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Research Article

Physico-Chemical Parameters and Heavy Metals Composition of Water, Sediment and Fish Species of Oyan Lake, Nigeria

Ayodele OP[1]*, Fafioye OO[2] and Oladunjoye RY[2]

[1]*Department of Fisheries Technology, Federal College of Technology, Ishiagu, Nigeria*

[2]*Department of Zoology and Environmental Biology, Olabisi Onabanjo University, Ago-Iwoye, Nigeria*

***Corresponding Author:** Ayodele OP, Department of Fisheries Technology, Federal College of Technology, Ishiagu, Nigeria.

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Abstract

The level of heavy metals (Cd, Pb, Cu, Zn, Mn) were evaluated in the gills, muscles and liver of four commercially available fish species (*Coptodonzillii, Oreochromis niloticus, Chrysichthysnigrodigitatus* and *Brycinus nurse*) of Oyan River Lake, Nigeria. Eighty adult of all four fish species were procured from fishermen in Oyan Lake over a period of 4 months. Water and sediment samples of the Lake were also collected. Levels of heavy metals were detected using an Atomic Absorption Spectrophotometer. Water pH values ranged between 7.50 and 7.94. Heavy metals (Mn, Cu, Zn, Cd and Pb) were not detected in all the water samples. Manganese, copper and zinc were detected in the sediments of Oyan Lake. Among the metals present in the sediment samples, manganese was highest in concentration. Lead (Pb) and Cadmium (Cd) were not detected in the sediment and fish organs. In the fish organs, Zinc was higher than Manganese and Copper in concentration. *C. zillii* had the highest concentration of all the three metals detected while they were lowest in B. nurse. Although, Pb and Cd were below detectable level in the water, sediment and commercially available fish species, the levels of Mn, Zn and Cu detected in the sediment were above internationally reported acceptable levels. Therefore, the commercially available fish species of Oyan Lake, Nigeria (*C. zillii, O. niloticus, B. nurse* and *C. nigrodigitatus*) may not be totally safe for consumption.

Keywords: Bioaccumulation; Water Sediments; Fish; Bio-Monitoring

Introduction

Heavy metals may enter aquatic systems from different natural and anthropogenic sources including industrial or domestic wastewater, application of pesticides and inorganic fertilizers, storm runoff, leaching from landfills, shipping and harbour activities, geological weathering of the earth crust and atmospheric deposition [1]. These metals could be deposited in aquatic organisms as a result of bioaccumulation via the food chain process and become toxic when accumulation reaches a substantially high level [2]. Several researches have also shown that accumulated heavy metals in fish, either from water, diet and contaminant residues could be bio-magnified higher than those measured in the water, sediment and food [3-5]. Therefore, accumulation of heavy metals in tissues of fish has been identified as an indirect measure of the abundance and availability of metals in the aquatic environment [6].

Metal accumulation in fish tissues poses a direct threat for human being [7]. For instance, lead may cause learning disabilities, impaired protein and haemoglobin synthesis and shorten the lifespan of red blood cells which leads to severe anaemia (hypochromic microcytic anemia) in children [8]. Toxic effects of cadmium in human were also identified as renal failure, accumulation in the bone resulting in calcium loss and malfunctioning of peripheral and central nervous system [9]. Nickel impairs the biological activity of cells and lungs and causes nasal cancer in long-term exposure; respiratory, nervous, digestive and psychological disorders [8]. Zinc causes slow growth in children, reduced fertility, dry mouth, headache and nausea [9]. Although fish can be effective in preventing cardiovascular disease (CVD), the fish found in waters with heavy metals may increase the incidence of some illnesses such as cancer [10].

Oyan Lake covers a land area of about 4,000 hectares. The Lake is a significant source of fish for the people living in and around Abeokuta. Fish from the lake constitute a great proportion of both fresh and processed fish sold in major fish markets in Abeokuta. Investigation of the heavy metals in fishes has become important to estimate freshwater pollution and the risk potential of human consumption [11]. The safety of commercially available fish species of Oyan Lake especially in term of heavy metal accumulation is therefore essential. This study was therefore to determine the levels of accumulation of Mn, Cu, Zn, Cd and Pb in the gill, muscle and liver of four commercially available fish species Redbelly tilapia - *Coptodonzillii,* Nile tilapia - *Oreochromis niloticus,* Silver catfish – *Chrysichthysnigrodigitatus* and Silversides -*Brycinus nurse*) of Oyan Lake.

