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Study on the Distribution of Heavy Metals in Different Tissues of Fishes from River Benue in Vinikilang, Adamawa State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. JCA designed the study, supervised the analyses of the study, performed the statistical analysis, and wrote the first draft of the manuscript. SM collected, prepared the field samples and contributed in the experimental set up. BSY and ZMC handled the literature search and review. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

Aims: This study is aimed to determine the levels of some heavy metals in different species of fish and to compare the results with other standard values.
Study Design: The gills, liver, stomach, kidney, bones and flesh of four common fish species (*Tilapia zilli, Clarias anguillaris, Synodentis budgetti and Oreochronmis niloticus)* were collected for analysis of heavy metals.
Place and Duration of Study: This study was carried out in River Benue, Vinikilang, Adamawa State, Nigeria between the periods of January 2011 to January 2012.
Methodology: Sample collection and preparations were carried out using standard procedures. The concentrations of Cu, Zn, Co, Mn, Fe, Cr, Cd, Ni and Pb were carried out using Flame Atomic Absorption Spectrophotometer (AAS, Unicam 969).
Results: Iron was the most abundant metal in the studied tissues of all the fish species. In the fishes analyzed Fe accumulation was the maximum in all the organs but its highest

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value of 12.65 µg/g was significantly observed in the Gills of *Synodentis budgetti* ($p < 0.05$), the liver of *Tilapia zilli* was second while the flesh of *Heterotis niloticus* shows the least value. From the result of this study, the tissues accumulation was observed in the order of gills>liver>stomach>kidney>bones>flesh. The gills of all the fish tend to accumulate significant high levels of heavy metal than other tissues. Accumulation of metal in different species is the function of their respective membrane permeability and enzyme system, which is highly species specific and because of this fact metals accumulated differently in the tissues of fishes as observed in the study.

Conclusion: Based on the above results, it can therefore be concluded that metals bioaccumulation in the entire fish species study did not exceeds the permissible limits set for heavy metals by FAO, FEPA and WHO. Therefore these fishes are fit for consumption.

Keywords: Distribution; heavy metals; fish; gills; liver; stomach; kidney; bones; flesh Vinikilang; River Benue.

1. INTRODUCTION

Due to industrialization, the number of factories and population has increased rapidly. The contamination of freshwaters with a wide range of pollutants has become a matter of concern over the last few decades (Canli and Kalay, 1998; Dirilgen, 2001; Vutukuru, 2005). The natural aquatic systems have been extensively contaminated with heavy metals released from domestic, industrial and other man- made activities (Velez and Montoro, 1998). Heavy metal contaminations have devastating effects on the ecological balance of the recipient environment and a diversity of aquatic organisms (Ashraj, 2005; Vosyliene and Jankaite, 2006). Among animal species, fishes are the inhabitants that cannot escape from the detrimental effects of pollutants (Olaifa et al., 2004). The studies carried out on various fishes have shown that these metals alter the physiological activities and biochemical parameters both in tissues and blood (Basa and Usha, 2003). The toxic effects of heavy metals have been reviewed, including their bioaccumulation by several workers (Rani, 2000). It is known that metals accumulate on sediment surface in benthic living things, planktonic organisms and other living matter and is enhanced through food chain. Fish accumulate xenobiotic chemicals, especially those with poor water soluble occurs because of the very intimate contact with the medium that carries the chemicals in solution or suspension and also because fish have to extract oxygen from the medium by passing the enormous volumes of water over gills.

Heavy metals are natural trace components of the aquatic environment, but their levels have increased due to industrial wastes, geochemical structure, agricultural and mining activities (Singh et al., 2006; Sprocati et al., 2006). All these sources of pollution affect the physiochemical characteristics of the water, sediment and biological components and thus the quality and quantity of fish stocks (Al-Rawi, 2005; Mantovi et al., 2005; Singh et al., 2006). Fish is generally appreciated as one of the healthiest and cheapest source of protein and it has amino acid compositions that are higher in cysteine than most other sources of protein. Heavy metals like copper, iron and zinc are essential for fish metabolism while some others such as mercury, cadmium, arsenic and lead have no known role in biological systems (Sallam et al., 1999; Schmitt et al., 2005; Has-Schon et al., 2007). Studies from the field and laboratory experiments showed that accumulation of heavy metals in a tissue is mainly dependent on water concentrations of metals and exposure period; although some other environmental factors such as salinity, pH, hardness and temperature play significant roles in metal accumulation (Singh et al., 2006; Jeffree et al., 2006a; Has- Quan et al., 2006;

Schon et al., 2007). Ecological needs, size and age of individuals, their life cycle and life history, feeding habits and the season of capture were also found to affect experimental results from the tissues (Kime et al., 1996; Rurangwa et al., 1998). The obvious sign of highly polluted water, dead fish, is readily apparent, but the sublethal pollution might result only in unhealthy fish. Very low-levels of pollution may have no apparent impact on the fish itself, which would show no obvious signs of illness, but it may decrease the fecundity of fish populations, leading to a long-term decline and eventual extinction of this important natural resource (Krishnani et al., 2003; Burger and Gochfeld, 2005). Such low-level pollution could have an impact on reproduction, either indirectly via accumulation in the reproductive organs, or directly on the free gametes (sperm or ovum) which are released into the water. Control of reproduction in fish is complex and regulated by a wide range of factors and low-level pollution could affect any part of this pathway. Steroid hormones are very important and play essential roles in maintaining reproductive functions (Kime et al., 1996; Rurangwa et al., 1998).

Fish, apart from being a good source of digestible protein, vitamins, minerals and polyunsaturated fatty acids are also an important source of essential heavy metals. In the future, seafood will even be a more important source of food protein than they are today and the safety for human consumption of products from aquaculture is of public health interest (WHO, 1999). Fish are often at the top of aquatic food chain and may concentrate large amounts of some metals from the water (Mansour and Sidky, 2002). Unlike organic contaminants that loose toxicity with time by biodegradation, heavy metals cannot be degraded; their concentration can be increased by bioaccumulation Aksoy, 2008. Metal bioaccumulation is largely attributed to differences in uptake and depuration period for various metals in different fish species (Tawari-Fufeyin and Ekaye, 2007). Multiple factors including season, physical and chemical properties of water can play a significant role in metal accumulation in different fish tissues (Kargin, 1996). Industrial development; fertilizers; livestock manure; air pollution; increases in pesticide usage and mining have led to increasing levels of heavy metals in aquatic environments (Cooper, 1993; Guerrero and Kesten, 1993).

Metal residues problems in the fish tissues are serious, as reflected by the high metal concentrations recorded in the water and sediments (Romeo et al., 1999; Wong, et al., 2001). The gills are directly in contact with water. Therefore, the concentration of metals in gills reflects their concentration in water where the fish live, whereas the concentrations in liver represent storage of metals in the water (Romeo et al., 1999).

Studies on heavy metals in rivers, lakes, fish and sediments (Özmen et al., 2004; Begüm et al., 2005; Fernandes et al., 2008; Öztürk et al., 2008; Pote et al., 2008; Praveena et al., 2008) have been a major environmental focus especially during the last decade. Sediments are important sinks for various pollutants like pesticides and heavy metals and also play a significant role in the remobilization of contaminants in aquatic systems under favourable conditions and in interactions between water and sediment. Fish samples can be considered as one of the most significant indicators in fresh water systems for the estimation of metal pollution level Rashed, 2001). The commercial and edible species have been widely investigated in order to check for those hazardous to human health (Begüm et al., 2005).

