Heavy metals in *Hepsetus odoe* (Bloch, 1794), *Sarotherodon galilaeus* (Linnaeurs, 1758) and water in Lake Eleiyele, Ibadan

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Abstract

Accumulation of heavy metals in fish is an important issue, because of threat to fish and the health risks associated with fish consumption. Studies were undertaken in 2010 and 2015 to determine the concentrations of heavy metals in gills and muscle tissues of Hepsetus odoe (predator), Sarotherodon galilaeus (prey) and water from Eleyele lake. Fish samples obtained from local fishermen (using gill and cast nets) were wrapped in polythene bags, then frozen before digestion and analyses. Surface water samples (2-10 cm) were collected and filtered before analysis for heavy metals. Data obtained were subjected to descriptive statistics and ANOVA. Zinc was the dominant metal in H. odoe, S. galilaeus and water in 2010. Lead (13.67 and 7.64); chromium (3.82 and 6.47), nickel (4.72 and 6.56) mg/kg dry weight in muscles and gills respectively; cadmium (4.5 mg/kg dry weight in gills) exceeded recommended limits in food fish. Lead, nickel, cobalt and cadmium were not detectable in gills, muscle of S. galilaeus and water in the Lake in 2010. Higher concentrations of all metals were recorded in 2015 with lead becoming dominant (28.36 and 24.46 mg/kg dry weight) in gills and muscles respectively. Zinc, copper, and nickel exceeded maximum recommended limits in H. odoe and S. galilaeus in 2015. Lead, chromium and nickel (1.09, 0.62 and 1.12 mg/L respectively) exceeded recommended limits in water in 2015. The increasing concentrations of heavy metals emphasizes regular monitoring and control of influents into the Lake.

Key words: African pike, Mango tilapia, water quality, organs, bioconcentration

Introduction

Global demand for food is expected to rise by about 70 percent by the year 2050 while the world's population at the same time will increase from greater than 6.8 to 9 billion (FAO, 2006; UNCTAD, 2011). In developing countries such as Nigeria, inland fish, particularly small native fishes are the main sources of animal protein but often, they are either not available or too costly (Jamu *et al.*, 2011; Hall *et al.*, 2013; Olaifa, 2015). Major threats to wild fish populations include changes in habitats due to natural or human activities and over exploitation (McBride, 2012). Fish provides high class protein containing all essential amino acids, mineral elements such as calcium, phosphorus, zinc, iron, selenium, iodine and other trace minerals; vitamins A, D, E, B- complex for normal human or animal growth and development. In addition to protein and micronutrients, fish contain the omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in biologically usable forms (Gogus and Smith, 2010; Abdoel-Yazeed, 2013).

Fish and seafood earn income for many developing countries but the barrier to fish trade include market quality-related and safety-related requirements. Inland fisheries face significant issues relating not just to fishing pressure but also the impacts of infrastructure development, drainage, land reclamation, continuous or periodic water withdrawals and water quality impacts from urban, industrial and agricultural use (Foresight, 2011; FAO, 2012).

Hepsetus odoe (Bloch, 1794) commonly called the African or Kafue pike is a torpedo-shaped or elongated, predatory and piscivorous fish with a pronounced snout. The upper and lower jaws possess sharp rows of teeth (two rows upper and one row lower jaw). There are two canines in each jaw (Merron *et al.*, 1990). *H. odoe* inhabits the slow-moving areas of deep fresh waters (Jubb and Manning, 1961; Froese and Pauly, 2018a). *H. odoe* also occurs in coastal lakes and swamps, preferring quiet deep waters and lives for 4-5 years (Entsua-Mensah and Lalèyè, 2010). The scales of *H. odoe* are rough numbering 49-58 along its lateral line. The dorsal fin has nine rays (two unbranched and seven branched). The females of *H. odoe* are repeat spawners producing about 6440 eggs each season. Males mature at 140 mm while females do so at 160 mm (Merron *et al*, 1990, Ogunola *et al.*, 2018). Approximately 50% of the diets of *H. odoe* consists of cichlids and mormyrids while juvenile forms prey on small invertebrates (Sanyanga and Feresu, 1994, Ogunola *et al.*, 2018).

