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Cadmium, Copper, Lead and Zinc Tissue Levels in Bonga Shad (*Ethmalosa fimbriata*) and Tilapia (*Tilapia guineensis*) Caught from Imo River, Nigeria

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Abstract: An investigation of the muscle-liver tissue concentrations of heavy metals (Cd, Cu, Pb and Zn) in two commercially important fish species (*Ethmalosa fimbriata*-Bonga shad and *Tilapia guineensis*-Tilapia) caught from three stations within Imo River was carried out in 2004. Heavy metal contents varied significantly ($p>0.05$) depending on the fish species and on the type of tissues. The concentrations of the essential elements (Zn, Cu) were relatively higher in the muscle and liver tissues than the non-essential metals (Pb, Cd). The trends in tissue elemental concentrations in both species of fish was Zn>Cu>Pb>Cd. Heavy metal levels in liver tissues of both fish species were comparatively higher than levels obtained from muscle tissue. In general, *T. guineensis* showed higher levels of metal concentrations than *E. fimbriata.* The concentrations of Cu, Cd, Pb and Zn in both fish species were within tolerance limits that are safe for human consumption.

Key words: Heavy metal accumulation, *Ethmalosa fimbriata*, *Tilapia guineensis,* Imo river

Introduction

In recent times, human mediated activities have led to the introduction of many potentially hazardous inorganic compounds, heavy metals into our environment particularly as a result of industrial attributable point sources (Udosen, 1998). Heavy metals are natural trace components of aquatic ecosystems (Fernandez-Leborans and Olalla-Herrero, 2000; Yilmaz, 2005) and may be available at much lower concentrations in waters compared to major cations and anions (Radojevic and Bashkin, 1999). Aside natural sources of heavy metals in aquatic environments, human-mediated/ anthropogenic sources include industrial wastes arising from manufacturing, mining, agricultural and metal finishing plants. Other anthropogenic sources are domestic wastewaters, non-point and atmospheric precipitation (Langston *et al*., 1999; Van den Broek *et al*., 2002). However, there has been a growing concern as a result of enhanced elemental levels in aquatic ecosystems as well as in tissues of aquatic organisms especially fishes (Kalay and Canli, 2000; Riba *et al*., 2003; Akueshi *et al*., 2003).

Although many heavy metals are considered as essential macro- and micro-elements especially at non-adverse-effect-levels (Borovik, 1990; Hossain and Khan, 2001), they can exert toxic effects at concentrations encountered in polluted environment. Additionally, metals unlike many organic pollutants are known to biopersist in the environment (Radojevic and Bashkin, 1999) and can become bioconcentrated in the food chain (Eja *et al*., 2003), so that levels in the upper members of the chain are elevated than concentrations in the overlying water column. Within recent years, there has been an increasing interest in the utilization of fishes as bioindicators of the integrity of aquatic environmental systems (Fausch *et al*., 1990; Whitefield, 1996; Wildianarko *et al*., 2000; Akueshi *et al*., 2003). Several

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studies have indicated enhanced levels of both non-essential and essential heavy metal load in muscle and liver tissues of fishes (Ekpo and Ibok, 1999; Zyadah, 1999; Flessas *et al*., 2000; Hossain and Khan, 2001).

The coastal aquatic ecosystems of the Niger Delta region of Nigeria has of recent received much attention because of the considerable man-mediated perturbations these fragile environments have been subjected to, through accidental or deliberate oil spill, untreated industrial wastewater and sewage discharges and agricultural runoffs. Imo River is one of the numerous lowland rivers found in the Niger Delta, located within latitude 4°25'-4°45' N and longitude 7°19'-7°45' E. It extends along the coast from the River Niger in the north and discharges into the Atlantic Ocean in the south at the Bight of Bonny. Along the banks of the river, semi-urban settlements are sited. Also, located down the lower reaches of the river is Aluminium Smelting Plant (ALSCON) at Ikot Abasi, Akwa Ibom State. Oil exploitation activities are prevalent in the upper reaches of this coastal water system. In view of the industrial, agricultural and oil drilling activities, Imo River receives large amount of untreated wastewater and sewage, domestic wastes and icthyocides, used by local fish-farmers. Moreover, it is a multi-use resource for artisanal and commercial fishing and transportation. It is important to note however, that the degradation of the hydrological integrity of the ecosystem constitute a concern considering the health statuses of its flora and fauna and the health implications the consumption of its products could have on the people of the region.