Heavy metals such as copper, iron, chromium and nickel are essential metals since they play an important role in biological systems, whereas cadmium and lead are non-essential metals, as they are toxic, even in trace amounts (Fernandes et al., 2008). For the normal metabolism of the fish, the essential metals must be taken up from water, food or sediment

(Canli and Kalay, 1998). These essential metals can also produce toxic effects when the metal intake is excessively elevated (Tüzen, 2003).

River Benue in Vinikilang, Adamawa State, received a wide variety of waste from agricultural activity within Vinikilang area. The river is one of the main fish supply sources for this area. Most farmers within the Vinikilang area of Benue State use fertilizers and synthetic chemical pesticides to control pests on vegetables including a number of highly persistent organochlorine and organophosphorus pesticides. Pesticides and other agrochemicals are extensively used in agricultural production to check or control pests, diseases weeds and other plant pathogens in an effort to reduce or eliminate yield losses and preserve high product quality. Lack of knowledge of the use and the effects of these pesticides and agrochemicals among small and large scale farmers has resulted in their misuse and consequently the waste generated flows into the river Benue and may contaminates the river with a variety of heavy metals acting as point sources. Such contaminations might accumulation in the various organs of fishes; such accumulation may affect humans and other species that depend on such fish as food.

2. MATERIALS AND METHODS

2.1. Sampling Area and Sample Collection

Sampling was from the River Benue in Vinikilang region of Adamawa State, Nigeria**.** Fish samples (*Districhodus rostratus, Heterotis niloticus, Lates niloticus and Citharinus citharium*) were caught using gill nets from River Benue in Vinikilang Adamawa State, Nigeria; Fish samples of uniform size were collected in order to avoid the possible error due to size differences. The fish were labeled with an identification number. Samples of fishes were transported to the laboratory on the same day and later dissected to remove the bone, liver, stomach, gill, flesh and kidney of each species of fish by an expert in the department of fisheries, University of Maiduguri, Nigeria.

2.2. Digestion of Fish Samples for Heavy Metal Determination

The bone, liver, stomach, gill, flesh and kidney of each fish samples (8.0g) were dried at 105ºC until they reach a constant weight. Each dried sample was ground, using porcelain mortar and a pestle. The ground fish tissues were transferred to a porcelain basin and put into a Thermicon P muffle furnace at a temperature of 550ºC for 4 hrs. Samples were digested with tri-acid mixture (HNO_3:$HClO_4$ H_2SO_4 = 10:4:1) at a rate of 5 mL/per 0.5 g of sample and were placed on a hot plate at 100ºC temperature. Digestion was continued until the liquor becomes clear. All the digested liquors were filtered through Whatmann 541 filter paper and diluted to 25 ml with distilled water of the element in the sample solution times 20 as additional factor in µg/g dry weight. Determination of Cu, Zn, Co, Mn, Fe, Cr, Cd, Ni and Pb were made directly on each final solution using Perkin-Elmer AAnalyst 300 Atomic Absorption Spectroscopy (AAS).

2.3. Calibration Solution

Standard solution of each sample Cu, Zn, Co, Mn, Fe, Cr, Cd, Ni and Pb were prepared according to Sc 2000 manufacturer procedure for Atomic absorption spectroscopy to be used. A known 1000 mg/l concentration of the metal solution was prepared from their salts.

2.4. Data Handling

Data collected were subjected to One-way analysis of variance (ANOVA) and were used to assess whether samples varied significantly between species, possibilities less than 0.05 ($p<0.05$) were be considered statistically significant.

3. RESULTS

3.1. Concentrations of Heavy Metals

Fig. 1 presents the levels of heavy metals in the tissues of *Districhodus rostratus*. Levels of Fe ranged from 1.45 to 4.56 µg/g; 0.01 to 0.56 µg/g Zn; 0.21 to 0.55 µg/g Mn; 0.15 to 1.13 µg/g Cr; 0.22 to 0.98 µg/g Cu; 0.22 to 0.64 µg/g Cd; 0.05 to 0.48 µg/g Pb; 0.11 to 0.75 µg/g Ni; 0.14 to 0.45 µg/g Co. The order of metal bioaccumulation in these tissue are Fe>Cu>Cr>Cd>Ni>Zn>Mn>Co>Pb.

The levels of heavy metals in the organs of *Heterotis niloticus* are as presented in Fig. 2. Fe ranged from 0.12 to 0.42 µg/g; 0.02 to 0.45 µg/g Zn; 0.06 to 0.23 µg/g Mn; 0.11 to 0.21 µg/g Cr; 0.11 to 0.56 µg/g Cu; 0.17 to 0.62 µg/g Cd; 0.11 to 0.48 µg/g Pb; 0.18 to 0.62 µg/g Ni; 0.13 to 0.27 µg/g Co. The order of metal bioaccumulation in these tissue are Ni>Cd>Pb>Cd>Cu>Fe>Zn>Co>Mn. For that of *Lates niloticus* and *Citharinus cithariumare* the concentrations of heavy metals is as presented in Figs. 3 and 4, the levels of Fe ranged from 0.14 to 3.43 µg/g; 0.12 to 1.56 µg/g Zn; 0.06 to 0.56 µg/g Mn; 0.21 to 0.87 µg/g Cr; 0.07 to 0.45 µg/g Cu; 0.13 to 0.69 µg/g Cd; 0.01 to 0.31 µg/g Pb; 0.03 to 0.23 µg/g Ni; 0.05 to 0.31 µg/g Co.

3.2. Comparison of Heavy Metals among Species of Fish

Fig. 5 shows the comparison in the concentrations of heavy metals in the fish gills samples among the four species of fish. Fe ranged from 0.42 to 4.56 µg/g; 0.45 to 1.56 µg/g Zn; 0.16 to 0.55 µg/g Mn; 0.36 to 1.13 µg/g Cr; 0.12 to 0.98 µg/g Cu; 0.22 to 0.64 µg/g Cd; 0.11 to 0.48 µg/g Pb; 0.18 to 0.75 µg/g Ni; 0.27 to 0.62 µg/g Co. Gill surfaces are the first target of water-born metals (Spicer and Weber, 1991). The microenvironment of the gill surface consists of an epithelial membrane which primarily contains phospholipids covered by a mucous layer (Bolis et al., 1984). According to Reid and Mcdonald (1991), the gill surface is negatively charged and thus provides a potential site for gill-metal interaction for positively charged metals Gill tissue of *Districhodus rostratus* was the highest in terms of metals accumulation, while *Citharinus cithariumare* shows the least levels of metals accumulations, Laboratory experiments have indicated that in fishes which take up heavy metals from water, the gills generally show higher concentration than in the digestive tract. On the other hand, fish accumulating heavy metals from food show elevated metal levels in the digestive tract as compared to the gills (Ney and Vanhassel, 1983; Heath, 1990). The gills of all the fish tend to accumulate high significant high levels of heavy metal than other tissues. The gills of *Districhodus rostratus* had shown more metals accumulation than other tissues. On the basis of the results of this study, the major route of uptake of heavy metals in different fish species might be as a result of feeding habits. The concentrations of Fe, Zn, Cr, Cu, Pb and Ni were observed to be higher in the gill of *Districhodus rostratus* while *Lates niloticus* accumulate high concentrations of Mn and Cd compared to other species of fishes.

