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Research Article

Bioaccumulation of Some Heavy Metals in Some Organs of Three Selected Fish of Commercial Importance from Niger River, Onitsha Shelf, Anambra State, Nigeria

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Abstract: The present study reports the bioaccumulation of cadmium (Cd), zinc (Zn), lead (Pb) and mercury (Hg) in the gills, muscles and intestine of Tilapia zillii, Malapterurus electricus and Clarias gariepinus sampled from fishermen at Niger River, Onitsha shelf. Heavy metals in gills, muscles and intestine of fishes was investigated using Varian AA240 Atomic Absorption Spectrophotometer. Mean cadmium concentration in the fish organs was highest (0.068 ± 0.02 mg/kg) in the gills and lowest (0.040 ± 0.01 mg/kg) in the muscles. The descending order of mean cadmium concentration in the organs is gills > intestine > muscles. T. zillii and C. gariepinus had the maximum and minimum mean cadmium concentration of 0.087 ± 0.04 mg/kg and 0.043 ± 0.01 mg/kg, respectively. Cadmium concentration in the fish organs were lower than the FAO/WHO standard for seafood, thus the fishes with this levels of heavy metals are safe for human consumption. The mean concentration of zinc in the organs of the studied fish species was highest (8.180 ± 3.508 mg/kg) in intestine and lowest (4.176 ± 1.091 mg/kg) in the muscles. The descending order was intestine > gills > muscles. Mean zinc concentration was maximum (8.848 ± 3.39 mg/kg) in T. zillii and minimum (5.084 ± 1.17 mg/kg) in M. electricus. These values were below the FAO/WHO recommended standard limit of zinc (10–20 mg/kg) in fish samples. Lead and mercury were not detected in any of the fish. The result obtained in this study, revealed that Niger River is contaminated to varying levels by zinc and cadmium. Control measures recommended include public enlightenment on the need to desist from anthropogenic activities that could lead to water pollution.

Keywords: Bioaccumulation; Heavy metals; Fish organs; Niger River; Nigeria

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Introduction

Aquatic environments have been grossly polluted by heavy metals in recent times. Thus heavy metal contamination of aquatic environments has become a problem of great concern to man. This situation has arisen as a result of the rapid growth of population, increased urbanization and expansion of industrial activities, exploration and exploitation of natural resources, extension of irrigation and other modern agricultural practices as well as the lack of environmental regulation (Idowu, 2004). Heavy metals may be precipitated, absorbed on solid surface, remain soluble or suspended in water or may be taken up by fauna and flora and eventually be accumulated in aquatic organisms including fish that are consumed by human beings (Adefemi et al., 2008; Francesconi, 2010). Fish is one of the main sources of protein enriched food all over the world (Mansour and Sidky, 2002). Consumption of fish contaminated with heavy metals is injurious to human health; these metals accumulate in the body tissues to dangerously poisonous levels (Mansour and Sidky, 2002; Tchounwou et al., 2012; Jaishankar et al., 2014). Heavy metal contamination has devastating effects on the ecological balance of aquatic ecosystems and adverse effect on aquatic organisms (Vosyliene et al., 2003; Ashraj, 2005; Farombi et al., 2007). Among the animal species, fish are the aquatic environment inhabitants that cannot escape from the detrimental effects of heavy metallic pollutants (Olaifa et al., 2004; Vinodhini and Narayanan, 2008; Elnimr, 2011). Fish are widely used to evaluate the health of aquatic ecosystem because pollutants build up in the food chain and are responsible for adverse effects and death of animals in the aquatic ecosystems (Farkas et al., 2002; Baby et al., 2010). Most of the freshwater fishes are confined to specific micro-habitat within inter-connected river/stream ecosystem. If such ecosystem becomes contaminated by heavy metals, fish species either migrate to less polluted segment of river/stream ecosystem or die off which ultimately disturb the food chains (Rashed, 2001). High level of heavy metals has apparent lethal and chronic effects on fish (Akan et al., 2012; Jaishankar et al., 2014). Thus, the utility of fish for assessing environmental conditions in aquatic ecosystem has gained prominence in recent years (Ikem et al., 2003; Yilmaz, 2003; Adefemi et al., 2008; Adeniji et al., 2008; Ogundiran et al., 2010; Akan et al., 2012). Fish in water bioacumulates heavy metals *via* different gateways including intake of food and water, suspended particulate matter, and as well as metal ion exchange *via* gills and skin. Through these routes, heavy metals are absorbed into blood and transported to various organs for storage or excretion. Concentrations of heavy metals in different tissues/organs of fishes are directly influenced by contamination in aquatic environment, uptake, regulation and elimination inside the fish (Nussey, 2000).

Onitsha is an important and industrial city in South-eastern Nigeria with Head Bridge, Oseokwuodu and Mariner among others as notable business hotspots. Different municipal and industrial wastes generated are discharged into the Niger River. Heavy metals do not deteriorate and can build up in aquatic organisms particularly fishes inhabiting the river. This study was carried out to assess the levels of heavy metals (Cd, Zn, Pb and Hg) in organs of three commercial fish species of the river with the aim of ascertaining whether the concentration level of these metals constitute health hazards to consumers. The result of this study will provide additional information on the heavy metals pollutants of aquatic ecosystems of south-eastern Nigeria.

