INVESTIGATION OF TRACE METALS IN THE TISSUES OF A FRESHWATER FISH (*Crysichthys nigrodigitatus*) FROM THE IKPOBA RIVER DAM, BENIN CITY NIGERIA

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ABSTRACT

The concentrations of zinc (Zn), cadmium (Cd), copper (Cu), lead (Pb) and chromium (Cr) were evaluated in whole fish, muscle, liver and gills of the benthic fresh water fish, Crysichthys nigrodigitatus, from Ikpoba River Dam in Benin City, Nigeria, by atomic absorption spectrometric technique. The concentrations of the aforementioned trace metals were also determined in water and sediment. The concentration profile of Zn in fish tissue in descending order was liver > muscle > whole fish > gills while for Cd the profile in descending order was liver > whole fish > gills > muscle. The concentration profile in descending order for Cr, Pb and Cu was liver > whole fish > muscle > gills, liver > gills >whole fish > muscle and muscle > whole fish > liver > gills respectively. The concentration profile of the metals in descending order in water was Zn > Pb > Cd > Cr > Cu while in sediment the concentration profile was Zn > Cu > Pb > Cd > Cr. The mean concentration of Cr in the examined fish tissues exceeded the WHO maximum allowable limit for food and fish while the mean concentration of Pb in water exceeded the WHO maximum allowable limit for drinking water. It was advocated that regulatory agencies should further monitor the Dam in other to produce sufficient data to implement better management strategies which would alleviate negative impacts.

Keywords: Trace Metals, Zinc, Cadmium, Copper, Lead, Chromium, *Crysichthys nigrodigitatus,* Ikpoba Dam, Benin City, Nigeria

INTRODUCTION

The Committee for Inland Fisheries of Africa (CIFA, 1989) reported that freshwater fishes are vital to Africa's proteinous food security and should be protected from damage by wastes arising from the ever increasing urbanization, industrialization, and agricultural and forestry activities. These activities already resulted in increased contamination and in some cases pollution of surface waters. It is well documented that trace metals and organic compounds can be accumulated by aquatic biota (GESAMP, 1993; Calamari and Naeve, 1994).

Furthermore, the toxic effect of hazardous waste generated by industrial and domestic activities on aquatic animals has been documented (Corrales and Horton, 1995). The pollution of the aquatic environment with trace metals has become a global problem during recent years owing to the fact that they are indestructible and majority of them have toxic effects on organisms (Macfarlane and Burchett, 2000). The concentration of a metal in an organism has been described as the product of equilibrium between the concentration of the metal in the organism's environment and its rate of ingestion and excretion (Idodo-Umeh, 2002).

Previous studies have revealed that various aquatic bodies and their resources in Nigeria contain varying levels of trace metals (Ezemonye, 1992; Fufeyin, 1994; Wangboje and Oronsaye, 2001; Ogri *et al.,* 2003). Trace metals may be introduced into the aquatic environment as a result of natural processes or through anthropogenic processes (Calamari and Naeve 1994). There are five potential routes for a pollutant to enter fish and these include food, non-food particles, gills, oral consumption of water and the skin (Heath, 1991). According to Villareal-Trevino *et al.* (1986), trace metals such as copper, zinc, lead and chromium are present in domestic drainage pipes. Furthermore lead and cadmium have not been shown to play any beneficial roles, but rather they inhibit biological systems in fish. Lead produces changes in the pigmentation patterns of certain fish species and modifies the physiochemical changes of the cellular pigment by direct interference with the germinal plasma. The Ikpoba River Dam has been reported to receive effluents containing a wide range of pollutants including trace metals (Fufeyin, 1994). This study has been undertaken specifically to determine the concentrations of zinc, cadmium, chromium, lead and copper in whole fish, muscle, liver and gills of a benthic fresh water fish, *Crysichthys nigrodigitatus* from the Ikpoba River Dam, which is widely consumed by inhabitants of the city.

MATERIALS AND METHODS

Study Area: The Ikpoba River flows through Benin City, Edo State, Nigeria and lies within Latitude 6.5°N and Longitude 5.8°E. The river is dendrite in the upper reaches and its head waters originate from the Ishan Plateau. The river was impounded in 1977, forming the Ikpoba Dam. The dam is situated some 3.75km South-East of the University of Benin. The dam at full capacity is 3.25km long and 0.6km wide with a mean crest level of 36.8 metres. The storage capacity of the dam is l.5 million m^3. Some activities in the area include fishing, farming, cattle grazing, fetching of water and car washing. There is a sand excavation site within the catchment area. The study area is surrounded by arable farm land. Samples of water, fish and sediments were collected from the Okhoro site and the low lift pump station site of the dam in January, March, July and September 2007. The study area is about 1.2km in length within the dam.

Sampling and Analysis

Water: Duplicate water samples were collected at random in one litre plastic bottles with screw caps at 30cm depth. The water samples were fixed with 5ml of concentrated nitric acid and transported to the laboratory within 24 hours in an ice chest. In the laboratory, the samples were stored at -5°C in a Sonoko deep freezer (Ademoroti, 1996).