The present study investigated the cadmium, copper, lead and zinc concentrations in two commercially important species of fishes- Bonga shad (*E. fimbriata*) and Tilapia (*Tilapia guineensis*) caught within the Imo River system. These species differ in feeding habits and habitat. Bonga shad is a highly commercial species and occurs in inshore waters, lagoons, brackish and marine environments. It feeds by filtering phytoplankton, chiefly diatoms (Whitehead, 1985). On the other hand, *T. guineensis* are benthopelagic, usually occurring in freshwater and brackish systems. It is a commercial species and feeds on shrimps, plankton, bivalves and detritus (Teugels and Thys van den Audenaerde, 1991). In general, these two species of fish are very important in commercial/artisanal fishery in Imo River system and adjourning waters. They are marketed fresh, smoked and dried.

Materials and Methods

Bonga shad (*Ethmalosa fimbriata*) and Tilapia (*Tilapia guineensis*) were caught using gill nets from three locations representing the upper, middle and lower reaches of the river. The first station (OBG) is located on 4°29' N,7°8' E, upstream of Imo River (Rivers State) where a number of small-scale industrial activities are sited. The second station (IAS) is located in Ikot Abasi (Akwa Ibom State), where the Aluminium Smelting plant is sited. Moreover, domestic wastewaters are channeled into the water body within this area. The third station (DRN) representing the downstream region of the river was chosen far from any industrial activities. The fishes collected at each station were labeled with an identification number, the date and place of collection, before they were taken to the laboratory for analysis in ice-packed coolers, until being placed into a freezer at 4°C.

Pretreatment of Samples Collected

Samples of fishes from each location were taken to the laboratory on the same day and later dissected to remove the liver and epixial muscle on the dorsal surface of each species of fish. The livers and pieces of edible muscle tissues (8.0 g) were dried at 105°C until they reached a constant weight. Each dried sample was ground, using porcelain mortar and pestle and 0.5 g of the powdered form was separately digested using perchloric and nitric acids in a silica beaker and later evaporated to dryness on a hot plate. The white residue of each digest was dissolved in 10 mL of 20% nitric acid. The solutions were filtered into acid-washed volumetric flasks and diluted to 50 mL prior to elemental analysis. Replicates, three blanks and standards were treated similarly. Concentrations of cadmium, copper, lead and zinc were then determined using an inductively coupled plasma spectrometer (Optima 3000-Perkin Elmer).

Results and Discussion

The investigated metal levels in liver and muscle tissues were measured as mg kg^{-1} on a dry weight basis. Importantly, considerations will be made on the tissue elemental contents and the bioconcentrated ratio in muscle with respect to liver. However, more emphasis will be on the heavy metal concentration in the muscle because of its dietary significance. The mean concentrations recorded for copper (Cu), cadmium (Cd), lead (Pb) and zinc (Zn) in muscle and liver tissues of *E. fimbriata*-Bonga shad and *Tilapia guineensis*-Tilapia are presented in Fig. 1 and 2, respectively. As indicated in Fig. 1, zinc levels were relatively higher in both the muscle and liver tissues of *E. fimbriata* than other elements considered. Zinc concentrations in muscle tissues were 7.78±5.40, 11.48±0.20 and 14.00±3.12 mg kg^{-1} dry weight at IAS, DRN and OBG stations, respectively. On the other hand, Zn levels in the liver tissues of *E. fimbriata* indicated higher values with DRN, OBG and IAS stations recording concentration of 39.26±1.00, 33.00±2.41 and 26.41±3.53 mg kg^{-1}dry weight, respectively. The average concentrations of copper obtained at OBG, IAS and DRN stations for liver and