Materials and Methods

Study area

The Niger River at Onitsha, Nigeria **(Figure 1)** (Salvof-Amakom, 2003) lies approximately between latitudes 50 N and 70 N and longitude 70 E and 80 E of southern Nigeria (Nsofor et al., 2007). The Niger River is the principal river of western Africa, extending about 4,180 km. Its drainage basin is 2,117,700 km^2 in area (Gleick, 2000). Its source is in the Guinea Highlands in southeastern Guinea. It runs in a crescent through Mali, Niger, on the border with Benin and then through Nigeria, discharging through a massive delta, known as the Niger Delta or the Oil Rivers, into the Gulf of Guinea in the Atlantic Ocean. The Niger River is the third-longest river in Africa, exceeded only by the Nile River and the Zaïre River. Its main tributary is the Benue River. The Niger River confluences with Benue River at Lokoja in Kogi State, Nigeria. Unfortunately, this river has been seen as a giant sink for dumping of domestic, agricultural and industrial wastes. Human activities in and around the river include swimming, fishing, laundry, boating and dumping of refuse.

Sampled fishes and heavy metals assay

One hundred and twenty (120) fish specimens comprising of 49 *T. zillii,* (14.50 ± 0.33 cm, 112.49 ±12.96 g), 29 *M. electricus* (17.16 ± 0.99 cm, 87.03 ± 12.94 g) and 43 *C. gariepinus* (20.20 ± 7.55 cm, 266.23 ± 31. 04 g) were bought from fishermen who caught the fishes from the Niger River at three fish landing sites (Niger River Head Bridge, Oseokwuodu and Mariner) in Onitsha between June – December 2018. The sampled fishes were transported in ice-chest to Department of Biological Science Laboratory, Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra State, Nigeria. The fish sampled were dissected to remove the gills, intestine and muscles. The first gill arch and

Figure 1: Niger River at Onitsha showing the Niger Bridge at Onitsha (Salvof-Amakom, 2003).

rackers, mid gut and dorso-ventral muscles of each sampled fish were macerated using a porcelain mortar and pistil. 2 g of each of the macerated fish organ was weighed out and placed in a digestion flask and digested with 20 mL of a mixture of acid (650 mL of concentrated nitric acid (HNO_3) and 80 mL hydrochloric acid (HCl)) by heating in a fume cupboard until a clear digest was obtained. Digested solutions of the fish samples were filtered using Whatman 541 filter paper and made up to 100 mL using deionized distilled water. The various digest organs were analyzed in triplicates for cadmium, lead, mercury and zinc using Varian AA240 Atomic Spectrophotometer (Kojuncu et al., 2004; APHA, 2005; Nwosu et al., 2014).

Data analysis

Statistical analysis was carried out using one-way Analysis of Variance (ANOVA) to determine the bioaccumulation relationships in the various organs of the fish. The distribution of the data was normal at $p>0.05$. The significance between metal bioaccumulation in *T. zillii, M. electricus* and *C. gariepinus* was assessed using Duncan's multiple range test (Duncan, 1955).

Results

The results of levels of bioaccumulation in the three fish species are shown in **Table 1**. The concentration of cadmium in *T. zillii* ranged from 0.049 ± 0.03 mg/kg in muscles to 0.119 ± 0.01 mg/kg in intestine. Cadmium concentration ranged from 0.032 ± 0.02 mg/kg in muscles to 0.056 ± 0.01 mg/kg in gills of *M. electricus*, and 0.033 ± 0.02 mg/kg in intestine to 0.055 ± 0.01 mg/kg in gills of *C. gariepinus*. Furthermore, within this freshwater ecosystem, the level of cadmium in fish ranged from 0.000 ± 0.001 mg/kg in fish intestine caught at River Niger at Onitsha to 14.20 mg/kg in *Chryschthys nigrodigitatus* gills caught from River Niger at Asaba (**Table 2**). From previous studies within this ecosystem, the detectable level of cadmium in water and sediment ranged from 0.006 ± 0.001 mg/L (River Niger at Creek Road, Onitsha) to 0.157 ± 0.022 mg/L (River Niger at Central Drainage, Onitsha) and 0.061 ± 0.039 mg/L (River Niger at Onitsha) to 2.31 ± 0.18 mg/kg (River Niger at Lokoja, Kogi State) respectively for water and sediment (**Table 2**). The order of cadmium concentration in the fish organs sampled was intestine > gills > muscles for *T. zillii*; gills > intestine > muscles for *M. electricus* and gills > muscles > intestine for *C. gariepinus*. There was variation in the mean concentration of cadmium in the fish organs. The maximum mean value of 0.068 ± 0.02 mg/kg was recorded in the gills, while the minimum value of 0.040 ± 0.01 mg/kg was recorded in the muscles (**Figure 2**). The descending order of occurrence was gills > intestine > muscles. The mean concentration of cadmium in the various fish species ranged from 0.043 ± 0.01 mg/kg in *C. gariepinus* to 0.087 ± 0.04 mg/kg in *T. zillii* (**Figure 3**).

The zinc concentration in *T. zillii* ranged from 5.419 ± 1.21 mg/kg in muscles to 12.199 ± 1.08 mg/kg in intestine. *M. electricus* had mean zinc concentration minimum and maximum values of 3.735 ± 1.07 mg/kg in muscles and 5.777 ± 1.32 mg in gills. Zinc concentration in *C. gariepinus* ranged from 3.376 ± 1.12 mg/kg in muscles to 6.602 ± 1.61 mg/kg in intestine (**Table 1**). Furthermore, within this freshwater ecosystem, the detectable level of zinc in fish ranged from 0.36 ± 0.249 mg/g in Bagrus bayad caught from River Niger at Onitsha to 75.23 mg/kg in

Table 1: Comparison of concentration (mg/kg) of heavy metals in the selected organs of different fish collected from Niger River.