Bioindicators: The fish samples were captured using baited hooks and set gill nets while operating from a dug-out canoe. The fish were washed in flowing water to remove adhering debris and transported to the laboratory within 24 hours in an ice chest. In the laboratory, the samples were stored at -5°C prior to further analysis.

Sediment: Duplicate sediment samples were collected using an Eckman grab apparatus. Samples were placed in black polythene bags that had previously been soaked overnight in 5% nitric acid and rinsed with distilled water. Samples were thereafter transported to the laboratory within 24 hours in an ice chest. In the laboratory, the samples were stored at -5°C.

Analyses: On the day of analyses, all frozen samples were allowed to thaw at room temperature (28°C). The water samples were vigorously shaken and aspirated into the flames of a Varian Techtron Spectra B atomic absorption spectrophotometer for trace metal determination (APHA, 1989). The fish samples after defrosting were identified (Idodo-Umeh, 2002), dissected to separate the muscle, liver and gills. All sampled sections of the fish was oven dried to constant weight at 105 ± 2°C and then ground to powder. One gram of ground fish each section sampled was digested using a 1:5:1 ratio mixture of 70% perchloric acid, concentrated nitric acid and concentrated tetraoxosulphate (VI) acid at 80 ± 5°C until colourless solutions were obtained (Streedevi *et al.,* 1992). The final volume was made up to 20ml with deionised water. The sediment samples were oven dried to constant weight at 105 ± 2°C, ground to powder and sieved through a 200 mm grid mesh to remove ungrounded materials. One gram of each ground sample was digested using a 1:5:1 ratio mixture of 70% perchloric acid, concentrated nitric acid and concentrated tetraoxosulphate (VI) acid (Streedevi *et al.,* 1992). Blank solutions were handled as detailed for the samples. Digested fish and sediment samples were analysed read using a Varian Techtron Spectra B atomic absorption spectrophotometer. The concentration of trace metals in water were expressed in mg/l while the trace metal concentrations in fish and sediment were expressed in mg/kg. Statistically, all data were presented as means of triplicate determinations.

RESULTS

The concentration of Zn in water ranged from 0.07 - 0.96 mg/I while the concentration of Pb in water ranged from 0.05 - 0.08 mg/l. The concentration of Cd in sediments ranged from 0.46 - 0.75 mg/kg while the concentration of Cu in sediments ranged from 8.14 - 9.25 mg/kg. The trace metal profile in water in descending order was Zn > Pb > Cd > Cr > Cu, while the trace metal profile in sediments was Zn > Cu > Pb > Cd > Cr (Table 1). The highest concentration of Zn recorded in whole fish was 14.95 mg/kg while to lowest concentration of zinc was recorded in the gills with a value of 10.52 mg/kg. Generally, the concentration of Zn in descending order was liver > muscle > whole fish> gills. The highest concentration of Cd was recorded in the liver with a value of 25.42 mg/kg, while the lowest concentration of the metal was recorded in the muscle with a value of 0.14 mg/kg. The concentration profile of Cd in descending order was liver > whole fish > gills > muscle (Table 2). The highest concentration of Cr recorded in the gills was 2.66mg/kg while the lowest concentration recorded in the liver was 10.13 mg/g. The Cr profile in descending order was liver> whole fish > muscle > gills (Table 2). The highest concentration of Pb recorded in the liver 9.86mg/kg, while the lowest concentration recorded in whole fish was 3.76 mg/kg. The Pb profile in descending order was liver > gills > whole fish > muscle (Table 2).

The highest concentration of Cu recorded in the whole fish was 12.98 mg/kg while the lowest concentration recorded in the muscle was 14.45 mg/kg. The Cu profile in descending order was muscle > whole fish > liver > gills (Table 2). The distribution co-efficient (DC) values for trace metals in the Ikpoba River Dam expressed the solubility of trace metals in aquatic systems. The highest DC value of 0.069 was computed for Cd, closely followed by a value of 0.068 recorded for Cr. The Lowest DC value of 0.003 was computed for Cu (Table 3). Comparison of trace metal concentrations in water with some other studies indicated that the dam water had save levels of Zn, Pb, Cd, Cr and Cu (Table 4). The comparison of trace metal concentrations in the fish with some other fishes from earlier studies indicated that the trace metal concentrations in *Crysichthys nigrodigitatus* from the Ikpoba River Dam were higher than recommended limits (Table 5). Similarly, trace metals concentration in the sediment from the Ikpoba River Dam were higher than recommended limits (Table 6).

