areas.

For zinc, the concentration was observed in all the samples but the higher concentrations were found in the liver. The accumulation pattern of zinc follows' the order liver>gill>muscle as shown in figure 3. "

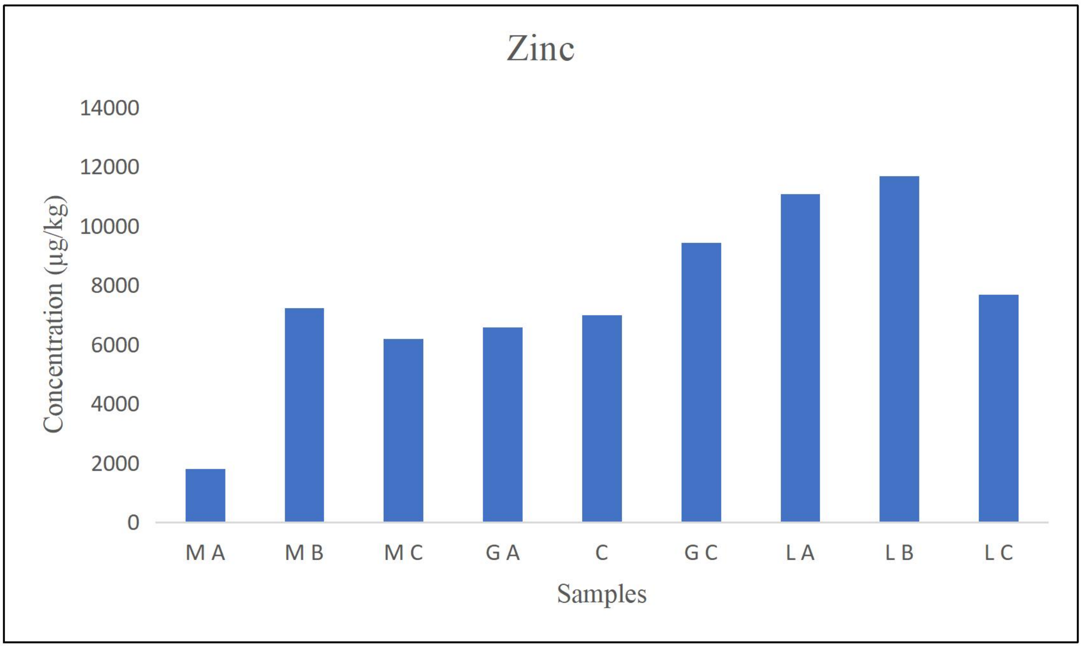

Figure 3: Mean Zinc concentration ± SD (µg/kg) in Tilapia tissue

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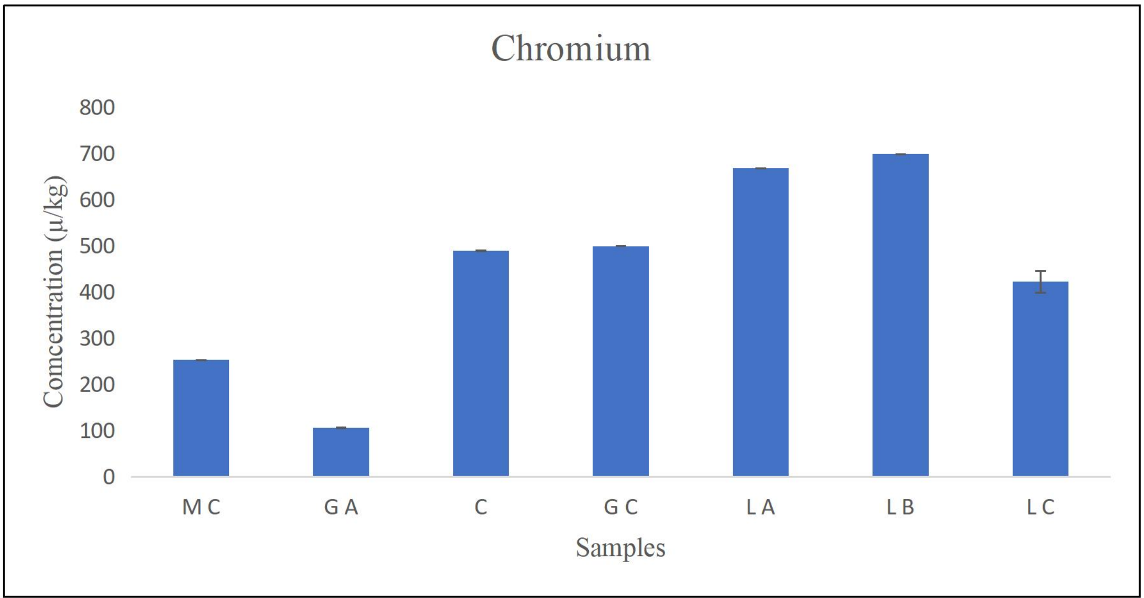