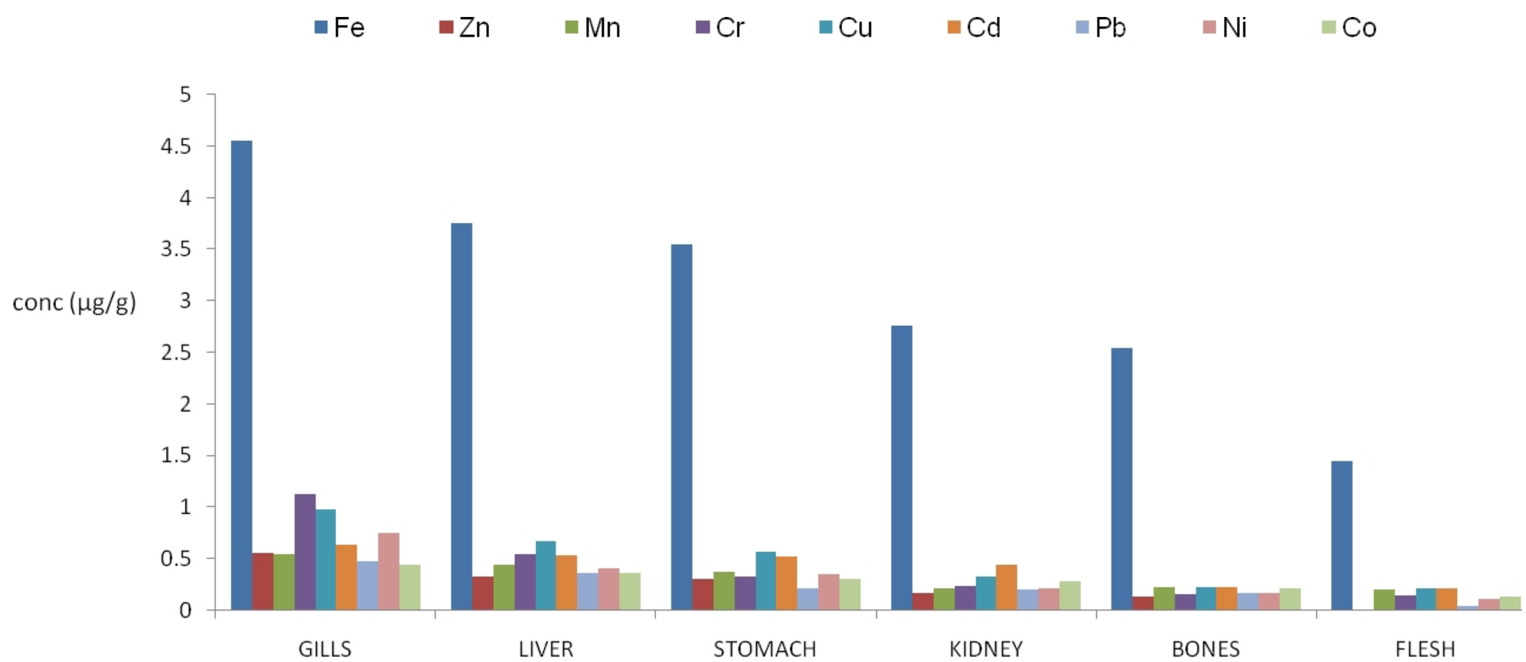

Fig. 1. Mean concentrations of heavy metals in the gills, liver, stomach, kidney, bones and flesh of *Districhodus rostratus* from river Benue in Vinikilang, Adamawa State, Nigeria

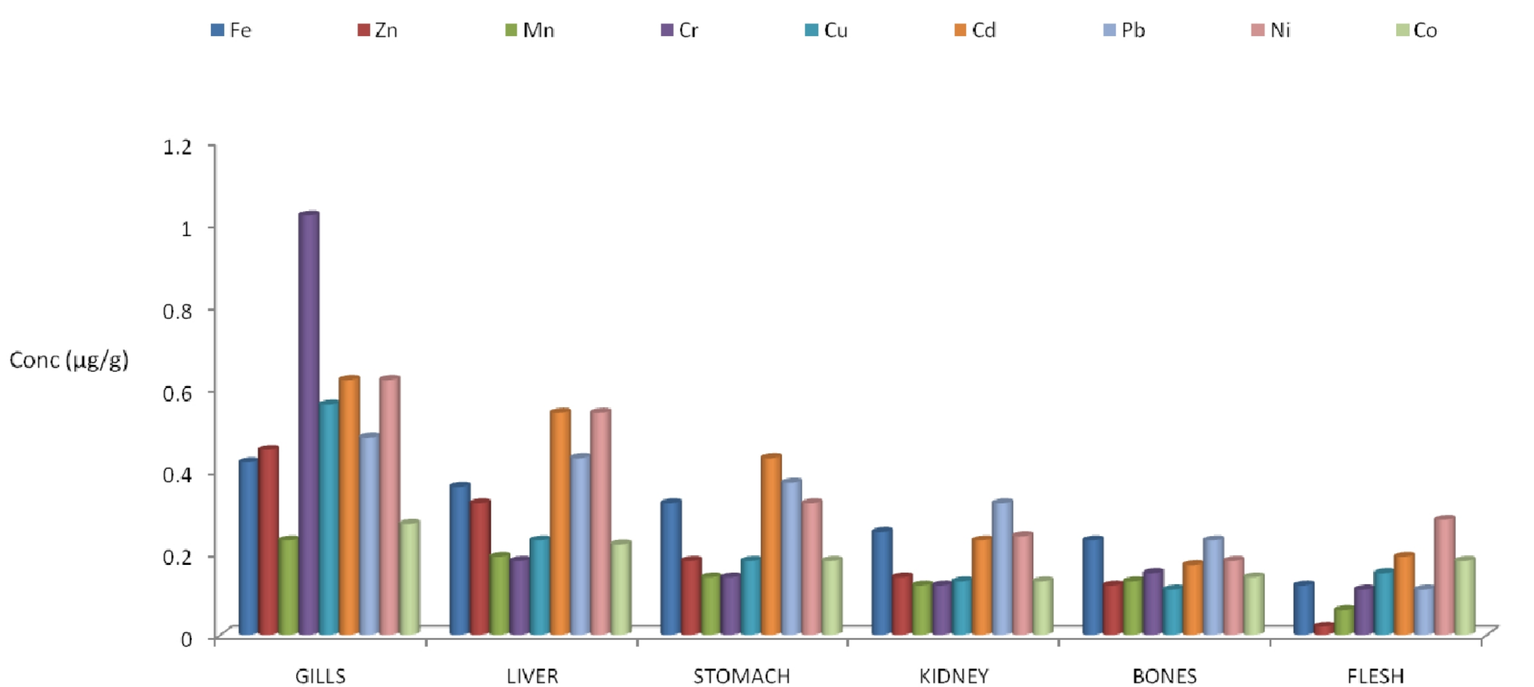

Fig. 2. Mean concentrations of heavy metals in the gills, liver, stomach, kidney, bones and flesh of *Heterotis niloticus* from river Benue in Vinikilang, Adamawa State, Nigeria