Sarotherodon galilaeus (Linnaeus, 1758) or mango tilapia is a widespread fish species found in fresh or brackish water habitats in northern and central Africa (Froese and Pauly*,* 2018b). *S. galilaeus* is a species of fish of the cichlid family measuring up to 41 cm in length and about 1.6 kg in weight. *S. galilaeus* is omnivorous, consuming phytoplankton, detritus and algae (Oso *et al.*, 2006). *S. galilaeus* is an obligate, particulate feeder during the larval and juvenile phases but an obligate, filter feeder at adult stage (Awaïss *et al.*, 2010). Mating is monogamous and both parents protect the young as mouth brooders (Froese and Pauly, 2018b).

Dissolved heavy metals are difficult to destroy, readily absorbed, and accumulate in tissues of aquatic organisms. These metals biomagnify along the food chain and may become toxic at high concentrations (Sen *et al.*, 2011). Pathways of metal accumulation in fish include ingestion of food, suspended particulate matter, and metal ion exchange through gills and skin (Ayandiran *et al.*, 2009; Akan *et al.*, 2012; Bashir *et al.*, 2013). The gills, skin and digestive tracts of fish are potential sites for the absorption of water-borne pollutants (Nussey *et al.*, 2000; Jezierska and Witeska, 2006; Amirah *et al.*, 2013; Abreu *et al.*, 2016).

Metal accumulation and distribution in organs of fish is species- specific. Fish accumulate metals in the tissues through absorption while man can be exposed to metals via the food web (Olaifa *et al.,* 2004; Jezierska and Witeska, 2006; Chen *et al.*, 2011; Anand and Kumarasamy, 2013). The target tissues such as liver, kidney and gills are usually involved in metabolic activities while muscles accumulate relatively lower levels of heavy metals (Zhang *et al.*, 2007).

Many factors influence metal uptake by fish such as sex, age, size, reproductive cycle, feeding behaviour and living environment (El-Moselhy *et al.,* 2014).

The concentrations of metals in living organisms depend on the levels in the environment, and equilibrium between the rate of ingestion and excretion (Idodo-Umeh, 2002). Toxic effects of metals occur when excretory, metabolic, storage and detoxification mechanisms cannot counter the uptake and storage (Jezierska and Witeska, 2006; Olaifa and Fabusoro, 2017). Fishes are good indicators of heavy metal contamination in aquatic systems because they occupy different trophic levels, are of different sizes, ages and consumed worldwide. Even in small quantities, fish can significantly improve the quality of dietary protein intake by complementing the essential amino acids of other foodstuffs (FAO, 2018). Studies were undertaken with the aim of assessing the levels of heavy metals (chromium (Cr), Nickel (Ni), Lead (Pb), Cobalt (Co), Copper (Cu), Zinc (Zn) and Cadmium (Cd) in the gills and muscle tissues of *H. odoe*, *S. galilaeus* and water from Lake Eleiyele in Ibadan, Oyo State, Nigeria.

Materials and Methods

Study area

Eleiyele Reservoir is a man-made lake located between Latitude 7° 25^1 N to 7° 27^1 N and 3° 50^1 to 3° 52^1 E in Ibadan metropolis in southwest Nigeria at an altitude of 125 m above sea level and a catchment area of 323.7 km^2. The dam that created the Lake was constructed in 1942 with a total storage capacity of 5.46 km^3 (Egborge, 1977). Seasonal temperature varies with the mean temperature (24.5 $^{\circ}$C) occurring in August. Rainfall peaks occur in May/June and September/October with the mean annual rainfall as 1262.3 mm. It is a flood-controlled lake with a maximum depth of 12 m during the floods. The main source of water to the lake is River Ona which flows southwards to Lagos lagoon and Atlantic Ocean (Akponine and Ayoade, 2012).