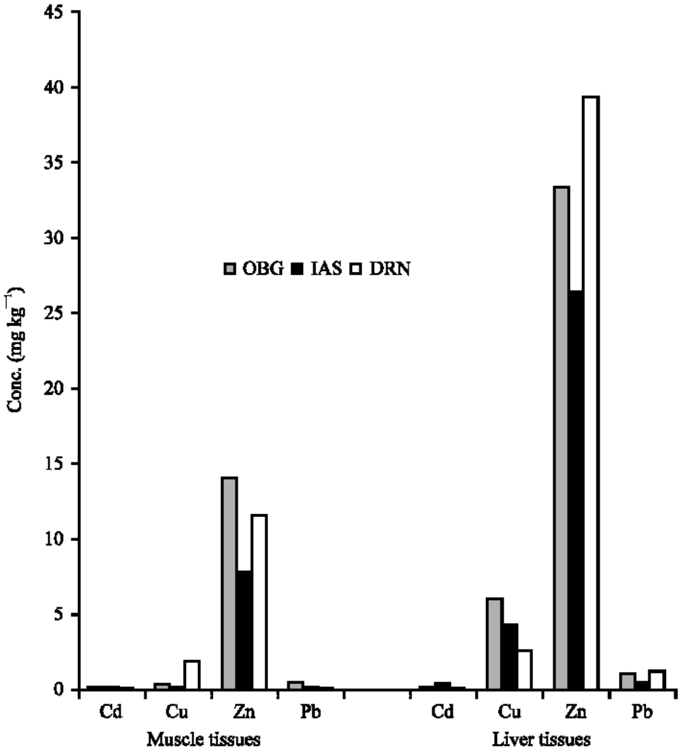

Fig. 1: Tissue elemental concentration in *Ethmalosa fimbriata* caught from Imo river ecosystem

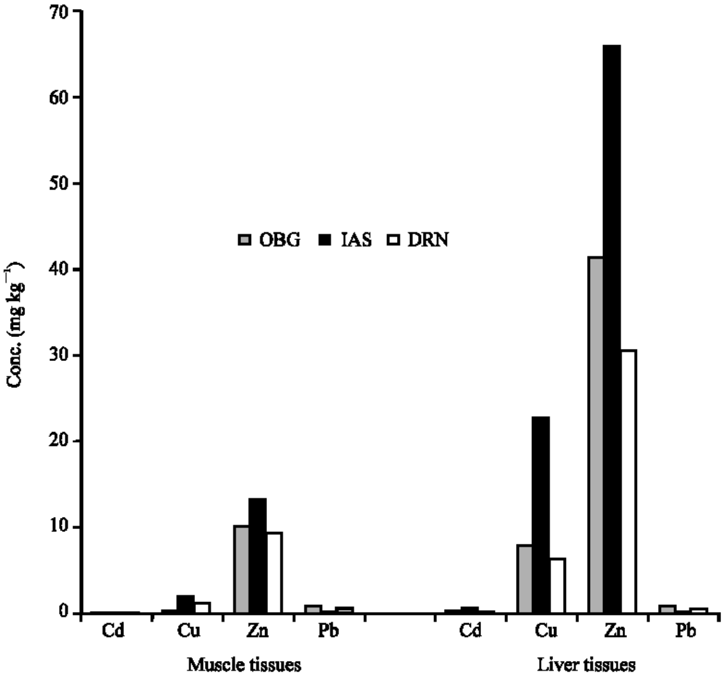

Fig. 2: Tissue elemental concentrations in *Tilapia guineensis* caught from Imo river ecosystem

muscle tissues of the fish species were 6.03±1.00, 4.29±1.16, 2.62±0.10 and 0.47±0.24, 0.21±0.40, 1.93 mg kg^{-1} dry weight, respectively. The variation of Pb and Cd levels in *E. fimbriata* followed the trend as Zn and Cu, which recorded higher concentrations in the liver than muscle tissue. The concentrations of Pb (0.56±0.28, 0.19±0.36, 0.09±0.24 mg kg^{-1} dry wt.) and Cd (0.09±0.01, 0.1±0.01, 0.02±0.01 mg kg^{-1} dry wt.) found in the muscle tissues at OBG, IAS and DRN stations, respectively were however lower than values obtained from the liver tissues, which were Pb: 1.06±0.02, 0.55±1.20, 1.32±0.10 mg kg^{-1} and Cd: 0.28±0.03, 0.40±0.01, 0.03±0.01 mg kg^{-1} dry wt. In general, the trend in elemental bioaccumulation in *E. fimbriata* in both muscle and liver tissues was Zn>Cu>Pb>Cd.

All the metals considered were detected in the target organ (liver) of *Tilapia guineensis* albeit at different levels and their respective mean levels at the three stations in the liver and muscle tissues were: Cd (0.26±0.24 and 0.02±0.01 mg kg^{-1}); Zn (45.91±18.17 and 10.96±2.07 mg kg^{-1}); Pb (0.47±0.39 and 0.59±0.19 mg kg^{-1}) and Cu (12.30±8.93 and 1.10±0.84 mg kg^{-1}). The concentrations of all these metals in liver tissues of *Tilapia* species were comparatively higher than levels obtained from the muscle tissues, with Zn displaying the highest tissue load (Fig. 2). This observation presupposes the low metal absorption potential in the muscle and moreover confirms earlier reports that target organs such as liver, gonads and gills of aquatic organisms have inherent potential to bioaccumulate heavy metals at enhanced levels compared to the muscle tissue (Abdel-Moniem *et al*., 1994; Arellano *et al*., 1999; Huang, 2003; Yilmaz, 2005). In general, muscle tissues of aquatic biota are not considered as excellent bioaccumulator of heavy metals (Kargin and Erdem, 1991; Shoham-Frider *et al*., 2002; Yilmaz, 2005).