Metals	Fish species	Gills (Mean ± S.E.)	Muscles (Mean ± S.E.)	Intestine (Mean ± S.E.)	Mean concentrations (Mean ± S.E.)	FAO/WHO (2011) permissible limit for fish (mg/kg)
Cadmium (Cd)	*Tilapia zillii*	0.094 ± 0.02^b	0.049 ± 0.03^a	0.119 ± 0.01^b	0.087 ± 0.04	2.0
	Malapterurus electricus	0.056 ± 0.01^a	0.032 ± 0.02^a	0.049 ± 0.01^a	0.046 ± 0.01	
	Clarias gariepinus	0.055 ± 0.01^a	0.040 ± 0.02^a	0.033 ± 0.02^a	0.043 ± 0.01	
	Mean concentration	0.068 ± 0.02	0.040 ± 0.01	0.067 ± 0.05		
Zinc (Zn)	*Tilapia zillii*	8.925 ± 1.02^b	5.419 ± 1.21^a	12.199 ± 1.08^c	8.848 ± 3.38	10-20
	Malapterurus electricus	5.777 ± 1.32^b	3.735 ± 1.07^a	5.738 ± 1.02^b	5.084 ± 1.17	
	Clarias gariepinus	5.548 ± 1.51^b	3.376 ± 1.12^a	6.602 ± 1.61^b	5.207 ± 1.64	
	Mean concentration	6.750 ± 1.89	4.176 ± 1.09	8.180 ± 3.51		
Lead (Pb)	*Tilapia zillii* *Malapterurus electricus* *Clarias gariepinus* Mean concentration	ND	ND	ND	ND	0.3
Mercury (Hg)	*Tilapia zillii* *Malapterurus electricus* *Clarias gariepinus* Mean concentration	ND	ND	ND	ND	0.5-1.0

ND – Not detected

Superscript a & b indicates significant differences ($p<0.05$)

Table 2: Cadmium, zinc, lead and mercury levels in water, sediment and fish of River Niger, Nigeria

Heavy Metal	Location	Water	Sediment		Organism	Source
Cadmium (Cd)	Onitsha	0.014 µg/L	-	-	-	Adeaga et al., 2017
	Fadama, Onitsha	0.022 µg/L	-	-	-	Adeaga et al., 2017
	Onitsha	0.012 ± 0.006 mg/L	-	0.31 ± 0.0421 mg/L	*Macrobrachium rosenbergi*	Nsofor et al., 2014a
	Agenebode, Edo	0.0452 ± 0.01 mg/L	-	0.04667 mg/Kg	*Oreochromis niloticus*	Wangboje and Ikhuabe, 2015
	Agenebode, Edo	0.00950 ± 0.01 mg/L	-	0.07667 mg/Kg	*Clarias gariepinus*	Wangboje and Ikhuabe, 2015
	Agenebode, Edo	0.0110 ± 0.03 mg/L	-	0.09167 mg/Kg	*Clarias nigrodigitatus*	Wangboje and Ikhuabe, 2015
	Agenebode, Edo	0.0219 ± 0.0376 mg/L	-	0.08567 mg/Kg	*Barbus occidentalis*	Wangboje and Ikhuabe, 2015
	Onitsha (Site 1)	nd ± 0.00 mg/L	nd ± 0.00 mg/L	0.001 ± 0.003 mg/kg	Fish (gills)	Izuchukwu Ujah et al., 2017
	Onitsha (Site 2)	nd ± 0.00 mg/L	nd ± 0.00 mg/L	0.000 ± 0.001 mg/kg	Fish (intestine)	Izuchukwu Ujah et al., 2017
	Onitsha (Site 1)	nd ± 0.00 mg/L	nd ± 0.00 mg/L	0.003 ± 0.007 mg/kg	Fish (skin)	Izuchukwu Ujah et al., 2017
	Onitsha (Site 2)	nd ± 0.00 mg/L	nd ± 0.00 mg/L	0.004 ± 0.002 mg/kg	Fish (flesh)	Izuchukwu Ujah et al., 2017
	Onitsha (Upstream)	0.019 ± 0.013 mg/L	0.061 ± 0.039 mg/L	-	-	Ezeabasili et al., 2015b
	Onitsha (Otumoye)	0.063 ± 0.013 mg/L	0.300 ± 0.028 mg/L	-	-	Ezeabasili et al., 2015b
	Onitsha (Creek road)	0.006 ± 0.001 mg/L	0.082 ± 0.007 mg/L	-	-	Ezeabasili et al., 2015b
	Onitsha (Downstream)	0.045 ± 0.015 mg/L	0.255 ± 0.043 mg/L	-	-	Ezeabasili et al., 2015b
	Onitsha (Central drainage)	0.157 ± 0.022 mg/L	0.148 ± 0.018 mg/L	-	-	Ezeabasili et al., 2015b
	Onitsha (Fish market)	0.012 ± 0.006 mg/L	-	0.31 ± 0.04 mg/L	*Chryschthys nigrodigitatus* kidney	Nsofor et al., 2014b
	Ajaokuta (DS, 2003-2004)	0.08 ± 0.02 mg/L	-	-	-	Olatunji and Osibanjo 2012
	Ajaokuta (WS, 2003-2004)	0.06 ± 0.02 mg/L	-	-	-	Olatunji and Osibanjo 2012
	Ajaokuta (DS, 2004-2005)	0.04 ± 0.01 mg/L	-	-	-	Olatunji and Osibanjo 2012
	Ajaokuta (WS, 2004-2005)	0.02 ± 0.01 mg/L	-	-	-	Olatunji and Osibanjo 2012
	Asaba	-	-	14.20 mg/kg	*Chryschthys nigrodigitatus* gills	Nwajei et al., 2012
	Asaba	-	-	11.20 mg/kg	*Clarias anguillaris* gills	Nwajei et al., 2012
	Asaba	-	-	12.10 mg/kg	*Tilapia zilli* gills	Nwajei et al., 2012
	Asaba	-	-	10.60 mg/kg	*Chryschthys nigrodigitatus* muscle	Nwajei et al., 2012
	Asaba	-	-	9.60 mg/kg	*Clarias anguillaris* muscle	Nwajei et al., 2012
	Asaba	-	-	12.10 mg/kg	*Tilapia zilli* muscle	Nwajei et al., 2012

