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Bioaccumulation of heavy metal in three fresh water fishes caught from cross river system

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ABSTRACT

Three freshwater fishes (Tilapia zilli, Oreochomis niloticus and Schilbe mystus were caught from Cross River system between the period of February to April, 2012. The bone, liver and gills from the three species were carefully dissected for the determination of heavy metals. Levels of heavy metals were determined using Perkin-Elmer Analyst 300 Atomic Absorption spectrophotometer (AAS). The maximum concentration of heavy metals studied was observed in the liver tissues, while bone tissues had the least concentration. The highest concentration of copper was observed in O. niloticus, while Schilbe mystus show the least. For cobalt concentration, the maximum was obtained in Schilbe mystus and the minimum in T. zilli and O. niloticus. High levels of Lead (Pb), Iron (Fe), and Cobalt (Co) were found in the liver tissues of T. zilli and O. niloticus, while Schilbe mystus had the least concentrations. Variations in the parameters determined were found to be statistically significant ($P< 0.05$). Based on the result obtained, the levels of the elements under study in the three species were within tolerance limits that are safe for human consumption.

Key words: Heavy metal, Toxicity, Bioaccumulation, Bone, Gills, Liver.

INTRODUCTION

The natural aquatic systems may extensively be contaminated with heavy metals released from domestics, industrial and other man-made activities (Vutukuru, 2005; Dirilgen, 2001; & Canlie, *et al.*, 1998). Heavy metals contamination may have devastating effects on the ecological balance of the recipient environment and a diversity of aquatic organisms (Farombi *et al.,* 2007; Vosyline *et al.,* 2006; & Ashraj, 2005).

Over the past decades the increasing use of metals in industry is causing serious environmental pollution through effluent and emanations. Among the myriad of organic and inorganic substances released into the aquatic ecosystems, heavy metals have received considerable attention due to their toxicity and potential bioaccumulation in many aquatic species (Blarins, 1985; Cupta and Mathus, 1983).

In general studies in heavy metal can be very important and interesting particularly in the field of ocean sciences and other related discipline. The alarming rate of disease associated with impacts of heavy metals and the potential effects of heavy metal on the aquatic biota have made it of concern on the need to measure the accumulation of heavy metals; particularly certain metals which pose an imminent health hazard to humans and are reported from several studies.