However, the liver is the preferred organ for metal accumulation as could be deduced from the present study (Karadede and Unlu, 1998; Shoham-Frider *et al*., 2002). In both the Tilapia and Bonga shad, relatively high concentrations of Zn and Cu were found in the liver. Similar reports of preferential bioaccumulation of Zn and Cu in liver to muscle tissues of biota are available (Amundsen *et al*., 1997; Roditi-Elasar, 1999; Al-Yousuf *et al*., 2000; Yilmaz, 2003). Several researchers have documented the anomalous concentrations of essential elements especially Zn and Cu than other heavy metals in tissues of fishes (Farkas *et al*., 2000; Wong *et al*., 2001; Chou *et al*., 2003). Moreover, in aquatic organisms, the liver plays a prime role in the sequestration of adsorbed metal through detoxification by cysteine-rich metal binding proteins (metallothioneins), synthesized in response to changes in heavy metal balance (Langston *et al*., 1999).

The degree to which a metal is concentrated by a species, expressed in this study as the muscle to liver ratio (MLR) of metal concentrations was relatively higher for Pb (0.34) than Cd (0.26), Zn (0.29) and Cu (0.28) in *E. fimbriata*. Thus, the order of metal MLR in *E. fimbriata* is Pb>Zn>Cu>Cd. However, a different order was found in *T. guineensis* species: Cd>Pb>Zn>Cu. The MLR was higher for Cd (0.42) than Pb (0.38), Zn (0.20) and Cu (0.09). This presupposes that the rate of homeostasis of essential elements was relatively higher in *E. fimbriata* than *T. guineensis* (Chen and Chen, 2001). This is expected and the observation is supported by the higher concentration of the non-essential element, Cd in *E. fimbriata* which could have induced the metallothioneins to displace the essential metals (Zn, Cu) from pre-existing MTs (Riba *et al*., 2003). Cadmium levels in *T. guineensis* were lower in both muscle and liver tissues (Fig. 2).

Tissue elemental load in aquatic organisms is variable and species dependent, as well as being a function of the biota's environment (Eja *et al*., 2003; Canli and Atli, 2003). However, the affiance of metal uptake from an impacted ecosystem through direct or indirect ingestion or absorption through biomembranes in food and water could differ in relation to metabolism, physiology, ecological requirements, pollution gradients of pelagic column, sediment and food as well as the prevailing temperature and salinity (Romeo *et al*.,1999). *T. guineensis* are benthopelagic species with sedentary habits. Therefore, the relatively higher tissue elemental concentrations observed when compared to *E. fimbriata* may be attributed to its feeding habits and the contamination gradients of the pelagic column of Imo River with respect to its sediment compartment. Benthopelagic fishes have been reported as having high levels of heavy metals derived primarily from residual toxic levels in water and sediment (Huang, 2003). More so, taking the species factor into consideration, the heavy metal difference were significant ($p>0.05$). In general, this study revealed that the muscle tissues of *E. fimbriata* indicated higher preference for the bioaccumulation of non-essential elements (Pb, Cd) than Zn and Cu. This was however in contrast to the muscle metal bioaccumulation preference indicated by *T. guineensis* for essential elements.

Conclusions

Since there are many environmental factors which have been claimed by various researchers to influence the bioaccumulation of heavy metals to toxic levels in organisms, it would be unreasonable to attribute the levels of these metals in *E. fimbriata* and *T. guineensis* to any specific factor(s). It is perhaps more rational to posit that these elemental tissue load might have been largely influenced by their feeding habits as well as the contamination gradients of the Imo River surface water and sediment. From the results, the concentrations of heavy metals in liver and muscle tissues of both species investigated did not exceed the acceptable levels proposed for human consumption (USEPA, 1995). However, the levels of Cd and Pb in the species call for serious concern because they could bioaccumulate and biopersist in their tissues over time. This study therefore highlights this potential danger (Cd- and Pb-poisoning), which could occur owing to long-term consumption of these species. Thus, precautions need to be taken in order to forestall future heavy metal pollution in the river as well as in the biota. This research is however a precursor to the holistic approach needed to fully assess the elemental contents of sediments, water and several other biota of the Imo River ecosystem.

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