Materials and Methods

Study area

This study was carried out at the Oyan River Lake located in Abeokuta North Local Government Area of Ogun State, south-west of Nigeria (7°15`N; 3°16`E). The lake is a tributary of the Ogun River used primarily to supply raw water to Lagos and Abeokuta.

Samples collection

- **Fish sample:** Eighty (80) adult fish specimens, twenty each of *Coptodonzillii*, *Oreochromis niloticus, Chrysichthysnigrodigitatus,* and *Brycinus nurse* were procured from fishermen in Oyan Lake over a period of 4 months. The fish species were put in sterile polythene bags and taken in icebox to the laboratory. All fish samples were dissected with sterile scissors to remove gills, muscles and livers. The organs were air dried for four days before being ground with mortar and pestle. Ground fish samples were thereafter labelled separately for digestion and analysis of heavy metals.
- **Water Sample:** Water samples were collected in 600ml sample bottles from four sampling sites once a month for four months. Before sampling, sample bottles were pre-cleaned with 10% nitric acid and de-ionized water. The bottles were rinsed at least three times with water from the sampling site. The bottles were immersed to about 20cm below the water surface to prevent contamination of heavy metals from air. All samples were immediately taken to the laboratory for analysis.
- **Sediment Sample:** Bottom sediment samples were obtained from the same points where water samples were collected. The samples were taken using labelled 600ml sample bottles which were pre-cleaned with 10% nitric acid and de-ionized water and taken to the laboratory for analysis.

Digestion

Soil samples were air dried separately for four days to obtain a constant dry weight from each sample. The dried soil samples were ground to powder using laboratory ceramic mortar and pestle, and sieved with 0.5mm sieve to get a powdery soil sample. Each fish organ was air dried and crushed with laboratory ceramic mortar and pestle. 0.50g of the sample was weighed into the digestion tube and 10ml of the acid mixture was added. The acid mixture was a combination of nitric acid and perchloric acid in the ratio 2:1. 10 ml of digestion mixture was added and placed on the tecator digestion block; the temperature was set at 250^{o}C and digested for 2½ hours under the fume cupboard. The tecator digestion block was pre-heated to 150^{o}C before the digestion tube was introduced. After digestion, the tube was left in the fume cupboard to cool. After cooling, it was transferred into 25ml volumetric flask with wash bottle.

Heavy metals determination

Digested samples were then poured into auto-analyzer cups and concentrations of heavy metals (cadmium, lead, copper, zinc, manganese) in each were determined with an Atomic Absorption Spectrophotometer (AAS) using Buck Scientific model 210VGP, USA.

Measurement of water parameters

Water parameters i.e. electrical conductivity, pH and chloride, were measured using electrical conductivity meter, pH meter and vernier chloride ion-selective electrode respectively in the laboratory.

Data analysis

Data were subjected to statistical analyses using the Statistical Package for Social Sciences (SPSS) version 20.0 [12]. Analysis of Variance (ANOVA) and descriptive statistics were used to compare the metal concentration between the fish organs and between the fish species. Means were presented as Mean ± Standard error of mean. Means were separated using the Student-Newman-Keuls (SNK).

Results

Physico-chemical Parameters of Water and Sediment Metal Composition

The physico-chemical parameters of water of Oyan Lake during the study period are presented in Table 1. The pH values recorded were between the range of 7.50 and 7.94. Electrical conductivity and chloride concentration also recorded mean values of 0.15 ± 0.01 m/s and 30.61 ± 2.63 mg/l respectively. The presence of heavy metals (Mn, Cu, Zn, Cd and Pb) was below detection level in all water samples collected for the study.