Collection of specimens

Hepsetus odoe is an endemic predatory fish and the only member of the Family *Hepsetidae* in Africa (Roberts, 1984). *H. odoe* and *S. galilaeus* samples were obtained twice weekly from Eleiyele Lake during a 10- week study in each year (2010 and 2015) using gill and cast nets. Five fish samples were taken per sampling time. The fish samples were wrapped in polythene bags and taken to the Department of Aquaculture and Fisheries' laboratory for freezing and further processing. Water samples for analysis were collected twice weekly at the time of fish sampling in 1-litre plastic bottles for 10 weeks in each year.

Sample preparation and analysis

The fish samples were frozen for a week before thawing at room temperature for analyses. Each fish sample was dissected to separate gills and muscles (without bones), and oven- dried at 80°C for 12 hours. A porcelain mortar was used to grind and homogenize the dry tissue samples following which acid digestion was conducted on 2 g of the dried powdered samples. The weighed sample was transferred into Berzelius beakers and digested in 5 ml of $HCLO_4$ and HNO_3 (FAO/SIDA, 1983).

The digested samples were analyzed for lead, zinc, chromium, nickel, cobalt, cadmium and copper (Pb, Zn, Cr, Ni, Co, Cd and Cu) using a flame atomic absorption spectrophotometer (Buck Scientific Model 210 VGP, USA) according to Odiete (1999) and Olaifa *et al.*, (2003).

The water samples for heavy metal analysis (250-500 ml) were collected and Aliquots of 500 mls of the collected water samples were filtered using a Whatman No. 42 filter paper into plastic bottles and preserved in the refrigerator before analysis. Analysis for heavy metals in water was conducted using an atomic absorption spectrophotometer (Chapman, 1992).

All data obtained were subjected to analysis of variance (ANOVA) followed by Duncan's multiple range test as a post-hoc test, with the aid of SPSS 10 computer statistical software package. Concentrations of heavy metals in both fish and water samples were compared to the recommended concentrations of heavy metals in water and food fish (WHO, 1985; FAO, 1983; FEPA, 2003) (Table 1).

Table 1: Recommended levels of heavy metals in water (mg/l) and Food Fish (mg/kg)

Material	Pb	Zn	Cr	Ni	Cu	Cd	Co
Water							
WHO (1985)	0.05	5.0	0.05	0.05	1.0	0.05	0.05
FEPA (2003)	<1.0	20	<1.0	<1.0	<1.0	<1.0	<1.0
Food fish							
WHO (1985)	2.0	1000	0.1-0.5	0.5-0.6	1.0-3.0	2.0	0.1-0.5
FAO (1983)	2.0	1000	<1.0	2.0	<30	<1.0	<1.0

Pb = lead, Zn = zinc, Cr = chromium, Ni = nickel, Cu = copper, Cd = cadmium, Co = cobalt

Results

Heavy metals in water samples collected from Eleiyele Lake in 2010 and 2015.

Zinc (2.62 mg/L) was dominant in 2010, while lead, nickel, cadmium and cobalt were not detected in the water in Eleiyele lake (Table 2). In 2015, Zinc (0.2 mg/L), copper (0.3 mg/L), cadmium (0.04 mg/L) and cobalt were within the limits recommended in water while lead, chromium, nickel (1.09, 0.62 and 1.12 mg/L) respectively exceeded the limits. Differences were observed in the heavy metal concentrations in water of Eleiyele Lake between 2010 and 2015. Lead, nickel, cadmium and cobalt that were below detectable levels in 2010 were measured in 2015. In addition the quantity of chromium and cupper increase in 2015 over the values observed in 2010, however the value of zinc was significantly reduced in 2015 compared to 2010.

Table 2: Heavy metals in water (mg/L) in 2010 and 2015 in Eleiyele Lake

Heavy metals in water (ppm=μg/L)	2010	2015
Pb	-	1.09a
Zn	2.62a	0.2c
Cr	0.1b	0.62b
Ni	-	1.12a
Cu	0.09b	0.3c
Cd	-	0.04d
Co	-	0.22c

- = Not Detected

Values with different letters are significantly different ($p<0.05$) using DMRT

Heavy metals in fish samples collected from Eleyele Lake in 2010 and 2015.