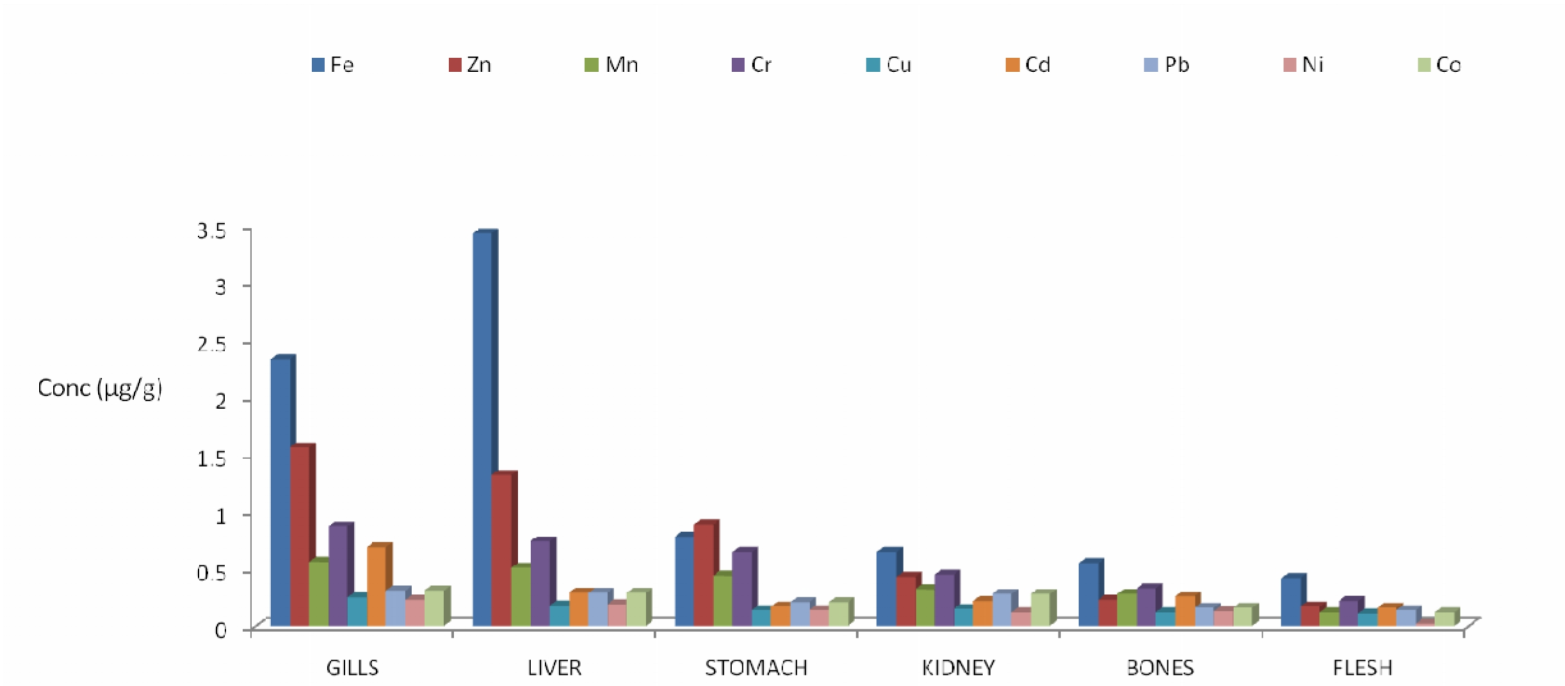

Fig. 3. Mean concentrations of heavy metals in the gills, liver, stomach, kidney, bones and flesh of *Lates niloticus* from river Benue in Vinikilang, Adamawa State, Nigeria

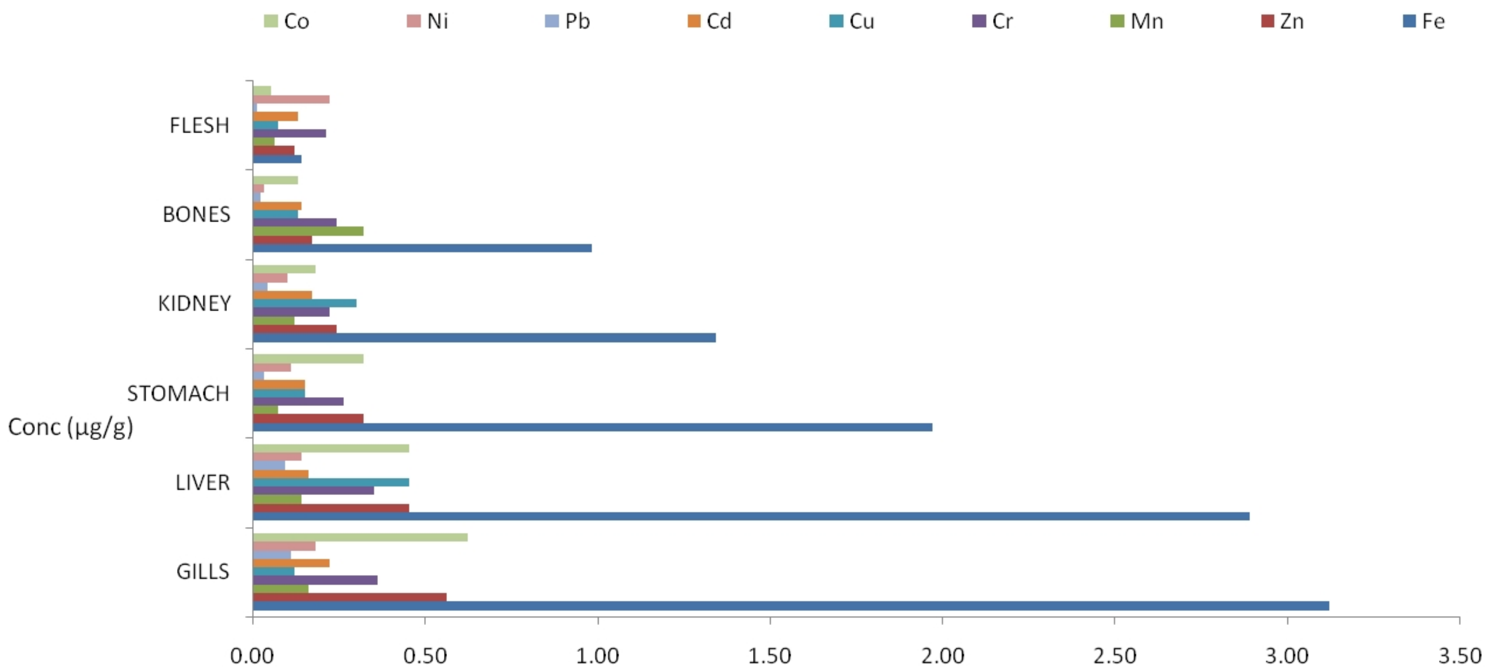

Fig. 4. Mean concentrations of heavy metals in the gills, liver, stomach, kidney, bones and flesh of *Citharinus catharium* from river Benue in Vinikilang, Adamawa State, Nigeria