		Mean (± SE)	Range
Water	pH	7.74 ± 0.06	7.50 - 7.94
	Electrical Conductivity (m/s)	0.15 ± 0.01	0.08 - 0.23
	Chloride (mg/l)	30.61 ± 2.63	21.60 - 36.02

Table 1: Physico-chemical parameters of the water of Oyan Lake.

*SE = Standard error of mean

Of all the metals tested, only manganese, copper and zinc were detected in the sediments of Oyan Lake (Table 2). Among the metals present in the sediment samples, manganese was highest in concentration with 92.48 ± 11.31 mg/l. This was however followed by zinc (14.21 ± 2.82mg/l) and copper (6.79 ± 1.07 mg/l) respectively. Lead (Pb) and Cadmium (Cd) were not detected in the sediment samples.

		Mean (± SE)	Range	Authority
Sediment	Mn (mg/l)	92.48 ± 11.31	72.73 - 154.81	0.1^{A}
	Cu (mg/l)	6.79 ± 1.07	2.36 - 11.54	1.3^{B}
	Zn (mg/l)	14.21 ± 2.82	5.66 - 25.01	5.0^{A}

Table 2: Sediment metal composition of Oyan Lake.

*SE = Standard error of mean; Ref = Reported maximum acceptable level in fish: A = WHO [13]; B = EPA [14].

Metal concentration (mg/kg) in the gill, muscle and liver of experimental fish species

Lead (Pb) and Cadmium (Cd) were not detected in the organs of the fish species used for this study (Table 2). In *C. zillii,* the concentration of manganese (Mn) was observed to be significantly higher ($P < 0.05$) in the liver than in other organs. This was followed by the muscle and the gills respectively. Concentration of Mn was also significantly ($P < 0.05$) higher in the gills of *O. niloticus* while it was not significantly different ($P > 0.05$) between the liver and the muscle. No significant difference ($P > 0.05$) was however recorded in the concentration of Mn among the gills, liver and muscle of *C. nigrodigitatus* and *B. nurse.*

The concentration of Cu in the organs of *C. zillii* was recorded to be significantly higher ($P < 0.05$) in the muscle than in other organs (Table 3). On the other hand, there was no significant difference ($P > 0.05$) in the concentration of Cu among the gills, liver and muscle of *O. niloticus, B. nurse* and *C. nigrodigitatus*. Similarly, the values of Zn recorded in the gills, liver and muscle of the studied fish species were not significantly different ($P > 0.05$).

Comparing metal bioaccumulation among the different fish species, Mn was significantly higher in the gills of *Oreochromis niloticus* ($P = 0.02$) and in the liver of *Coptodonzillii* ($P = 0.04$) (Table 3). Concentration of Mn was however not significantly different ($P = 0.47$) in the muscles between the different fish species. Cu concentration in the organs was also observed to be significantly different ($P < 0.05$) among the different fish species. However, there was no significant difference ($P > 0.05$) in the organ concentration of Zn between the different fish species.

Mean overall metal concentration (mg/kg) in the fish species

Table 4 presents the mean metal concentrations in the fish species of Oyan Lake during the study period. There was no significant difference ($P > 0.05$) recorded in the concentrations of Mn, Cu and Zn among the different fish species (*C. zillii, O. niloticus, B. nurse* and *C. nigrodigitatus*). However, these metals were higher in *C. zillii* than the other fish species. *B. nurse* recorded the least concentrations of Mn, Cu and Zn. There was no record of Pb and Cd in any of the fish species.

Mean overall metal concentrations (mg/kg) in the fish organs of oyan lake

The graphical comparison of metal concentration in the gill, muscle and liver of fish species in Oyan Lake is represented in Figure 1. Mn was observed to be higher in the gills than the liver and the muscles respectively. On the other hand, Cu was higher in the muscles while the concentration of Zn was higher in the liver. In the three organs however, concentration of heavy metals followed the trend: Zn > Mn > Cu.

Discussion

This study has revealed that the water, sediment and experimental fish species of Oyan Lake did not contain lead (Pb) and cadmium (Cd) at detectable level. However, the sediment and fish species of the Lake contained some levels of metals which are distributed in different proportions in the gills, muscle and liver.