Zinc was significantly higher than other metals in the gill and muscle of *H. odoe* though within the recommended limit for food fish while cobalt was not detectable in 2010 as shown in Figure 1. Higher mean concentration of zinc was observed in the gill compared to muscle of *H. odoe*. Lead (13.67 and 7.64 mg/kg dry weight in muscle and gills), chromium (3.82 and 6.47), Nickel (4.72 and 6.56 mg/kg dry weight respectively) in muscle and gills; and cadmium (4.5 mg/kg dry weight in gills) exceeded recommended limits in food fish. Lead, chromium and cadmium were also significantly different in gills and muscles of *H. odoe* in 2010.

In 2015, Lead had the highest concentration among the metals (24.46 and 28.36 mg/kg dry weight) in muscle and gills of *H. odoe* respectively. Apart from zinc, all the other metals exceeded the recommended concentrations in food fish. Lead, nickel, cadmium and cobalt which were undetectable in 2010 (Figure 1) were higher than recommended in food fish in 2015.

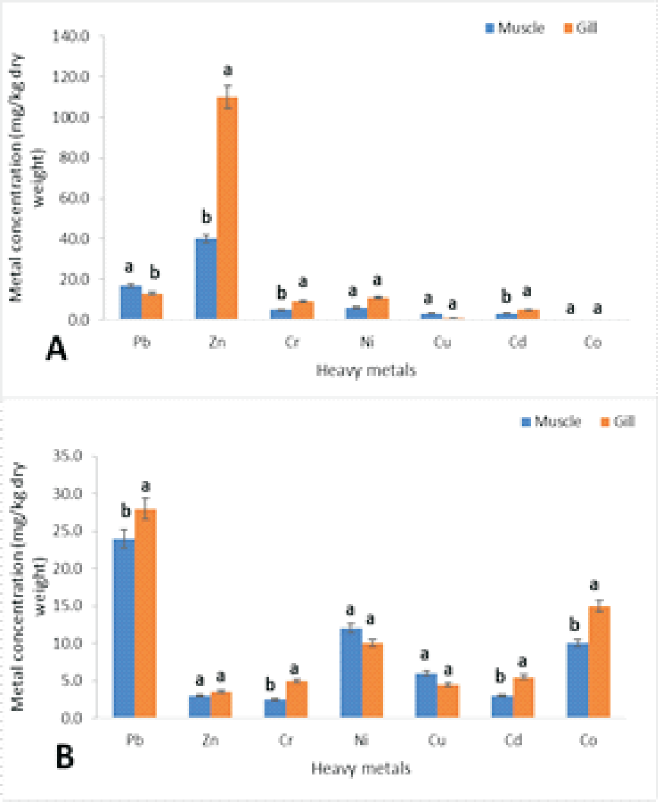

Figure 1: Heavy metal concentrations (mg/kg dry weight) in the gills and muscles of *H. odoe* in 2010 (A) and 2015 (B)

Bars with different letters are significantly different (p<0.05) using DMRT.

WHO recommended values (mg/kg) for Pb=2.0; Zn = 1000; Cr=0.5; Ni=0.6; Cu=3.0; Cd =2.0 and Co=0.5.

Zinc was significantly lower ($p<0.05$) in the muscle (1.52mg/kg dry weight) than gills (8.66 mg/kg dry weight) of *S. galilaeus*. Lead, nickel, cobalt and cadmium were not detectable in both gills and muscle of *S. galilaeus* in 2010 (Figure 2). Lead was higher than other metals in the muscles and gills of *S. galilaeus* in 2015. No significant differences were observed in concentrations of heavy metals between the gills and muscles in 2015. All the metals except zinc were higher in concentration than recommended in food fish by both the WHO and FAO.

The highest concentration of heavy metals in fish was zinc in *H. odoe* in 2010, cobalt was undetected in both *H.odoe* and *S. galilaeus* while Nickel was only present in *H. odoe* (Figure 3). Lead was the dominant metal in both *H. odoe* (28.38 mg/kg dry weight) and *S. galilaeus* (23.11 mg/kg dry weight) in 2015. All other metals were detectable at different mean concentrations in both fish species. Except for nickel, all the other metals were higher in *H. odoe* than *S. galilaeus* (Figure 3). Except zinc and copper, all the other metals were higher than the recommended limits (Table 1).