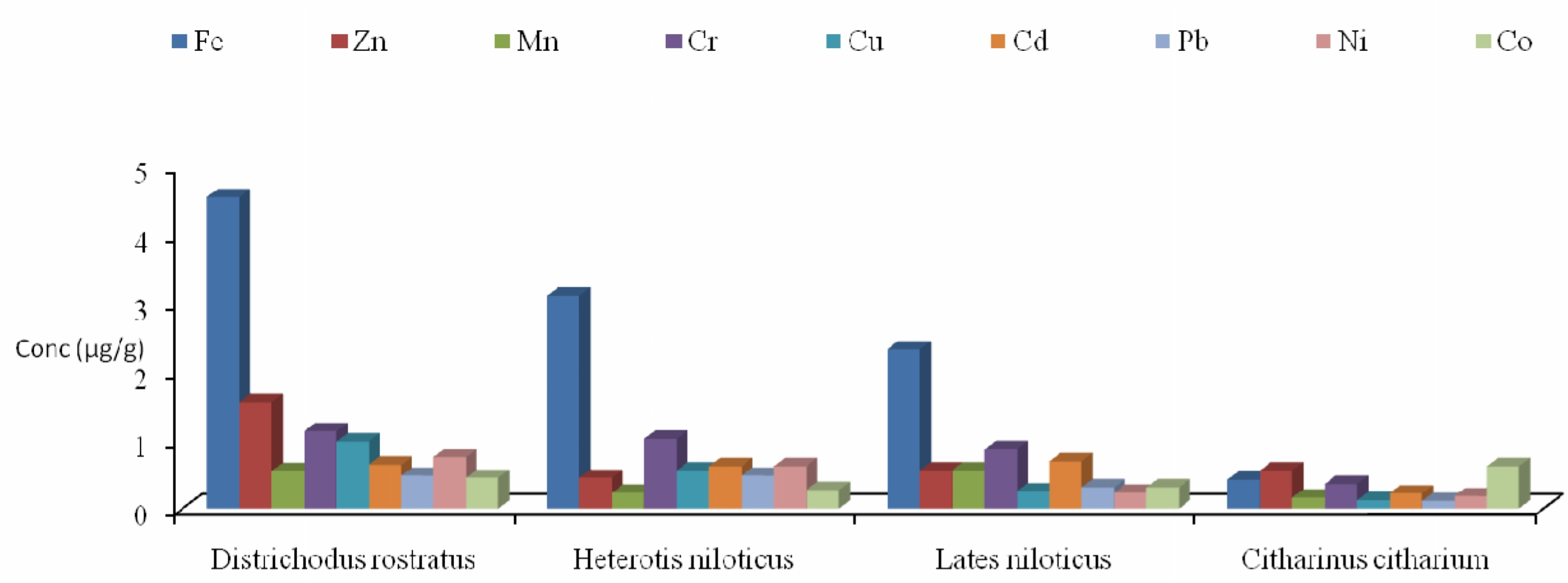

Fig. 5. Comparison in the concentration of heavy metals in the gills of different species of fish from river Benue in Vinikilang, Adamawa State, Nigeria

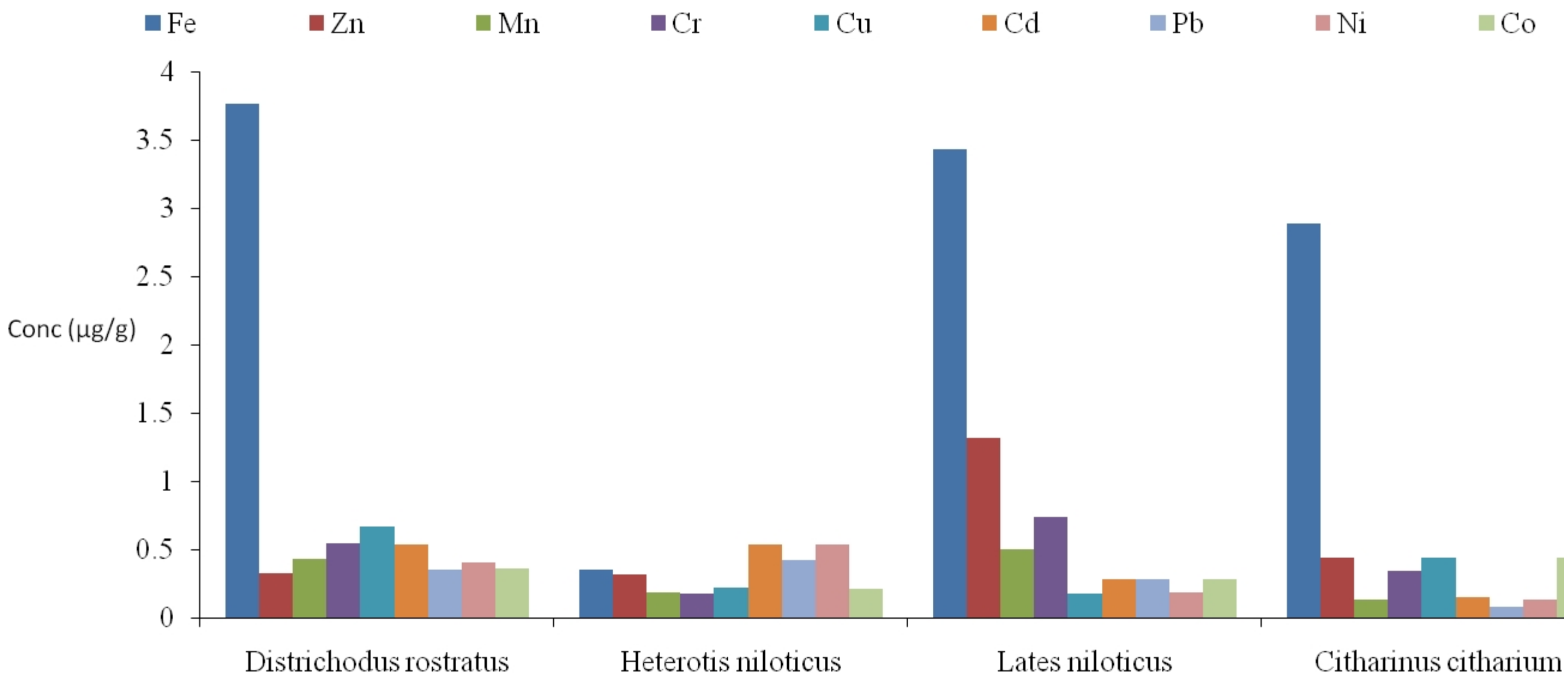

Fig. 6. Comparison in the concentrations of heavy metals in the liver of different species of fish from river Benue in Vinikilang, Adamawa State, Nigeria