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	Lokoja, Kogi (Mar)	-	2.0203 mg/kg	-	-	Ekwumemgbo et al., 2018
	Lokoja, Kogi (Jun)	-	1.1789 mg/kg	-	-	Ekwumemgbo et al., 2018
	Lokoja, Kogi (Sep)	-	0.5259 mg/kg	-	-	Ekwumemgbo et al., 2018
	Lokoja, Kogi (Dec)	-	0.7944 mg/kg	-	-	Ekwumemgbo et al., 2018
	Lokoja, Kogi (Dry season)	-	2.31 ± 0.18 mg/kg	-	-	Ekere et al., 2017
	Lokoja, Kogi (Wet season)	-	0.33 ± 0.15 mg/kg	-	-	Ekere et al., 2017
Zinc (Zn)	Onitsha	3.4 µg/L	-	-	-	Adeaga et al., 2017
	Fadama, Onitsha	15.8 µg/L	-	-	-	Adeaga et al., 2017
	Onitsha	0.321 ± 0.09 mg/L	-	4.35 ± 1.2 mg/L	*Macrobrachium rosenbergi*	Nsofor et al., 2014a
	Onitsha (Marina – DS)	0.278 ± 0.021 mg/L	-	-	-	Nsofor and Ikpeze, 2014
	Onitsha (Ose Market – DS)	0.317 ± 0.019 mg/L	-	-	-	Nsofor and Ikpeze, 2014
	Onitsha (Head bridge – DS)	0.188 ± 0.023 mg/L	-	-	-	Nsofor and Ikpeze, 2014
	Onitsha (Marina – RS)	0.419 ± 0.077 mg/L	-	-	-	Nsofor and Ikpeze, 2014
	Onitsha (Ose Market – RS)	0.411 ± 0.066 mg/L	-	-	-	Nsofor and Ikpeze, 2014
	Onitsha (Head bridge – RS)	0.260 ± 0.042 mg/L	-	-	-	Nsofor and Ikpeze, 2014
	Onitsha (Dry season)	0.261 ± 0.066 mg/L	-	3.55 ± 0.432 mg/L	*Clarias gariepinus*	Nsofor and Ikpeze, 2014
	Onitsha (Rainy season)	0.363 ± 0.089 mg/L	-	4.423 ± 0.693 mg/L	*Clarias gariepinus*	Nsofor and Ikpeze, 2014
	Onitsha (Fish market)	0.321 ± 0.09 mg/L	-	4.35 ± 1.20 mg/L	*Chryschthys nigrodigitatus* Kidney	Nsofor et al., 2014b
	Onitsha Axis	-	-	0.36 ± 0.249 mg/g	*Bagrus bayad*	Ezeonyejiaku et al., 2014
	Geregu, Kogi	ND	ND	5.5 ppm	*Bagrus bayad*	Omanayi et al., 2011
	Geregu, Kogi	ND	ND	9.3 ppm	*Oreochromis niloticus*	Omanayi et al., 2011
	Geregu, Kogi	ND	ND	12.2 ppm	*Synodontis membranaceus*	Omanayi et al., 2011
	Steel Complex, Kogi	ND	ND	4.4 ppm	*Bagrus bayad*	Omanayi et al., 2011
	Steel Complex, Kogi	ND	ND	10.2 ppm	*Oreochromis niloticus*	Omanayi et al., 2011
	Steel Complex, Kogi	ND	ND	10.3 ppm	*Synodontis membranaceus*	Omanayi et al., 2011
	Itobe bridge, Kogi	ND	ND	7.4 ppm	*Bagrus bayad*	Omanayi et al., 2011
	Itobe bridge, Kogi	ND	ND	10.3 ppm	*Oreochromis niloticus*	Omanayi et al., 2011
	Itobe bridge, Kogi	ND	ND	11.8 ppm	*Synodontis membranaceus*	Omanayi et al., 2011
	Asaba, Delta	1.15 ± 1.21 mg/L	-	-	-	Osakwe and Asuquo, 2017