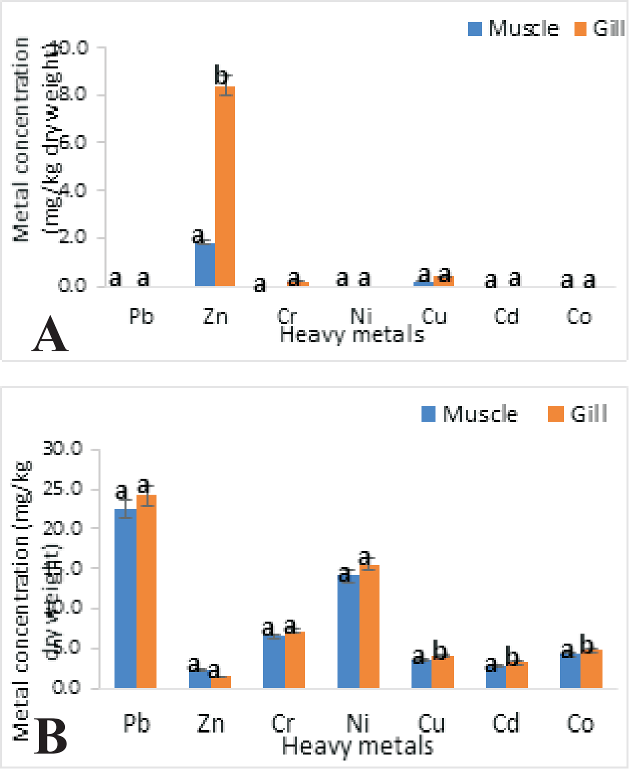

Figure 2: Mean Heavy metal concentrations in the muscles and gills of *S. galilaeus* (mg/kg dry weight) in Eleiyele lake in 2010 (A) and 2015 (B).

Bars (muscles and gills) with different letters for each heavy metal are significantly different ($p<0.05$) using DMRT.

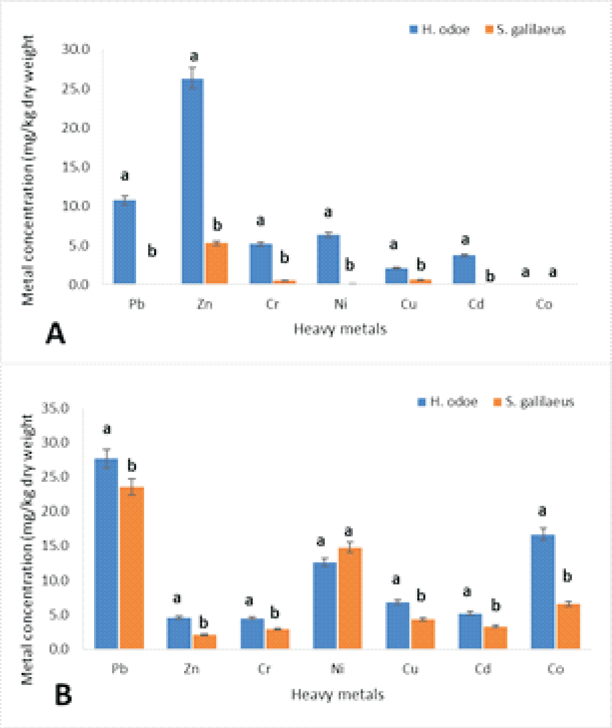

Figure 3. Heavy metal concentrations in *H.odoe* and *S. galilaeus* in 2010 (A) and 2015 (B).

Bars with different letters are significantly different ($p<0.05$) using DMRT

Discussion

Aquatic environments are the recipients of pollutants including heavy metals. While low concentrations are usually reported in water, higher values have been reported in fish in most Nigerian rivers and lakes (*Ajima et al.*, 2015) similar to this study. Metals in water changed in concentrations over the study period which could be due to anthropogenic sources like improper disposal of metal-containing products such as used batteries.