Figure 4: Mean Chromium concentration ± SD (µg/kg) in Tilapia tissue

The study revealed that chromium (Cr) was present in all samples except for two muscle samples, with the highest concentrations found in the liver. The pattern of metal accumulation observed was liver > gill > muscle. This pattern indicates that the liver is a primary site for the accumulation of heavy metals, likely due to its role in detoxification and metal sequestration. The liver's high metal concentration can be attributed to the binding of metals like copper (Cu), zinc (Zn), and cadmium (Cd) to metallothioneins or other ligands, which prevents their circulation in the organism. However, when fish is exposed to high metal concentrations, the liver's regulatory capacity is overwhelmed, leading to increased metal accumulation in the tissue [7,8].

The study's results also indicated that muscle tissues had the lowest concentrations of metals, while essential metals (arsenic (As), Cr, Cu, Zn) predominantly accumulated in the liver. Table 2, 3, and 4 demonstrate that all fish samples contained the lowest metal concentrations in muscle tissues, with the highest levels of As, Cr, Cu, and Zn found in the liver. Notably, lead (Pb) was not detected in any of the samples.

The elevated metal levels in the liver are consistent with its known function in metal sequestration. The proximity of Garbi Lake to the railway station suggests that exhaust gases from trains could be a significant source of metal contamination. These exhaust gases can enter the lake, leading to the bioaccumulation of toxic heavy metals in aquatic organisms, including fish. Continuous exposure to these contaminants results in the accumulation of heavy metals in different fish organs.

The presence of heavy metals in fish from Salon Wanki is likely due to the use of the lake for laundry activities. Detergents and chemicals from soaps can enter the lake, contributing to the accumulation of heavy metals in fish. Seasonal fluctuations in heavy metal levels can be influenced by factors such as growth, reproductive cycles, and changes in water temperature, which affect metal bioavailability in marine organisms [9,10,11].

Overall, the heavy metal levels varied significantly between different tissues of tilapia fish and across different sites, especially between natural sites. Fish from rivers exhibited higher heavy metal

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concentrations due to greater exposure to contamination [12,13]. The metal levels in the gills reflected the concentrations in the water, while the liver concentrations represented the storage of metals in the fish body.

This study provides valuable information, showing that tilapia fish from various sites of Nguru River had higher levels of heavy metals in the liver and lower levels in muscle tissues. These findings align with previous studies, such as Yilmaz *et al*., 2007 [10]. Importantly, the concentration of heavy metals in all fish organs did not exceed the limits allowed for human consumption, adhering to standards set by the EU in 2001 [14] and FAO/WHO,1987 [15].

CONCLUSION

The results of this study revealed that, the concentration of Pb was not detected in all the sample, this shows that Pb do not present any health risk to the consumers of the fish species from the sampling location. Also, the result shows that all the metals determined in this study follow the same accumulation pattern Liver> Gils> Muscle. This may be in connection with functions of these tissues/organs in the tilapia. This data can serve as a guideline for researchers and environmental managers to identify anthropogenic sources of the pollutant/heavy metal contaminants to better assess the need for remediation.

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