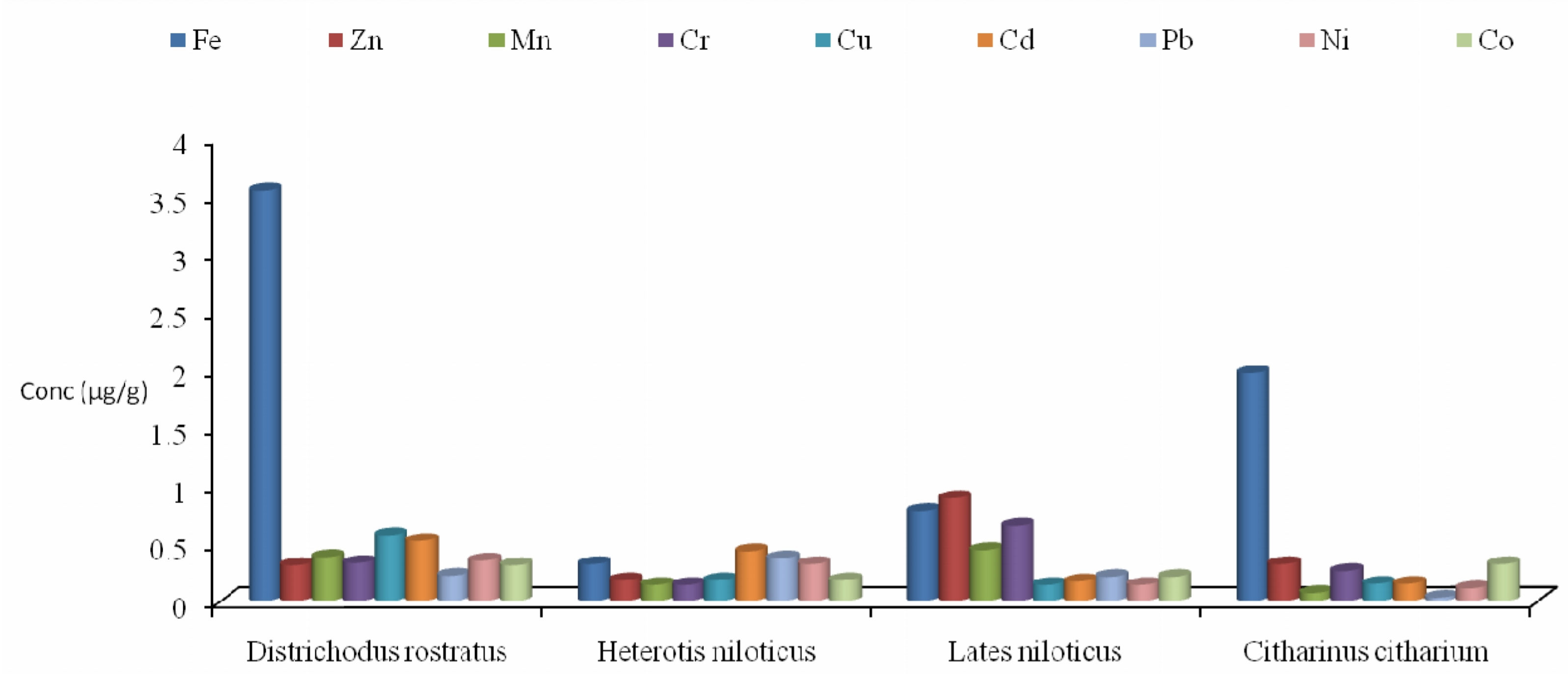

Fig. 7. Comparison in the concentrations of heavy metals in the Stomach of different species of fish from river Benue in Vinikilang, Adamawa State, Nigeria

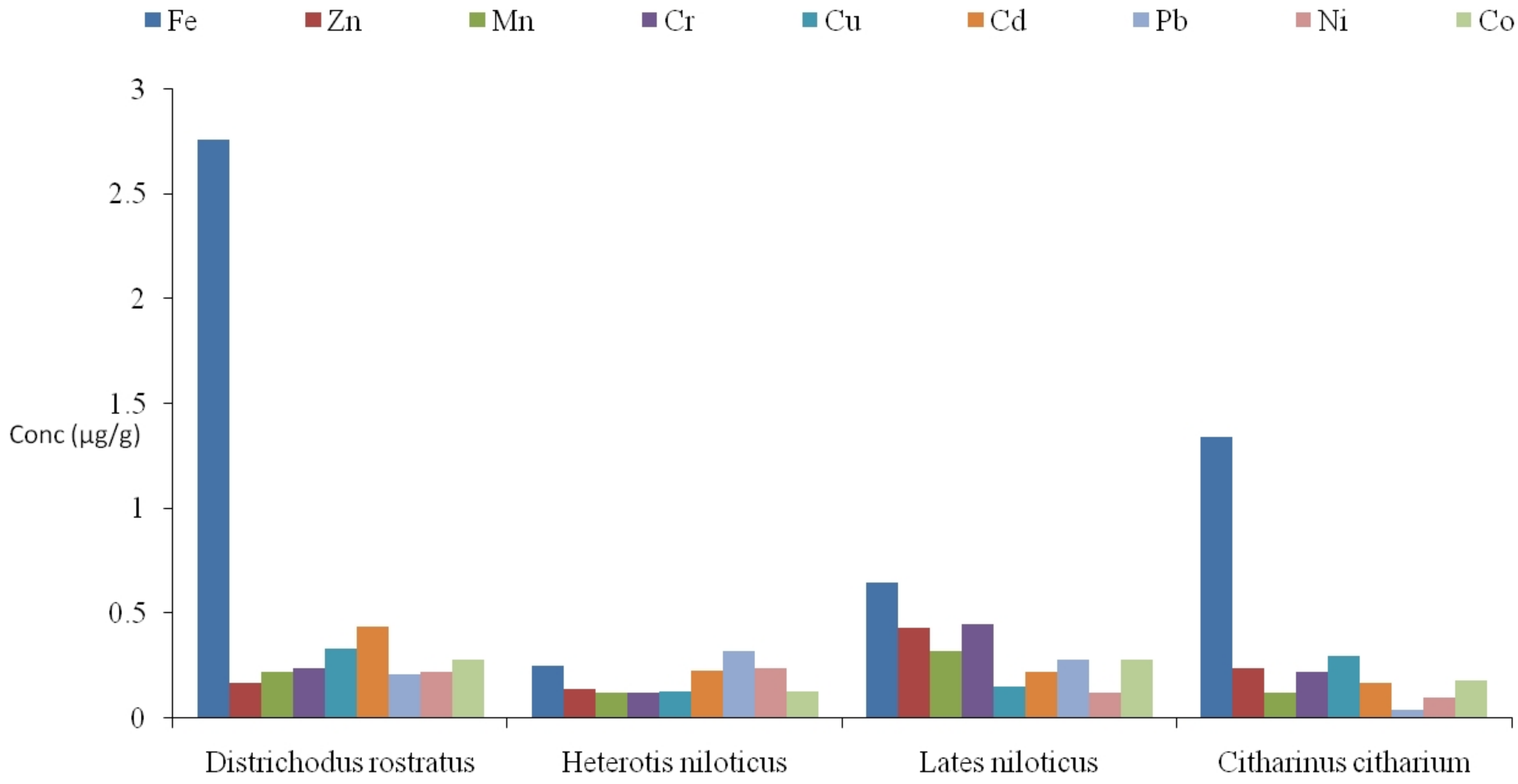

Fig. 8. Comparison in the concentration s of heavy metals in the kidney of different species of fish from river Benue in Vinikilang, Adamawa State, Nigeria