The ability of aquatic organisms to concentrate metals in their tissues greater than that in water depends on the uptake and depuration rates, concentrations of the metals in sediments and watershed, fish's feeding habits or modes and lipid contents of fish (Farkas *et al*., 2000; Gado and Midany, 2003, Nwabunike, 2016). During this study, lower concentrations of heavy metals were present in water than fish in both 2010 and 2015 indicating bioconcentration. There are several pathways through which metals enter fish such as diffusion into the bloodstream through the gills and skins, drinking water, eating sediments or detritus contaminated with heavy metals, or eating other organisms that have been exposed to metals (Solomon, 2008).

The concentrations of heavy metals were relatively lower in the muscles compared to gills of both *H. odoe* and *S. galilaeus* while zinc was the dominant metal in both fish species and water in 2010. Cobalt could not be detected in both fish species while Pb, Ni, Cd and Co were not detectable in both *S. galilaeus* and water. The higher concentrations of the heavy metals in the tissues of *H. odoe* than in *S. galilaeus* may be connected with the feeding relationship between both fish species as predator and prey respectively as bio-magnification can occur at higher trophic levels. *H. odoe* feeds mainly on cichlids including *S. galilaeus* (Stewart *et al*, 2003). Copper and chromium concentrations reported in 2010 were similar to previous reports on water and *Clarias gariepinus* from the same water body (Olaifa *et al.*, 2004).

Higher concentrations of all metals were recorded in the gills than muscles except for nickel and copper in 2015. These higher concentrations of metals in gills may be because they screen water intake into the body of fish and serve as the main route of metal ion exchange from water as they present very large surface areas that facilitate rapid diffusion of toxic metals. The metals accumulated in gills are usually assumed to be mainly from water (El-Moselhy *et al.*, 2014). The main targets of water borne zinc are usually the gills (Hogstrand, 2011) while copper and iron are readily concentrated in different tissues of fish (Adewoye *et al.*, 2005). Lead accumulates in fish tissues such as bones, gills, liver, kidneys, scales, while gaseous exchange across the gills to the blood stream is a major uptake mechanism (Oguzie, 2003; Brown and Margolis, 2012; Sen *et al.*, 2013).

Muscles are the main edible part of fish and can directly influence human health when they contain excessive metal residue (Pintaeva *et al.*, 2011). Though muscles are not active sites for metal biotransformation and accumulation, in polluted water, the concentration of metals in fish muscles may be greater than the permissible limits for human consumption (El Moselhy *et al.*, 2014). The concentrations of heavy metals reported in this study in 2015 were higher than reported by other workers (Olaifa *et al.,* 2004; Ekpo *et al.*, 2008, Oronsaye *et al.*, 2010; Ayeloja *et al.*, 2014) but similar to the observations for Ikpoba River, Benin City (Olele *et al.*, 2013). The mean concentrations of heavy metals in fish tissues were higher than in the water body similar to earlier reports (Olaifa *et al.,* 2004; Chale, 2012; Anim-Gyampo *et al.*, 2013).

According to Taub (2004), when lead is greater than 10 µg/L, gill function is impaired while embryos and fry are more sensitive to toxic effects of lead than adults. Cadmium in fish can cause skeletal deformities and impaired functions of the kidneys while cellular damage has been reported in the hepatopancreas of marine crustaceans (Solomon, 2008). Chromium is an essential trace element required in small amounts for carbohydrate metabolism but becomes toxic at higher concentrations (Solomon, 2008). Metals dissolve in water and are easily absorbed by fish and other aquatic organisms. Low concentrations of metals can be toxic due to bioconcentration of metals which means that their concentrations in body tissues may be higher than that present in water. The presence of metals in the environment can harm the organisms without killing them (Wright and Welbourn, 2002; Solomon, 2008).

Conclusion

The study of Eleiyele Lake showed elevated levels of the heavy metals in African pike (*H. odoe*) in 2015. Zinc and copper concentrations obtained in 2010 were within the acceptable limits for fish as recommended by World Health Organization (1985). However, except for zinc and copper, all the heavy metals tested were present in fish and water samples above permissible limits in 2015. This calls for further studies, regular monitoring, preventive and remediation measures to be taken to avoid further loading of heavy metals into the lake.

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