In the organs of the fish species of Oyan Lake, Zinc was higher than Manganese and Copper in concentration. Similarly, among the heavy metal detected in the tissues (liver, gill, muscle, skin, and head) of typical fish species in the Yangtze River Estuary by Zhao.,

		Coptodonzillii	*Oreochromis niloticus*	*Chrysichthysnigridigitatus*	*Brycinus nurse*	P - value	Authority
Mn	Gill	18.87 ± 6.08^{b}	56.07 ± 10.52^{a}	45.13 ± 11.34^{a}	21.54 ± 8.35^{a}	0.02*	1.00
	Muscle	33.34 ± 6.42^{ab}	16.01 ± 6.94^{b}	31.64 ± 11.83^{a}	22.02 ± 7.71^{a}	0.47	
	Liver	53.27 ± 11.38^{a}	18.19 ± 4.38^{b}	28.41 ± 7.87^{a}	21.13 ± 10.33^{a}	0.04*	
Cu	Gill	4.73 ± 1.16^{b}	4.79 ± 0.64^{a}	2.14 ± 0.47^{a}	0.69 ± 0.14^{a}	0.01*	30
	Muscle	17.91 ± 6.60^{a}	5.49 ± 1.43^{a}	1.86 ± 0.50^{a}	0.66 ± 0.09^{a}	0.01*	
	Liver	2.75 ± 0.45^{b}	5.38 ± 1.45^{a}	1.83 ± 0.60^{a}	0.91 ± 0.15^{a}	0.01*	
Zn	Gill	53.00 ± 6.46^{a}	57.89 ± 8.97^{a}	58.09 ± 8.99^{a}	49.28 ± 10.42^{a}	0.87	100
	Muscle	71.53 ± 7.98^{a}	49.17 ± 8.62^{a}	46.04 ± 8.82^{a}	45.22 ± 7.90^{a}	0.09	
	Liver	65.69 ± 7.11^{a}	58.64 ± 9.63^{a}	62.83 ± 13.00^{a}	57.88 ± 9.95^{a}	0.93	
Pb	Gill	-	-	-	-	-	2.00
	Muscle	-	-	-	-	-	
	Liver	-	-	-	-	-	
Cd	Gill	-	-	-	-	-	1.00
	Muscle	-	-	-	-	-	
	Liver	-	-	-	-	-	

Table 3: Metal concentration (mg/kg) in the gills, muscle and liver of four fish species of Oyan Lake.

^{abc}Mean (± Standard error) for each of the metals having similar superscript is significantly different between the organs at P < 0.05. *Mean values in the same row are significantly different at P < 0.05. Pb and Cd not detected.

Authority = Reported maximum acceptable level in fish [13,15].

	Mn	Cu	Zn	Pb	Cd
Coptodonzillii	35.98 ± 5.70^{a}	8.46 ± 2.56^{a}	63.41 ± 4.29^{a}	-	-
Oreochromis niloticus	32.69 ± 6.39^{a}	5.25 ± 0.71^{ab}	54.99 ± 5.14^{a}	-	-
Chrysichthysnigrodigitatus	34.56 ± 5.92^{a}	1.95 ± 0.29^{b}	55.78 ± 5.85^{a}	-	-
Brycinus nurse	21.57 ± 4.86^{a}	0.75 ± 0.07^{b}	51.16 ± 5.36^{a}	-	-
*WHO 2011, Mokhtar, 2009	1	30	100	2	1

Table 4: Mean overall metalconcentration (mg/kg) in the fish species of Oyan Lake, Nigeria.

^{abc}Mean (± Standard error) in the same column having similar superscript is significantly different at P < 0.05. *Reported maximum acceptable level in fish; Pb and Cd not detected.