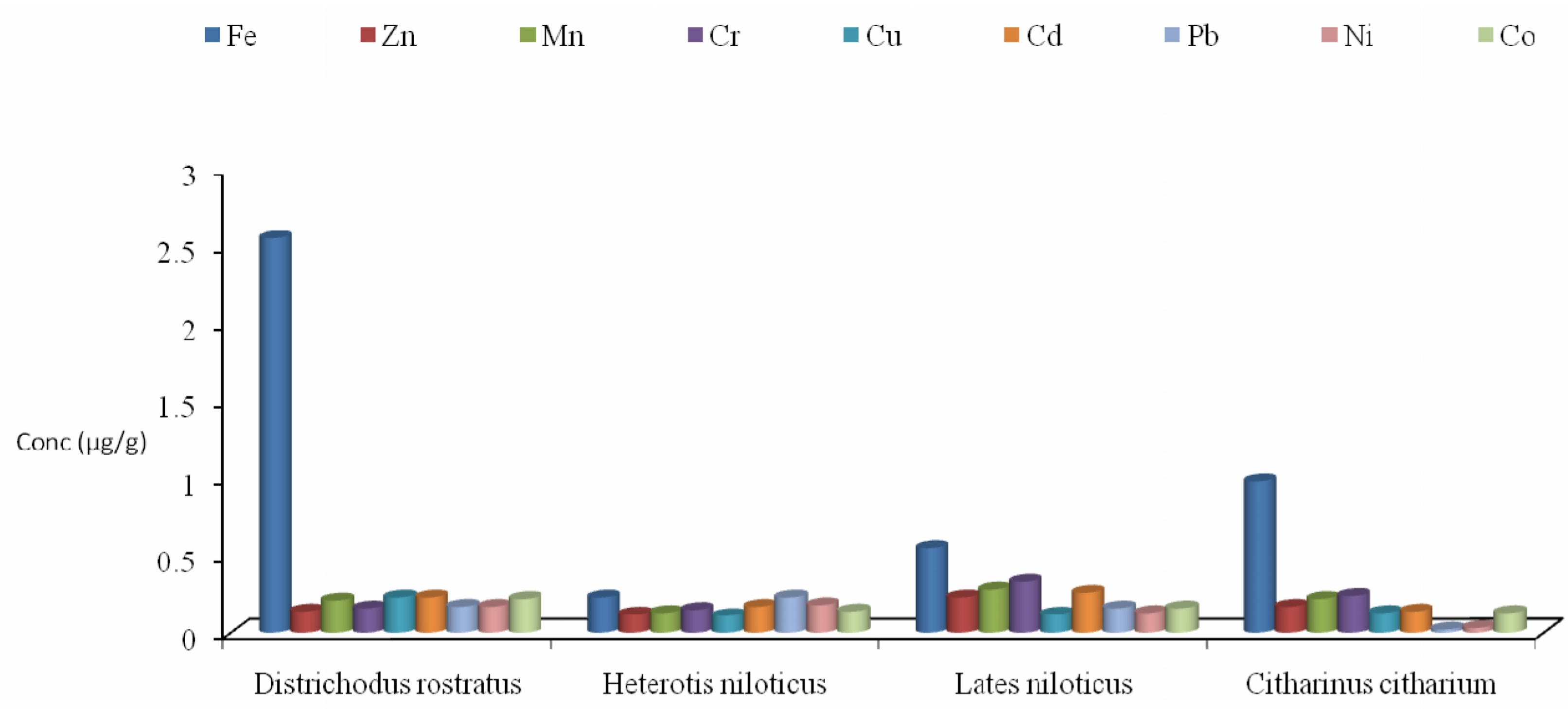

Fig. 9. Comparison in the concentration s of heavy metals in the bones of different species of fish from river Benue in Vinikilang, Adamawa State, Nigeria

Fig. 6 shows the comparison of heavy metals in liver tissues among species. Fe levels ranged from 0.36 to 3.76 µg/g; 0.33 to 1.32 µg/g Zn; 0.14 to 0.74 µg/g Mn; 0.18 to 0.74 µg/g Cr; 0.18 to 0.67 µg/g Cu; 0.16 to 0.54 µg/g Cd; 0.09 to 0.43 µg/g Pb; 0.14 to 0.54 µg/g Ni; 0.22 to 0.45 µg/g Co. The liver plays an important role in accumulation and detoxification of heavy metals (Yousafzai, 2004). Exposure of fish to elevated levels of heavy metals induces the synthesis of metallothioneine proteins (MT), which are metal binding proteins (Noel-Lambot and Disteche, 1978; Phillips and Rainbow, 1989). Fishes are known to posses the metallothioneine proteins (Friberg et al., 1971). Metallothioneine proteins have high affinities for heavy metals and in doing so, concentrate and regulate these metals in the liver (Carpene and Vašák, (1989). Metallothioneine proteins bind and detoxify the metal ion. In the present study, the liver of *Districhodus rostratus* show more accumulation of Fe, Cu and Cd. *Lates niloticus* shows more of Zn, Mn and Cr, while *Heterotis niloticus* accumulate Pb and Ni. In the present study the liver tissue was observed to accumulate the second highest heavy metal load after gills, which is similar to results of Narayanan and Vinodhini, 2008).

Fig. 7 shows the comparison of heavy metals in stomach tissues among the four species of fish. Fe levels ranged from 0.32 to 3.55 µg/g; 0.31 to 0.89 µg/g Zn; 0.14 to 0.44 µg/g Mn; 0.14 to 0.65 µg/g Cr; 0.14 to 0.57 µg/g Cu; 0.15 to 0.52 µg/g Cd; 0.21 to 0.37 µg/g Pb; 0.11 to 0.35 µg/g Ni; 0.18 to 0.32 µg/g Co. The stomach of *Lates niloticus* accumulates significant higher levels of Fe, Zn, Mn and Cr, while *Districhodus rostratus* shows more of Cu, Cd and Ni. These differences in the accumulation of heavy metals could probably due to different feeding or metal sequestering habits of the fishes.

Fig. 8 presents the comparison of heavy metals in kidney tissues among species. The concentrations of Fe ranged from 0.25 to 2.76 µg/g; 0.14 to 0.43 µg/g Zn; 0.12 to 0.32 µg/g Mn; 0.12 to 0.45 µg/g Cr; 0.13 to 0.33 µg/g Cu; 0.17 to 0.44 µg/g Cd; 0.04 to 0.32 µg/g Pb; 0.10 to 0.24 µg/g Ni; 0.13 to 0.28 µg/g Co. *Lates niloticus* tend to accumulate more levels of Fe, Zn, Mn and Cr, while *Districhodus rostratus* shows more of Cu, Cd and Co.

Fig. 9 presents the comparison of heavy metals in bone tissues among species. The concentrations of Fe ranged from 0.23 to 2.55 µg/g; 0.12 to 023 µg/g Zn; 0.13 to 0.28 µg/g Mn; 0.15 to 0.33 µg/g Cr; 0.11 to 0.23 µg/g Cu; 0.17 to 0.23 µg/g Cd; 0.16 to 0.23 µg/g Pb; 0.03 to 0.18 µg/g Ni; 0.13 to 0.22 µg/g Co.

4. DISCUSSION

4.1 Comparison of Heavy Metals in Fish Samples with Standard Values

4.1.1 Iron (Fe)

Iron was the most abundant metal in the studied tissues of all the fish species. In the fishes analyzed, Fe accumulation was the maximum in all the organs but its highest value was observed in both Gills and liver of *Districhodus rostratus,* while the stomach of *Heterotis niloticus* shows the least value. Studies reported in *C. gariepinus* (Osman et al., 2010) and *Tinca tinca* (Selda and Ismail, 2005) also revealed the maximum accumulation of Fe in liver. However in other studies the highest accumulation was observed in the organs of gills in the fishes *O. niloticus, L. niloticus* (Mohammad, 2008) *O. mossambicus (*Jenny and Avenant, 2006). Accumulation levels reported in the present study for gills and liver of *Districhodus rostratus* corroborates to the findings in *O. niloticus* and *L. niloticus* (Mohammad, 2008). Earlier reports showed Fe to be normally highest in gills (Philips, 1976) or in the liver

(Charbonneau and Nash, 1993). The present study showed gills with the highest Fe concentrations. The highest concentrations observed in the present study were below the high residue concentrations of Fe (34-107 ppm) in fish samples on MNW Refuge (Charbonneau and Nash, 1993).

4.1.2 Zinc (Zn)

The highest levels of Zn in the present study were observed in the gills of *Districhodus rostratus*. Other workers also reported the highest concentration of Zn in the gills of *Labeo dyocheilus, Wallago attu* and in liver of *C. punctatus* (Murugan et al., 2008). However highest accumulation was seen in other organs such as gills of *C. punctatus* (Vineeta et al., 2007), testis of *O. niloticus* and *L. niloticus* (Charbonneau and Nash, 1993). Accumulation of metals reported in the present study for gills and liver of *Districhodus rostratus* is comparable to *O. niloticus* (Charbonneau and Nash, 1993) and *C. punctatus* (Murugan et al., 2008) respectively. In the present study the least accumulation of Zn was seen in gills and other tissues of *Heterotis niloticus.* The permissible limits for Zn set by WHO (1989) is 40 ppm which is less than the values observed during this study. Zinc was detected in all the fish samples and the highest concentrations were observed in gills tissues followed by liver and stomach, while the flesh of all the fishes showed the least concentration of Zinc. The concentration of Zn in *Districhodus rostratus* and other species studied were below the NCBP 34.2µg/g. Fish can accumulate zinc from both the surrounding water and from their diet (Eisler, 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 (Baumann and May, 1984). Zinc does not appear to present a contaminant hazard to fish within this portion of River Benue.