	Asaba, Delta	0.94 ± 0.98 mg/L	-	-	-	Osakwe and Asuquo, 2017
	Onitsha, Anambra	0.95 ± 0.99 mg/L	-	-	-	Osakwe and Asuquo, 2017
	Onitsha, Anambra	0.73 ± 0.78 mg/L	-	-	-	Osakwe and Asuquo, 2017
	Agenebode, Edo	0.2175 ± 0.015 mg/L	-	71.47 mg/kg	*Oreochromis niloticus*	Wangboje and Ikhuabe, 2015
	Agenebode, Edo	0.2775 ± 0.05 mg/L	-	70.97 mg/kg	*Clarias gariepinus*	Wangboje and Ikhuabe, 2015
	Agenebode, Edo	0.225 ± 0.04 mg/L	-	65.70 mg/kg	*Clarias nigrodigitatus*	Wangboje and Ikhuabe, 2015
	Agenebode, Edo	0.239 ± 0.0571 mg/L	-	75.23 mg/kg	*Barbus occidentalis*	Wangboje and Ikhuabe, 2015
	Ajaokuta (DS, 2003-2004)	2.26 ± 0.49 mg/L	-	-	-	Olatunji and Osibanjo, 2012
	Ajaokuta (WS, 2003-2004)	2.62 ± 0.53 mg/L	-	-	-	Olatunji and Osibanjo, 2012
	Ajaokuta (DS, 2004-2005)	4.03 ± 0.66 mg/L	-	-	-	Olatunji and Osibanjo, 2012
	Ajaokuta (WS, 2004-2005)	1.98 ± 0.58 mg/L	-	-	-	Olatunji and Osibanjo, 2012
	Lokoja, Kogi (Mar)	-	22.4001 mg/kg	-	-	Ekwumemgbo et al., 2018
	Lokoja, Kogi (Jun)	-	15.4673 mg/kg	-	-	Ekwumemgbo et al., 2018
	Lokoja, Kogi (Sep)	-	17.7769 mg/kg	-	-	Ekwumemgbo et al., 2018
	Lokoja, Kogi (Dec)	-	13.6941 mg/kg	-	-	Ekwumemgbo et al., 2018
	Lokoja, Kogi (Dry season)	-	10.08 ± 3.79 mg/kg	-	-	Ekere et al., 2017
	Lokoja, Kogi (Wet season)	-	12.54 ± 0.28 mg/kg	-	-	Ekere et al., 2017
Lead (Pb)	Onitsha	0.15 µg/L	-	-	-	Adeaga et al., 2017
	Fadama, Onitsha	0.02 µg/L	-	-	-	Adeaga et al., 2017
	Asaba, Delta	0.04 ± 0.01 mg/L	-	-	-	Osakwe and Asuquo, 2017
	Asaba, Delta	0.08 ± 0.03 mg/L	-	-	-	Osakwe and Asuquo, 2017
	Onitsha, Anambra	0.05 ± 0.01 mg/L	-	-	-	Osakwe and Asuquo, 2017
	Onitsha, Anambra	0.04 ± 0.01 mg/L	-	-	-	Osakwe and Asuquo, 2017
	Agenebode, Edo	0.00475 ± 0.001 mg/L	-	0.01500 mg/kg	*Oreochromis niloticus*	Wangboje and Ikhuabe, 2015
	Agenebode, Edo	0.00875 ± 0.002 mg/L	-	0.03667 mg/kg	*Clarias gariepinus*	Wangboje and Ikhuabe, 2015
	Agenebode, Edo	0.0875 ± 0.003 mg/L	-	ND	*Clarias nigrodigitatus*	Wangboje and Ikhuabe, 2015
	Agenebode, Edo	0.00742 ± 0.0047 mg/L	-	ND	*Barbus occidentalis*	Wangboje and Ikhuabe, 2015
	Onitsha (Site 1)	0.056 ± 0.002 mg/L	0.566 ± 0.002 mg/kg	0.471 ± 0.322 mg/kg	Fish (gills)	Izuchukwu Ujah et al., 2017

	Onitsha (Site 2)	0.050 ± 0.001 mg/L	0.560 ± 0.002 mg/kg	0.313 ± 0.093 mg/kg	Fish (intestine)	Izuchukwu Ujah et al., 2017
	Onitsha (Site 1)	-	-	0.429 ± 0.281 mg/kg	Fish (skin)	Izuchukwu Ujah et al., 2017
	Onitsha (Site 2)	-	-	0.539 ± 0.235 mg/kg	Fish (flesh)	Izuchukwu Ujah et al., 2017
	Onitsha (upstream)	0.290 ± 0.030 mg/L	1.445 ± 0.282 mg/L			Ezeabasili et al., 2015b
	Onitsha (Otumoye)	0.424 ± 0.100 mg/L	0.201 ± 0.058 mg/L			Ezeabasili et al., 2015b
	Onitsha (Creek road)	1.236 ± 0.086 mg/L	0.791 ± 0.180 mg/L			Ezeabasili et al., 2015b
	Onitsha (downstream)	0.302 ± 0.031 mg/L	0.439 ± 0.063 mg/L			Ezeabasili et al., 2015b
	Onitsha (Central drainage)	0.335 ± 0.023 mg/L	1.234 ± 0.147 mg/L			Ezeabasili et al., 2015b
	Ajaokuta (DS, 2003-2004)	0.04 ± 0.03 mg/L	-	-	-	Olatunji and Osibanjo, 2012
	Ajaokuta (WS, 2003-2004)	0.02 ± 0.01 mg/L	-	-	-	Olatunji and Osibanjo, 2012
	Ajaokuta (DS, 2004-2005)	0.02 ± 0.01 mg/L	-	-	-	Olatunji and Osibanjo, 2012
	Ajaokuta (WS, 2004-2005)	0.02 ± 0.01 mg/L	-	-	-	Olatunji and Osibanjo, 2012
	Lokoja, Kogi (Mar)	-	2.5593 mg/kg	-	-	Ekwumemgbo et al., 2018
	Lokoja, Kogi (Jun)	-	0.8501 mg/kg	-	-	Ekwumemgbo et al., 2018
	Lokoja, Kogi (Sep)	-	0.8980 mg/kg	-	-	Ekwumemgbo et al., 2018
	Lokoja, Kogi (Dec)	-	0.5089 mg/kg	-	-	Ekwumemgbo et al., 2018
	Lokoja, Kogi (Dry season)	-	17.42 ± 8.53 mg/kg	-	-	Ekere et al., 2017
	Lokoja, Kogi (Wet season)	-	14.76 ± 0.18 mg/kg	-	-	Ekere et al., 2017
	Onitsha, Anambra	-	-	0.24 ± 0.04 mg/L	*Macrobrachium rosenbergi*	Nsofor et al., 2014a
	Onitsha (Fish market)	-	-	0.29 ± 0.04 mg/L	*Chryschthys nigrodigitatus* Kidney	Nsofor et al., 2014b
	Asaba, Delta	-	-	0.90 mg/kg	*Chryschthys nigrodigitatus* gills	Nwajei et al., 2012
	Asaba	-	-	5.40 mg/kg	*Clarias anguillaris* gills	Nwajei et al., 2012
	Asaba	-	-	4.30 mg/kg	*Tilapia zilli* gills	Nwajei et al., 2012
	Asaba	-	-	0.20 mg/kg	*Chryschthys nigrodigitatus* muscle	Nwajei et al., 2012
	Asaba	-	-	0.60 mg/kg	*Clarias anguillaris* muscle	Nwajei et al., 2012
	Asaba	-	-	1.10 mg/kg	*Tilapia zilli* muscle	Nwajei et al., 2012
	Onitsha Axis	-	-	2.689 ± 1.505 mg/g	*Bagrus bayad*	Ezeonyejiaku et al., 2014