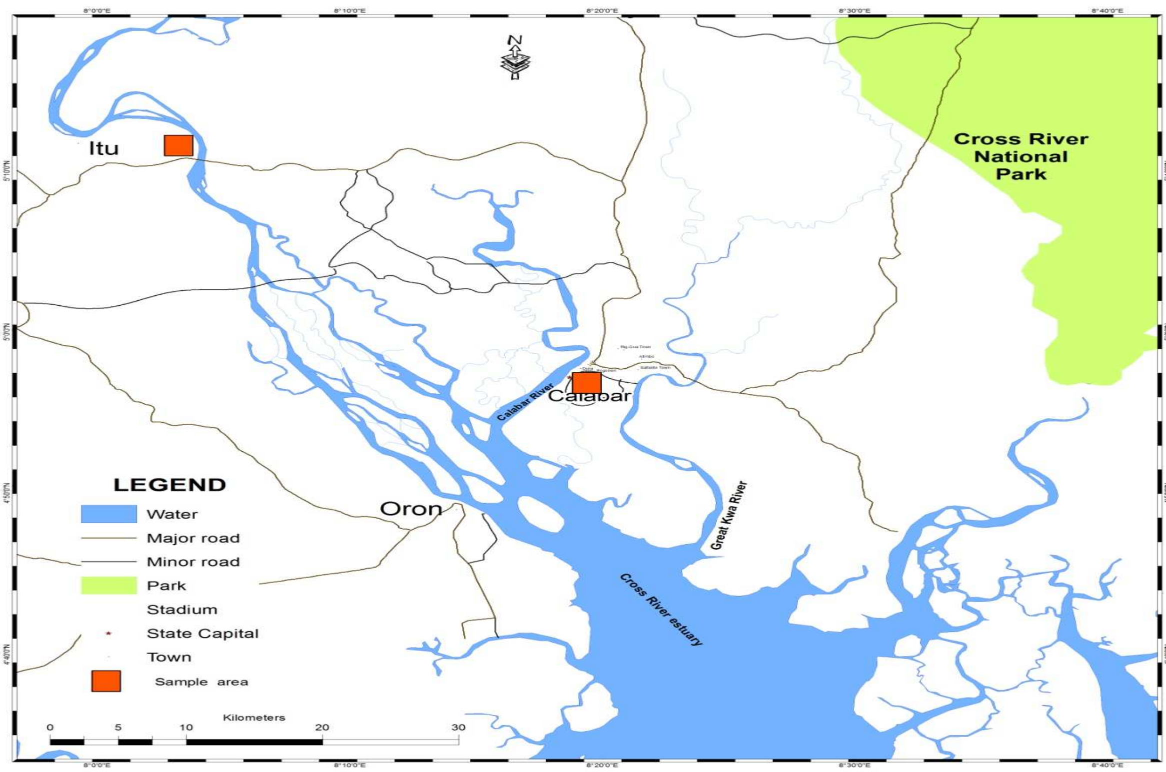
Studies were shown that heavy metals may alter the physiological activities and biological parameters both in tissue and in blood (Basa and Ranti; 2003; Canli 1995; Tort and Torres, 1988). Generally, water along the coast (including the estuaries) contains a variety of marine resources, namely fishes, shell fish and seaweed (Gregory *et al*, 1996; Muse *et al*, 1999) which attract fishing activities. The concern here is the contamination of water resources (fishes) by potential toxic chemical. Most of these toxic chemicals when present in a concentration above the recommended standard will result in chemical pollution. Many species of fish especially the benthos have been found to bioaccumulate most of these heavy metals in their tissue (Zn, Cu, Cd, Pb, Fe). Asuquo and Bassey, (1999) reported that the uptake of these toxins in the tissue of organism may create health hazard to human as its major predator and other fishes that prey on them.

Available information suggested that the concentration of toxic metals in many ecosystem are reaching unprecedented levels. Due to the steady load of contaminated dust in over crowded cities, the ambient concentration of toxic metals are now among the highest ever being reported. Therefore, the purpose of this research was to quantify the levels of some heavy metals (Cu, Co, Pb, Cr, Mn, Fe, Ni, Cd, and Zn) in bone, liver and gills of three commercially important spices of fishes (*Tilapia zilli, Oreochomis niiloticus* and *Schilbe mystus* caught within Cross River system, Cross River State, Nigeria.

MATERIALS AND METHODS

Study Area

The fish specimens were collected from the Cross River System Cross River State, Nigeria. The Cross River System is formed from numerous tributaries arising from the western slope of the Cameroon Mountains which have two spurs in Nigeria as Oban hills in the South and Obudu hills in the North (Moses, 1988). It is observed that the main River enters Nigeria from the Cameroon and flows first in a west ward direction then turn southwards and enters the Atlantic Ocean with limited Delta formation (Moses, 1988). The whole Cross River Estuary lies approximately between longitude 7^{o}30E and 10^o 00E and latitude 4^o and 8^{o}N. The river basin covers an area of 54,008km^2 of which 14, 000km^2 lies in the Cameroon and 39,500km^2 in Nigeria. The river is subject to seasonal flooding and about 8,000km^2 of the basin within Nigeria comes under flood. The estuary of the Cross River show large number of phytoplankton cell per unit volume and of these diatoms form 75%. The fish fauna of Cross River Estuary is rich and varied (as reported by Moses, 1988). (Fig. 1).



(Fig 1): Map of the study area showing the sampling site

Collection of specimen

Five Samples each of *Tilapia zilli, Oreochromis niloticus,* and *Schilbe mystus* were collected on a monthly basis for three months (February – April, 2012) at Nsidung beach (along Calabar River) and Abitu beach (along Great Kwa River) from the landings of basket trap fisheries of the artisanal fishermen.