4.1.3 Manganese (Mn)

Levels for Mn accumulation during the present study are shown in Figs. 1 to 4. The highest content of Mn in the studied tissues was observed in gills and liver of *Lates niloticus.* In the present study the observation that was made in gills and liver of *Lates niloticus* is similar to that observed in *O. mossambicus* (Jenny and Avenant, 2006) and *Tinca tinca* (Selda and Ismail, 2005). The levels of Mn accumulation that was observed in the liver of *lates niloticus* are comparable to the both *O. mossambicus (*Jenny and Avenant, 2006) and *Tinca tinca* (Selda and Ismail, 2005). Accumulation reported for Mn in the present study for stomach in all the species of fish study is also comparable to *Channa obscura* and *Tilapia zilli* respectively (Anim et al., 2010). Manganese (Mn) occurs naturally in sediments; in all the fish species study Mn tend to reside more in the gills and liver, while flesh shows the least level of accumulation. The permissible limit for Mn set by WHO (1989) is 0.01ppm whereas according to FEPA (2003) it is 0.05 ppm. Mn does appear to present a contaminant hazard to fish within this portion of River Benue.

4.1.4 Chromium (Cr)

Chromium does not normally accumulate in fish and hence low concentrations of Cr were reported even from the industrialized parts of the world (Moore and Ramamoorthy, 1984). The mean concentration of Cr found in the fish muscle samples from the Mediterranean coastal waters was 2.1µg/g. Even lower means were also reported from the Gulf of Aqaba for the muscle of *P. barberinus* (0.4µg/g.) and *Scarus variegatus* is 0.6µg/g (Wahbeh and Mahasneh, 1987). However, in the present study higher concentrations were found in gills of the examined fish, while livers show the second highest. However, Yousafzai (2004) reported that the gills were the site for maximum accumulation for Cr in *L. dyocheilus* and *W. attu*. The observation made in muscles of *Oreochromis mossambicus* and *Cyprinus carpio* (Jabeen and Chaudhry, 2009; Jabeen and Chaudhry, 2010) showed maximum concentration of Cr. Wahbeh and Mahasneh, (1987) investigated the following pattern of distribution of Cr in *L. rohita* gills >kidney >liver >skin >muscles, whereas in the present study the maximum accumulation of Cr was observed in the gills. The permissible limits set for Cr by FEPA (2003) are 0.05 and 0.15 mg/ kg respectively. Cr content observed in the tissues of all the species of fish exceeds this limit. In view of other sanctions, the present Chromium concentrations in gills which were the highest are well below the levels validated by USEPA (53.8 ppm) for fish tissue (Pastorok, 1987). However, surveys of contaminants in edible shellfish conducted by FDA (1998) reported chromium levels from 0.1 up to 0.9μg/g which is in line with the above threshold. The present chromium tissues concentrations in all the fish tissues study were below the 4.0 μg g-1 levels suggested by (Eisler, 1986) as indicative of Cr contamination.

4.1.5 Copper (Cu)

Copper revealed its maximum accumulation in the gills of all the four species of fish study, while flesh shows the least level; this is in agreements with the findings in *Carassius auratus (*DeBoeck, 2004). The distribution of copper were in the order of gills>liver>stomach>kidney>bones>flesh in the entire fish samples. Gills concentrate higher levels of copper while the lowest detected concentrations were found in the flesh. These high levels of copper in the gills might be due to the fact that freshwater fishes gills might be expected to be the primary route for the uptake of waterborne pollutants (Allen and Wilson, 1991). Copper toxicity in fish is taken up directly from the water via gills. The present study showed similar accumulation of copper in the gills. The present data also indicated that accumulation levels for Cu in gills and liver of *Districhodus rostratus* corroborates to the *O. niloticus (*AbdelBaki et al., 2011) and *Onchorynchus mykiss (*DeBoeck et al., 2004) respectively. Content of Cu accumulation in stomach and kidney of all the species study are similar to the *Rastrilliger kanagurta* (Irwandi and Farida, 2009) and *Tinca tinca (*Irwandi and Farida (2009) respectively. Effects of high concentrations of copper on fish are not well established; however, there is evidence that high concentrations in fish can experience 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 (Rompala et al., 1984). The permissible limit for Cu set by WHO (1989) is 30 ppm, which exceeds the accumulation levels obtained in the present study.

4.1.6 Cadmium (Cd)

Cadmium is accumulated primarily in major organ tissues of fish rather than in muscles and flesh (Moore and Ramamoorthy, 1984). This was the case in the present study as Cd in flesh shows the least level, whereas the highest mean values were found in gills and livers. Cadmium is a nonessential metal that is potentially toxic to most fish and wildlife, particularly freshwater organisms. The highest concentrations were observed in gills and liver tissues of all the species study, while the lowest concentrations were detected in flesh. These values detected did not exceed the NCBP concentration of 2.1μg/g threshold considered harmful to fish and predators (Schmitt and Brumbaugh, 1990; Robertson et al., 1991).

4.1.7 Lead (Pb)

Lead accumulates significantly in gills, livers, stomach, kidney, bones and flesh tissue of all the fish species. The concentrations of lead were higher in the following order gills>liver>stomach>kidney>bones>flesh. Similar findings were reported by Walsh et al. (1977) that the highest concentrations were in gills, kidney and spleen in rainbow trout. Lead is highly toxics to aquatic organisms, especially fish (Rompala et al., 1984). The biological effects of sublethal concentrations of lead include delayed embryonic development, suppressed reproduction and inhalation of growth, increased mucous formation, neurological problems, enzyme inhalation and kidney disfunction (Rompala et al., 1984). Lead concentrations in the gills, livers, stomach, kidney, bones and flesh tissue of all the fish species study were below the 0.6μg/g limit (Walsh et al., 1977).

4.1.8 Nickel (Ni)

The maximum concentrations of Nickel were detected in the gills of all the fish species study. From the result of these study, the concentration of nickel are in the order gills>liver>stomach>kidney>bones>flesh. Nickel level of 0.7μg/g is considered potentially lethal to fish and aquatic birds that consume them (Lemly, 1993). Nickel concentrations of 2.3 μg/g or greater, may cause reproductive impairment and lack of recruitment in fishes (Baumann and May, 1984). None of the samples in this study approached these levels of concern. Hence, nickel concentrations in the entire species of fish do not constitute any treat upon the consumption of these species of fish.

4.1.9 Cobalt (Co)

The maximum concentrations of cobalt were detected in the gills of all species of fish. The result is in line with the work of Buckley et al., (1982) which indicates that in fish, the liver and gills are the major storage organs for cobalt. Accumulation in the gills and liver can be the result of detoxicating mechanisms and may originate from metal in the food. However, the liver is the preferred organs for metals accumulation as could be deduced from the present study (Karadede and Unlu, 1998). Accumulation of metal in different species is the function of their respective membrane permeability and enzyme system, which is highly species specific and because of this fact metals accumulated in different orders in the fishes as observed in the study.

5. CONCLUSION

Iron was the most abundant metal in the studied tissues of all the fish species. The highest levels of all the metals in the present study were observed in gills and liver, while flesh shows the lowest levels. It can therefore be concluded that metals bioaccumulation in all the four fish species did not exceeds the permissible limits set for heavy metals by FEPA and WHO. Therefore these fishes are fit for human consumption.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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