	Onitsha (Dry season)	-	-	0.04 ± 0.007 mg/L	*Clarias gariepinus*	Nsofor and Ikpeze, 2014
	Onitsha (Rainy season)	-	-	0.416 ± 0.472 mg/L	*Clarias gariepinus*	Nsofor and Ikpeze, 2014
Mercury (Hg)	Onitsha	0.076 ± 0.007 mg/L	-	0.16 ± 0.0011 mg/L	*Macrobrachium rosenbergi*	Nsofor et al., 2014a
	Onitsha (Fish market)	0.016 ± 0.007 mg/L	-	0.16 ± 0.01 mg/L	*Chryschthys nigrodigitatus* Kidney	Nsofor et al., 2014b
	Onitsha (Upstream)	1.203 ± 0.134 mg/L	0.055± 0.011 mg/L	-	-	Ezeabasili et al., 2015a
	Onitsha (Otumoye)	0.057 ± 0.006 mg/L	1.562± 0.199 mg/L			Ezeabasili et al., 2015a
	Onitsha (Creek road)	1.531± 0.300 mg/L	0.513± 0.216 mg/L			Ezeabasili et al., 2015a

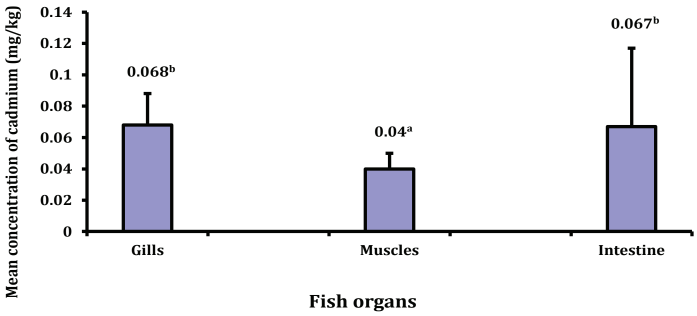

Figure 2: Mean concentration of cadmium in fish organs of three selected fish species of commercial importance from Niger River, Onitsha shelf, Anambra State, Nigeria. Superscript a & b indicates significant differences ($p<0.05$) in levels of cadmium using D.

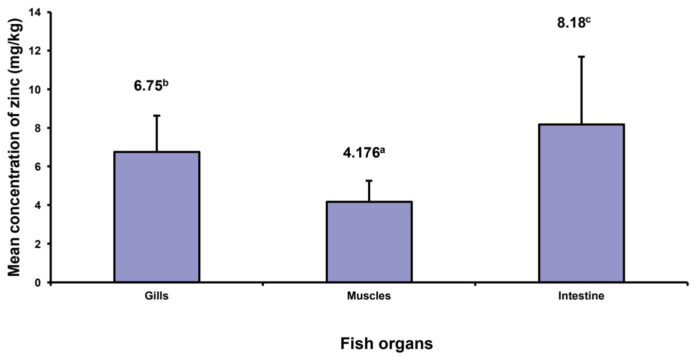

Figure 4: Mean concentration of zinc in the organs of the three selected fish species of commecial importance from Niger River, Onitsha shelf, Anambra State, Nigeria. Superscript a-c indicates significant differences in levels of zinc in the organs.

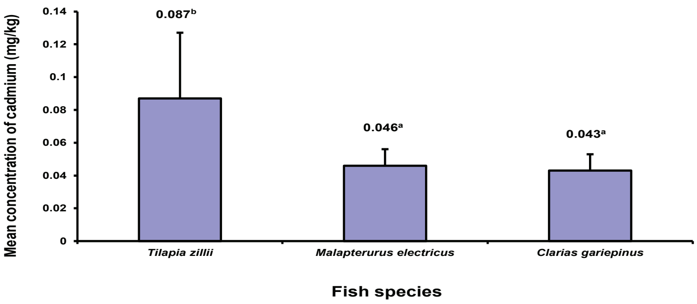

Figure 3: Mean concentration of cadmium in the three selected fish species of commercial importance from Niger River, Onitsha shelf, Anambra State, Nigeria. Superscript a & b indicates significant differences ($p<0.05$) in levels of cadmium in the fish.

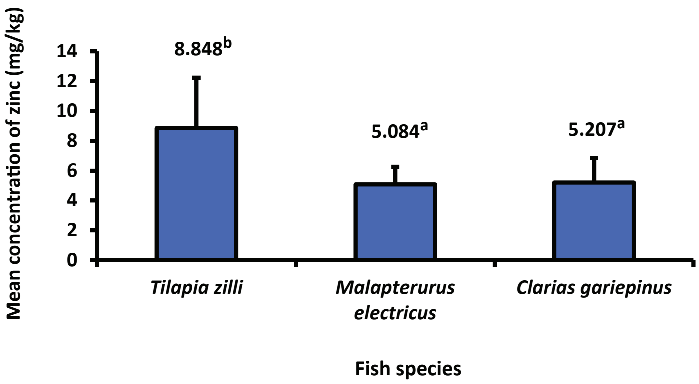

Figure 5: Mean concentration of zinc in three selected fish species of commercial importance from Niger River, Onitsha shelf, Anambra State, Nigeria. Superscript a& b indicates significant differences ($p<0.05$) in levels of cadmium using Ducan's multiple range test.