Preparation of sample

The study was carried out at pure and applied chemistry laboratory, University of Calabar, Calabar, Cross River State. Fish samples which consisted specimen of uniform size, were collected and used for the studies. The samples collected from the different sampling location were prepared and the composite was obtained prior to determination of heavy metals. The different organs (bone liver and gills) were carefully excised after rinsing with double distilled water and oven dried at 110^0C. The heavy metal contaminations in the dried samples were estimated after acid digestion, following the standard method of AOAC (2000) using Atomic Absorption Spectrophotometer. The results were express in μgg^{-1}. Metal per dry weight.

Statistical analysis

Analysis of variance (ANOVA) was used to test for significance different in the levels of heavy metal in the different groups of fishes.

RESULTS AND DISCUSSION

The concentration of heavy metals in the different organs (bone liver, and gills) of T. *zilli, O. niloticus* and *Shilbe mystus* are as presented in (Table 1 to 3). The fish organs studied are in the order of liver> gills > bone (Figure 1-3). The levels of Copper (Cu) in the different organs of the three species of fish range between 0.01±0.01 and 0.08± 0.12 μgg^{-1} (Table 1 to 3). The highest concentration of Copper (0.68± 0.12 µgg) was detected in the liver tissue of O. *niloticus* (Table 2) (Figure 2), while the lowest detected limit (0.01± 0.01 μgg^{-1}) was found in the bone tissue of *Schilbedae (Shilbe mystus)* (Table 3) (Figure 3).

Liver concentrates higher levels of Copper in all the three species of fishes than the other organs (Table 1 to 3) (Figure 3), this high level of Copper in the liver tissue for all the fishes is due to the fact that, the liver is a largest organ for accumulation of this element. For the gills samples, it may be due to the fact that fresh water fishes gills might be expected to be the primary route for the uptake of pollutants within the aquatic ecosystem (Allen *et al.*, 1991), WHO (1989) reported that Copper toxicity in fish is taken up directly from the water via gills and stored in the liver, the present study showed similar accumulation of Copper in the gills and livers. Effects of high concentration of Copper in fish are not well established; however, there is evidence that high concentrations in fish can lead to toxicity (Woodland *et al.*, 1994). However, the concentration of Copper levels in the liver and gills of *T. zilli, O. niloticus* and *Schilbe mystus* from Cross River system were below the maximum level of 1.0 μgg^{-1} reported by (Schmitt *et al.*, 1990). The different organs of all the three species of fishes are as presented in (Table 1 to 3) (Figure 1-3). The maximum concentration of Cobalt (0.58 1.01 μgg^{-1}) was detected in the liver tissue of *schillbe mystus* (Table 3) (Figure 3), while the minimum detection limit of (0.13± 0.01 μgg^{-1}) was observed in the bone tissue of *T. zilli* and *O. niloticus* (Table 1 and 2) and (Figure 1 and 2) respectively. Cobalt was not been considered in compliance policies or NCBP guidance. In *T. zilli, O. niloticus* and *schilbe mystus,* liver were the target organs of Cobalt, while the bone showed the lowest concentration. The result is in line with the work of (Buckley *et al.*, 1982) who in dilated that in fish, the liver is the major storage organ for Cobalt. However, the liver is the preferred organ for metal accumulation as could be deduced from the present study.