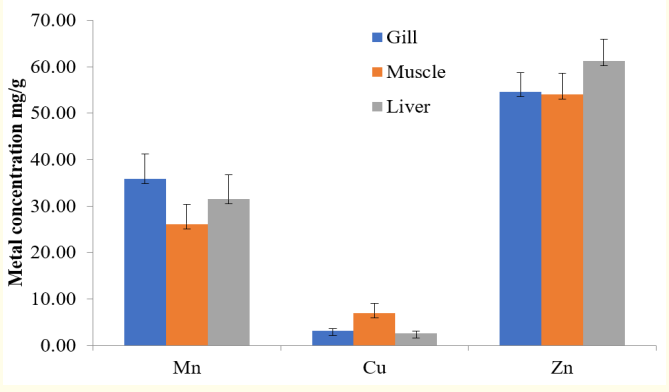

Figure 1: Mean overall metal concentrations (mg/kg) in the fish organs of Oyan Lake, Nigeria.

et al. [16], zinc exhibited the highest concentration in every tissue. This was attributed with the higher bioavailability and higher content of zinc in surrounding water and sediment [17]. As reported by Al-Weher [18], the most uptake of Zn metal was through the skin tissue and not the gills. The ability of fishes to accumulate Zn in their tissues through the skin could therefore be responsible for the elevated levels in the organs of the fishes of Oyan Lake as observed in this study.

Metals accumulation in the fish species observed exhibited inter-specific variation. El-Moselhy., *et al.* [19] also reported the exhibition of wide inter-specific variations in metals accumulation in all organs of the fishes of the Red Sea, Egypt. This was attributed to the feeding habit of the fish. Several factors such as ecological needs, swimming patterns, metabolic activities, and living environments have been proved to affect heavy metals accumulation ability of fishes [20]. Among these factors, living environment is often considered to be more important because aquatic systems are complicated and metal contaminants are not uniformly distributed [16]. As reported by Khaled [21], an herbivore accumulates higher concentrations of metals in their muscles than the carnivore. Similarly, Zhao., *et al*. [16] also submitted that high levels of metals in water are often detected in skin or gill tissue of pelagic fishes. Hence, inter-specific variation observed in the metal accumulation of the fish species of Oyan Lake could be attributed to their biological position and needs.

Conclusion

C. zillii had the highest concentration of all the three metals detected in the fishes (Mn, Zn and Cu). These were however lowest in B. nurse. The bioaccumulation of heavy metals in aquatic organisms as described by Eneji., *et al.* [22] depends on the ability of the organisms to digest the metals, the concentration of the heavy metals in the surrounding soil sediments and the feeding habit of the organism. Tilapia fish is a shallow water dwelling fish, which survives in close proximity to the entry point of water inflows [23]. At this point, water from polluted uplands may contain higher quantities of metals carried along by the sediments and are taken up during gaseous exchange and uptake of food particles by the fish. Coptodon zillii has also been described as an omnivorous fish with dietary preference for algae, vegetative matter, detritus and aquatic invertebrate larvae [24]. On the other hand, zooplankton, ephemeropteran imagines and higher plants constituted almost the whole diet of B. nurse [25]. Thus, the wide feeding range of *C. zillii* coupled with its position in the water body could be the predisposing factor for the higher occurrence of the detected metals (Mn, Zn and Cu) in it. Akan., *et al.* [26] also recorded higher concentration of Fe and Zn in the stomach and bone of *C. zillii* than other fishes collected at River Benue in Vinikilang, Adamawa State, Nigeria. Similarly, Eneji., *et al.* [27] also recorded higher levels of heavy metals in the liver of *C. zillii* than in *Albula vulpe.*

Although, lead (Pb) and cadmium (Cd) were below detectable level in the water, sediment and commercially available fish species of Oyan Lake, the levels of Mn, Zn and Cu detected in the sediment were above internationally reported acceptable levels [14]. Similarly, the levels of Mn in the gills, muscle and liver of the commercially available fish species were above acceptable levels [13,15]. However, the concentration of Cu and Zn in the gills, muscle and liver of the fish species were below the recommended acceptable limits [13,15]. Therefore, the commercially available fish species of Oyan Lake, Nigeria (*C. zillii, O. niloticus, B. nurse* and *C. nigrodigitatus*) may not be totally safe for consumption.

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