Barbus occidentalis caught from River Niger at Agenebode, Edo State (**Table 2**). Previous studies within this ecosystem indicated the detectable level of zinc in water and sediment to range from 0.188 ± 0.023 mg/L (River Niger at Head Bridge, Onitsha) to 4.03 ± 0.66 mg/L (River Niger at Ajaokuta, Kogi State) and 10.08 ± 3.79 mg/kg (River Niger at Lokoja, Kogi State) to 22.4001 mg/kg (River Niger at Lokoja, Kogi State) respectively for water and sediment (**Table 2**). The descending order of zinc concentration was intestine > gills > muscles in *T. zillii*; gills > intestine > muscles *M. electricus*; and intestine > gills > muscles in *C. gariepinus* the mean concentration of zinc in the organs of the studied fish species ranged from 4.176 ± 1.091 mg/kg in muscles to 8.180 ± 3.508 mg/kg in the intestine (**Figure 4**). The descending order of zinc concentration in the organs was intestine > gills > muscles. The mean zinc concentration in the fish samples is presented in **Figure 5**.

The heavy metals, lead (Pb) and mercury (Hg) were not detected in any of the organs of studied fishes. Within this freshwater ecosystem, the detectable level of lead in fish ranged from 0.01500 mg/g in Oreochromis niloticus caught from River Niger at Agenebode, Edo State to 5.40 mg/kg in the gills of *Clarias anguillaris* caught from River Niger at Asaba, Delta State (**Table 2**). Previous studies within this ecosystem indicated the detectable level of lead in water and sediment to range from 0.00475 ± 0.001 mg/L (River Niger at Agenebode, Edo State) to 1.236 ± 0.086 mg/L (River Niger at Creek Road, Onitsha) and 0.201 ± 0.058 mg/L (River Niger at Otumoye, Onitsha) to 2.5593 mg/kg (River Niger at Lokoja, Kogi State) respectively for water and sediment (**Table 2**).

Although mercury was not detected in any of the studied organs of fish, values reported for detectable level of mercury in fish from River Niger were similar in *Macrobrachium rosenbergi* (0.16 ± 0.0011 mg/L) and *Chryschthys nigrodigitatus* (0.16 ± 0.01 mg/L) caught from River Niger at Onitsha (**Table 2**). Equally the ecosystem had detectable levels of mercury in water and sediment ranging from 0.016 ± 0.007 mg/L (River Niger at Fish market, Onitsha) to 1.531± 0.300 mg/L (River Niger at Creek Road, Onitsha) and 0.055± 0.011 mg/L (River Niger upstream, Onitsha) to 1.562± 0.199 mg/L (River Niger at Otumoye, Onitsha) respectively for water and sediment (**Table 2**).

Discussion

Bioaccumulation of heavy metals does not only depend on the organs, but also on the interactions between metals and the target organs (Nanda, 2014). Fishes bioaccumulate heavy metals and thus act as good bioindicators of pollution (Ibemenuga, 2013). The observed variability in the concentration of heavy metals in the three fish species *T. zillii, M. electricus* and *C. gariepinus* is a reflection of varying degree of metal thresholds in the animals. Aquatic organisms concentrate metal from water and food either by absorption or ingestion. The levels of metal accumulated vary from organ to organ in fish species (Nwosu et al., 2014).

The mean concentration of cadmium in the fish species analyzed was lower than FAO/WHO standard for aquatic foods (FAO/WHO, 2011). The level of cadmium (0.043 ± 0.01 - 0.087 ± 0.04) for fishes in this study within the range of cadmium (0.087 ± 0.04 - 14.20 mg/kg) in fishes from River Niger ecosystem (Nwajei et al., 2012; Izuchukwu Ujah et al., 2017). The maximum levels of cadmium in fish from this study were lower than the maximum level of cadmium in the water (0.006 ± 0.001 - 0.157 ± 0.022 mg/L) and sediment (0.061 ± 0.039 - 2.31 ± 0.18 mg/kg) of River Niger (Ezeabasili et al. 2015b; Ekere et al. 2017). This result supports the uptake of cadmium from the environment without the setting in of biomagnification.

The detection of cadmium is worrisome considering the toxic effect of cadmium to fish and man. Sub lethal concentration of cadmium has been reported to cause histopathological alterations in the liver and kidney of *Chrysichthys nigrodigitatus* (Nsofor et al., 2014b). Toxic concentration of cadmium has also been reported to cause ita-itai disease in fish eating populace (Baby et al., 2010).

This metal is a highly toxic non-essential heavy metal and it does not have a role in biological processes in living organisms. Thus, even at very low concentrations, cadmium could be harmful to humans (Bernard, 2008). Cd is primarily toxic to the kidney, especially to the proximal tubular cells, the main site of accumulation. Cd can also cause bone demineralization, either through direct bone damage or indirectly as a result of renal dysfunction. In the industry, excessive exposures to airborne Cd may impair lung function and increase the risk of lung cancer (Bernard, 2008).

The mean concentration of zinc in the fish species analyzed was far lower than FAO/WHO standard for aquatic foods (FAO/WHO, 2011). The level of zinc (5.084 ± 1.17 - 8.848 ± 3.38 mg/kg) for fishes in this study was within the range of zinc (0.36 ± 0.249 - 75.23 mg/kg) in fishes from River Niger ecosystem (Ezeonyejiaku et al., 2014; Wangboje and Ikhuabe, 2015). The maximum levels of zinc in fish from this study were higher than the maximum level of zinc in the water (0.188 ± 0.023 - 4.03 ± 0.66 mg/L) but far lower than the maximum level of zinc in sediment (10.08 ± 3.79 - 22.4001 mg/kg) of River Niger (Ekere et al., 2017; Ekwumemgbo et al., 2018). This result supports the uptake of zinc from the environment.