Table 1: Mean Concentration of heavy metal in different organs of *Tilapia zilli* caught from Cross River system (Feb – April 2012)

Organs	Concentrations (μgg^{-1})								
	Cu	Co	Pb	Cr	Mn	Fe	Ni	Cd	Zn
Bone	0.02±0.01	0.13±0.01	0.01±0.01	0.03±0.01	0.23±0.05	0.22±0.01	0.01±0.01	0.12±0.02	0.13±0.02
Liver	0.53±0.10	0.34±0.02	0.33±0.05	0.18±0.02	0.32±0.03	0.36±0.02	0.03±0.01	0.26±0.05	0.56±0.05
Gills	0.34±0.13	0.45±0.02	0.10±0.02	0.19±0.02	0.26±0.05	0.28±0.02	0.03±0.02	0.02±0.01	0.27±0.05

Lead accumulates significantly in the bone, liver and gills of *T. zilli, O. niloticus* and *schilbe mystus* (Table 1 to 3) (Figure 1-3). The highest levels of Lead (0.33 ± 0.05 μgg^{-1}) was observed in the liver tissue of *T. zilli* (Table 1) (Figure 1) while the lowest limit (0.01± 0.01 μgg^{-1}) was detected in the bone of *T. zilli* (Table 1) (Figure 1). The concentration of Lead were higher in the following order liver > gills > bone. Similar findings were reported by (Buhler *et al.*, 1977) that highest concentrations were in gills, kidney and spleen in rainbow trout. (Oladimeji & Ofem, 1989) noticed in *O. niloticus*, the gills consistently accumulated higher amount of Lead as Lead nitrate. Lead is highly toxic to aquatic organism especially fish (Rompala *et al*,. 1984). The biological effects of sub-lethal concentrations associated with lead toxicity include; delayed embryonic development, suppressed reproduction, and inhibition of growth, increased mucous formation, neurological problems, enzyme inhalation and kidney disfunction (Rompala *et al.*, 1984 & Leland *et al.*, 1985). The levels of lead in the liver, gills and bone of the three species were below the 0.5 μgg^{-1} limits (Walsh *et al.*, 1977).

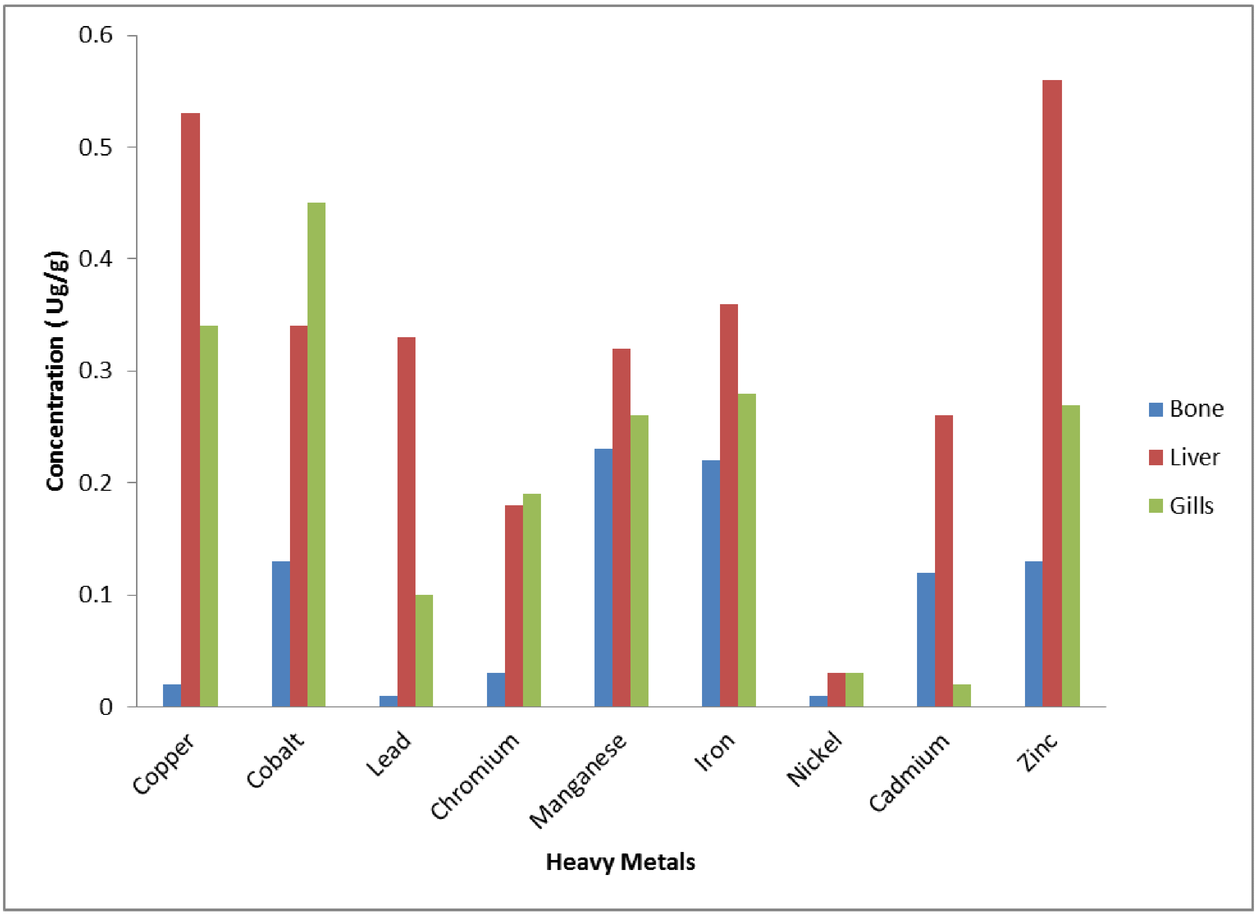


Fig 1: **Mean Variation of Heavy Metals in different organs of *Tilapia zilli caught* from Cross River System (Feb-April 2012)**

Table 2: Mean concentration of heavy metals in different organs of *Oreochromis nitloticus* caught from Cross River system (Feb – April 2012)

Organs	Concentrations (μgg^{-1})								
	Cu	Co	Pb	Cr	Mn	Fe	Ni	Cd	Zn
Bone	0.03±0.01	0.13±0.01	0.26±0.01	0.23±0.02	0.16±0.01	0.14±0.02	0.01±0.01	0.01±0.01	0.14±0.05
Liver	0.68±0.12	0.22±0.05	0.14±0.05	0.35±0.01	0.45±0.02	0.22±0.01	0.11±0.05	0.18±0.02	0.62±0.21
Gills	0.43±0.05	0.45±0.01	0.14±0.02	0.31±0.05	0.32±0.01	0.16±0.02	0.04±0.01	0.10±0.02	0.45±0.21

The concentration of Chromium in the different organs of the three species varied from 0.03 ± 0.01μgg^{-1} to 0.35 ± 0,01μgg^{-1} (Table 1 to 3) (Figure 1-3). It was found that the concentration of Chromium in the different organs of the three species from Cross river system varied from one organ to another. The highest concentration of Chromium (0.35 ± 0.01 μgg^{-1}) was detected in the liver tissue of *O. niloticus* (Table 2) (Figure 2), while the minimum (0.03 ± 0.01 μgg^{-1}) was observed in the bone of *T. zilli* and *schilbe mystus* (Table 1 and 3) and (Figure 1 and 2) respectively. Their lowest detection concentrations were found in the bone tissue. On the other hand, the highest concentrations of Cr were found in the liver and gills of the three species studied. No guideline documents are available for chromium in the edible parts of fish; neither was it asserted by NCBP. In view of other sanctions, the present Chromium concentration in the liver and gills of the three species which was the highest are well below the levels validated by USEPA (53.8ppm) for fish tissue (Pastorok, 1987). However, surveys of contaminants in edible shell fish conducted by FDA and National Marine Fisheries Service reported Chromium levels from 0.1 up to 0.9 μgg^{-1} (Adam's *et al.*, 1993), which is in line with the above threshold. The presents Chromium tissues concentrations for the study are below 4.0 μgg^{-1} levels suggested by (Eisler, 1986) as indicative of contamination.

Manganese tends to reside in the liver in all the three species studied, while the bone is the least accumulated organ. Hence, Mn concentration in the entire species of fish were below guide line limit of 0.7 μgg^{-1} set by (Charbonneau & Nash, 1993) and do not constitute any threat upon the consumption of these species of fish.