The very low level of zinc recorded in *C. gariepinus* was higher compared with the report of Nsofor et al. (2007) in Niger River who recorded 4.85 mg/L. Nevertheless, zinc has been reported to be toxic to fish and macro invertebrates at sub-lethal concentration (Ajiwe et al., 2000). A laboratory test had demonstrated that dissolved zinc was highly toxic to amphipods, less toxic to fathead minnows and least toxic to brook trout. *Salvelinus fontinalis*, the predominant fish species in the Animas River water shed study area. Significant toxic effects of zinc on early life stages of brook trout occurred at concentrations of 960 µg/L or greater (Besser and Leib, 2007). The danger of zinc is aggravated by its almost indefinite persistence in the environment because it cannot be destroyed biologically but are only transformed from oxidation state or organic complex to another (Murugan et al., 2008). Zinc is poisonous to fish, causing disturbances of acid-base and ion regulation, disruption of gill tissue and hypoxia (Murugan et al., 2008).

The fact that lead was not detected in the analysed fish organs did not exclude the uptake of lead in other aquatic organisms in River Niger. The minimum and maximum levels of lead recorded for fish (0.01500 - 5.40 mg/kg) (Nwajei et al., 2012; Wangboje and Ikhuabe, 2015), water (0.00475 ± 0.001 - 1.236 ± 0.086 mg/L) (Ezeabasili et al., 2015b; Wangboje and Ikhuabe, 2015) and sediment (0.201 ± 0.058 - 2.5593 mg/kg) (Ezeabasili et al., 2015b; Ekwumemgbo et al., 2018) were all lower than FAO/WHO standard for aquatic foods and environment (FAO/WHO, 2011; FAO, 2015).

Lead is a non-essential element and high concentrations can occur in aquatic organisms close to anthropogenic sources. It is toxic even at low concentrations and has no known function in biochemical processes (Tchounwou et al., 2012). Although, lead was not detected in any of the organs of fish species in this study, Martinez et al. (2004) had reported that in the gills of *Prochilodus* *lineatus* exposed to both lead concentrations during 96 hour bioassay, a higher occurrence of histopathological lesions such as epithelial lifting, hyperplasia and lamellar aneurism were recorded. Furthermore, *P. lineatus* did not show significant alterations in hematocrit during exposure to lead concentrations. Fish exposed to the highest lead concentration showed a significant decrease in Na+ plasma concentration after 48 hour, possibly reflecting a sodium influx rate decrease. *P. lineatus* exposed to both lead concentrations presented a classical general adaptation syndrome to stress, as hyperglycemia associated with lowered lipids and proteins was reported. Stress-response magnitude was dose-dependent. While the response to the lowest lead concentration might represent adaptation, the highest concentration seems to characterize exhaustion. The non-occurrence of lead in the fish organs reported in this study may be due to the non-uptake of lead from the river by the fishes either through water, food and up-take by the gills and skin (Obasohan, 2008). The bioaccumulation of metals in an organism's body can take place, if the rate of uptake by the organism exceeds the rate of elimination (Oguzie, 2003).

Mercury is a naturally occurring chemical, but it can become harmful when it contaminates fresh and seawater areas and foods. Fish and other aquatic animals ingest the mercury, and it is then passed along the food chain until it reaches humans. Although, mercury was not detected in any of the organs of fish species in this study, reports from other studies done in River Niger indicated the presence of low levels mercury in *Macrobrachium rosenbergi* and liver and kidney of *Chryschthys nigrodigitatus* (Nsofor et al., 2014a). Equally, environmentally safe levels of mercury has been associated with water (0.016 ± 0.007 - 1.531 ± 0.300 mg/L) and sediment (0.055± 0.011 - 1.562 ± 0.199 mg/L) of River Niger (Ezeabasili et al., 2015a). Bradford (2018) had reported that in humans mercury may cause a wide range of conditions including neurological and chromosomal problems and birth defects. Negative health effects from methyl mercury may include neurological and chromosomal problems. Long-term exposure to organic mercury can cause: uncontrollable shaking or tremor, numbness or pain in certain parts of the skin, blindness and double vision, inability to walk well, memory problems, seizures and death with large exposures.

Conclusion

The results obtained in this study, revealed that Niger River is contaminated to varying levels by toxic heavy metals. Zinc and cadmium had the highest level of bioaccumulation in the gills and intestine of sampled fishes. The result also indicated total absence of lead and mercury in all the three fish species. Studies from the field and laboratory experiments showed that bioaccumulation of heavy metals in organs are mainly dependent upon water concentration of metals and exposure period. Although, levels of heavy metals are not that high, a potential danger may occur in the future arising from the discharge of agricultural, industrial and domestic waste waters generated via human activities into this aquatic ecosystem.

Recommendations

It is evident from the result of this study that Niger River contains varying levels of heavy metals as shown by the metal levels in the three fish samples obtained from the water body. Hence, it is important to control the discharge of pollutants especially those from point sources such as industrial effluents and domestic wastes. To achieve this, the following recommendations are prefered: a) Public enlightenment on the need to desist from anthropogenic activities that could lead to water pollution, b) Enactment of laws by the government for industries and factories to treat their waste waters and sewage properly before disposing them into water bodies, c) Continuous monitoring exercise should be put in place to guard against excessive bioaccumulation of these metals and safeguard the safety, protection and well-being of consumers and d) Proper waste management should be developed through measures that encourage minimization, recycling and reuse of processed waste by both individuals and industries.

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