The concentration of Iron (Fe) in the three species of fish studied varied from 0.36 ± 0.05 μgg^{-1} to 0.14 ± 0.02 μgg^{-1}. The maximum concentration of iron was observed in the liver of *T. zilli* (table 1) (Figure 1) while the bone tissue of *O. niloticus* shows the least of concentration (Table 2) (Figure 2). The levels of concentration of Fe in the different tissue organ of the three species of fish studied were below the high residue concentration of Fe (34-107 ppm) in fish samples on MNW refuge (Charbonneau & Nash, 1993).

The maximum concentration of Nickel ($0.11 \pm 0.05\ \mu g\ g^{-1}$ to $0.12 \pm 0.02\mu g5^{-1}$) were detected in the liver of *T-zilli*, and some of *schilbe mystus* (Table 1 and 3) and (Figure 1 and 3) respectively, while the minimum levels of ($0.01\pm 0.01\mu gg^{-1}$) were detected in the bones of *T. zilli* and *O. niloticus* (Table 1 and 2) and (Figure 1 and 2) respectively. Nickel level of 0.7 μgg^{-1} is considered potentially lethal to fish and aquatic birds that consume them (Lemly A., 1993). Nickel concentration of 2.3 μgg^{-1} or greater, may cause reproductive impairment and lack of recruitment in fishes (Baumann & T. May, 1984). None of the samples in this study approached these levels of concern. Hence, nickel concentration in the entire species of fish does not constitute any threat upon its consumption.

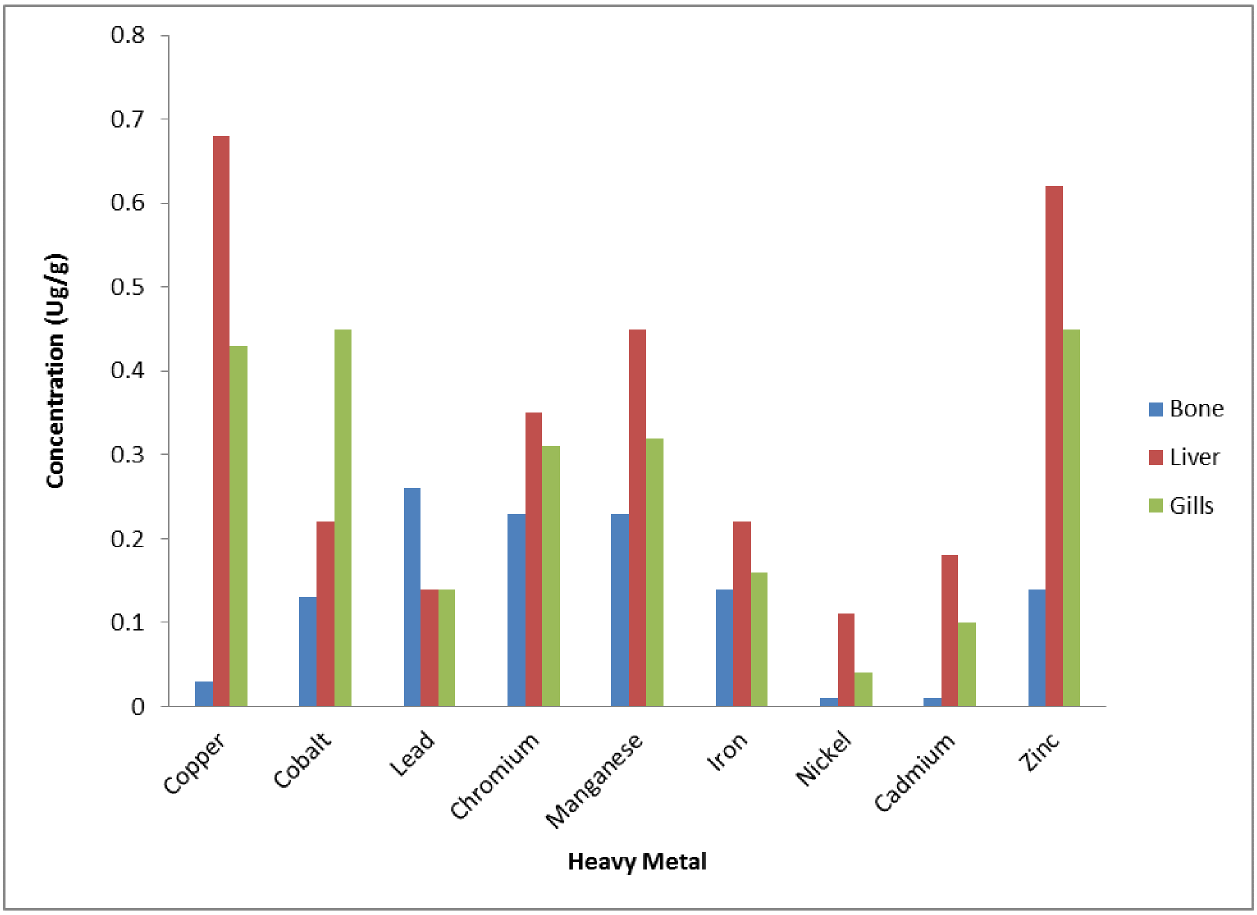


Fig 2: **Mean Variation of Heavy Metals in different organs of *Oreochromis nitloticus* caught from Cross River System (Feb-April 2012)**

Table 3: Mean concentration of heavy metals in different organs of *Schilbe mystus* caught from Cross River system (Feb – April 2012)

Organs	**Concentrations (μgg^{-1})**								
	Cu	Co	Pb	Cr	Mn	Fe	Ni	Cd	Zn
Bone	0.01±0.01	0.34±0.05	0.02±0.01	0.03±0.01	0.24±0.01	0.26±0.01	0.12±0.02	0.16±0.05	0.23±0.05
Liver	0.43±0.5	0.58±0.01	0.27±0.05	0.16±0.02	0.42±0.01	0.32±0.05	0.10±0.01	0.16±0.02	0.43±0.01
Gills	0.36±0.05	0.46±0.01	0.15±0.02	0.32±0.01	0.28±0.05	0.26±0.01	0.04±0.05	0.03±0.01	0.34±0.01

The highest concentration of Cadmium were observed in the liver tissue of *T. zilli*, *O. niloticus* and *schilbe mystus* while the lowest concentrations were detected in the bone tissues of the studied species (Table 1 to 3) (Figure 1-3). Cadmium is a non-essential trace metal that is potentially toxic to most fish and wildlife particularly freshwater organism (Robertson *et al.*, 1991). The highest concentrations of cadmium of the three species studied were below the 0.5 μgg^{-1} threshold considered harmful to fish and predators (Walsh *et al.*, 1977).

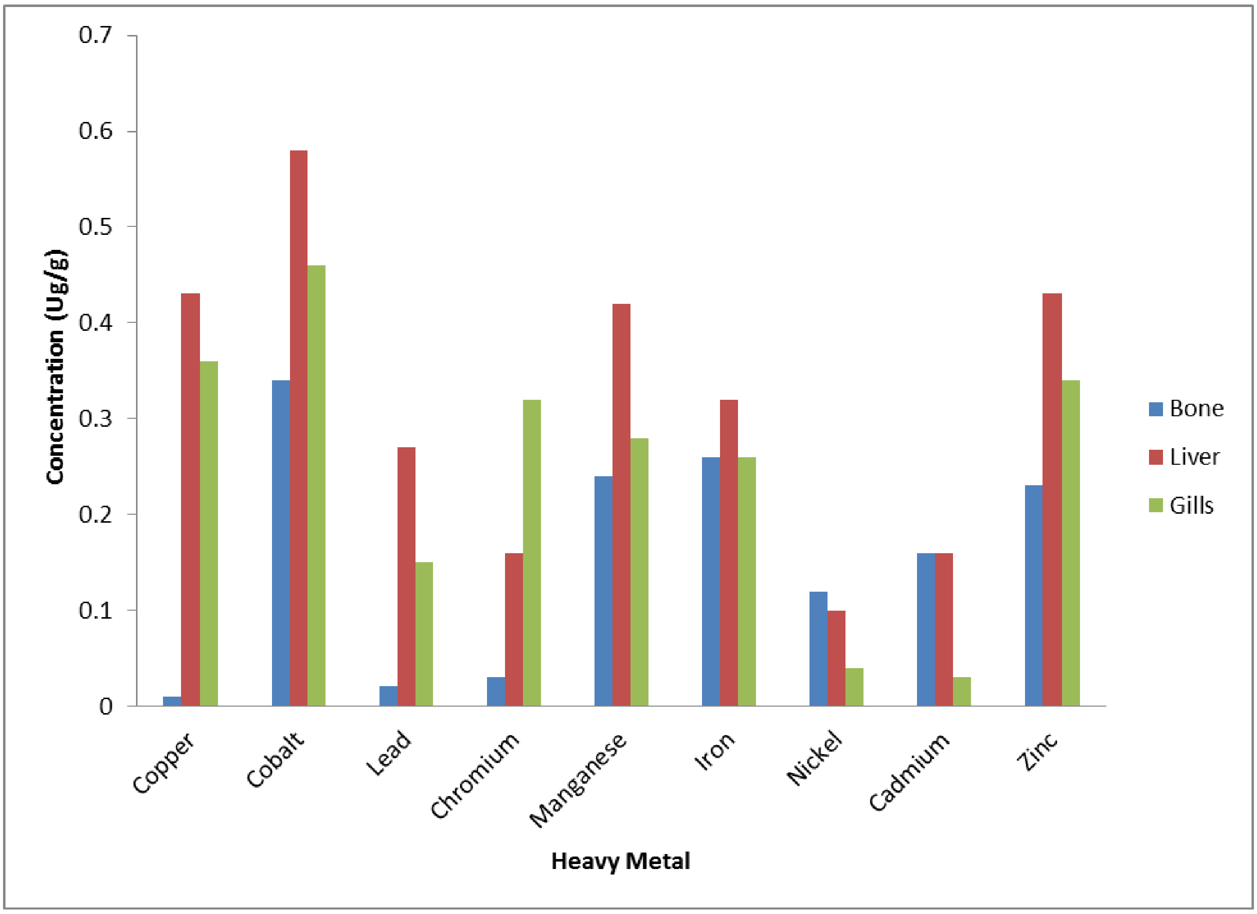


Fig 3: **Mean Variation of Heavy Metals in different organs of *Schilbe mystus* caught from Cross River System (Feb-April 2012)**

Zinc was detected in all the fish samples, and the highest concentration was in the liver tissue, followed by the gills, while the bone shows the least concentration (Table 1 to 3) (Figure 1-3). The concentration of Zn in T. *zilli*, *O. niloticus* and *Schilbe mystus* were below the NCBP 32.4 μgg^{-1}. Fish can accumulate zinc from both the surrounding water and from their diet (Eisher, 1993). Although Zinc is an essential element, at high concentration, it can be toxic to fish, cause mortality, growth retardation, and reproductive impairment (Sorenson E., 1991) zinc is capable of interacting with other elements and producing antagonistic, additive, or synergistic effect ((Eisher, 1993). Zinc does not appear to present a contaminant hazard to fish within this portion of Cross River system.

CONCLUSION

Fish absorb metals through ingestion of water or contaminated food. Heavy metals have been shown to undergo bioaccumulation in the tissue of aquatic organism on consumption of fish and aquatic organism these metals become transferred to man. However, it is not yet established whether the fishes in the river system have been severely affected by heavy metals based on the results obtained from the study. Although the results do not explicitly indicate a manifestation of toxic effects, the possibility that deleterious effects could manifest after a long period of consumption of fish caught from the river system, with trace metal contamination cannot be ruled out.

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