DISCUSSION

Aquatic biota including fish absorb and accumulate trace metals from water and the levels of metals accumulated vary from organ to organ (Gerhadt, 1992), Fish can regulate metal concentrations to a certain extent, where after bioaccumulation will occur (Heath, 1991). According to Kotze (1997), the ability of each tissue to either regulate or accumulate metals can be directly related to the total amount of metal accumulated in that specific tissue, furthermore physiological differences and the position of each tissue in the fish can also influence the bioaccumulation of a particular metal. In this study, Zn, Cd, Cr, Pb and Cu were detected in all the fish tissues analysed. Zn, Cd, Cr and Pb, had the highest concentration in the

Table 1: Mean concentrations of trace metals in water and sediment, from the ikpoba River Dam

Survey Period	Sample	Zn	Cd	Cr	Pb	Cu
January 2007	Water (mg/l)	0.96	0.05	0.02	0.06	0.02
	Sediment (mg/kg)	11.02	0.49	0.53	1.92	9.25
March 2007	Water (mg/l)	0.07	0.03	0.10	0.05	0.01
	sediment(mg/kg)	10.19	0.46	0.56	1.72	8.98
July 2007	Water (mg/l)	0.62	0.06	0.06	0.06	0.03
	Sediment (mg/kg)	13.14	0.75	0.36	2.42	8.52
September 2007	Water (mg/l)	0.45	0.04	0.03	0.08	0.04
	Sediment (mg/kg)	15.25	0.64	0.33	3.15	8.14

Table 2: Mean concentration of trace metals in the tissues of *Crysichthys nigrodigitatus* from the Ikpoba River Dam

Survey Period	Whole fish	Muscle	Liver	Gills
		Zinc (mg/kg)		
January 2007	14.28	14.05	25.05	14.19
March 2007	14.95	15.18	11.54	11.75
July 2007	13.25	16.33	20.92	10.52
September 2007	13.07	19.23	22.50	12.25
		Cadmium (mg/kg)		
January 2007	0.50	0.20	15.45	0.14
March 2007	0.34	0.21	20.13	0.25
July 2007	0.16	0.19	21.23	0.15
September 2007	0.09	0.14	25.42	0.28
		Chromium (mg/kg)		
January 2007	2.94	3.98	11.25	2.66
March 2007	0.45	1.06	11.04	1.75
July 2007	4.75	3.97	10.13	1.84
September 2007	4.77	2.85	12.23	1.51
		Lead (mg/kg)		
January 2007	5.24	4.27	4.35	4.48
March 2007	3.76	3.65	6.46	3.75
July 2007	4.15	4.52	7.49	2.35
September 2007	5.44	5.47	9.86	8.44
		Copper (mg/kg)		
January 2007	12.15	15.53	5.62	4.02
March 2007	11.56	14.45	7.45	6.28
July 2007	12.98	15.57	6.32	2.65
September 2007	9.66	16.44	4.65	9.18

Table 3: The distribution co-efficient values for trace metals from the Ikpoba River Dam

Trace metal	Mean level in water	Mean level in sediment	DC value
Zn	0.53	12.40	0.043
Cd	0.04	0.58	0.069
Cr	0.03	0.44	0.068
Pb	0.06	2.30	0.026
Cu	0.025	8.72	0.003

(After Booth, 1976)

Table 4: Comparison of trace metal concentrations in water of Ikpoba River Dam with some other studies

Water Body	Zn	Cd	Cr	Pb	Cu	Reference
Ikpoba River Dam	0.53	0.04	0.03	0.06	0.025	This study
Alaro River	ND	0.004	0.003	0.023	0.0025	Fakayode (2005)
Lower Ikpoba River	0.127	ND	0.059	0.082	0.129	Oguzie (2003)
Delimi River	8.5-18.0	1.5-2.1	ND	0.8-1.25	2.6-3.8	Njoku and Keke (2003)
Buguma Creek	0.010-0.43	0.01-0.11	0.01-1.49	0.01-0.61	ND	Ogbeibu and Oribhabor (2009)
Warri River	0.0-0.63	0.0-0.05	0.0-0.06	0.0-0.001	0.0-0.26	Okaka and Wogu (2011)
WHO Limit	5.0	0.05	0.05	0.05	1.0	WHO (1984)

ND = Not determined

Table 5: Comparison of trace metal concentrations (mg/kg) in fish with some other studies

Water body /fish species	Zn	Cd	Cr	Pb	Cr	Reference
Ikpoba River Dam *(Crysichthys nigrodigitatus*)	Whole fish: 13.88 Muscle: 16.41 Liver: 20.00 Gills: 12:18	Whole fish: 0.27 Muscle: 0.19 Liver: 20.55 Gills: 0.21	Whole fish: 3.22 Muscle: 2.97 Liver: 11.16 Gills: 1.94	Whole fish: 4.64 Muscle: 4.47 Liver: 7.04 Gills: 4.76	Whole fish: 11.59 Muscle: 15.49 Liver: 6.01 Gills: 5.53	This study
Ikpoba River (*Clarias gariepinus*)	Whole fish: 6.22 Muscle: ND Liver: ND Gills: ND	Whole fish: ND Muscle: ND Liver: ND Gills: ND	Whole fish: 0.88 Muscle: ND Liver: ND Gills: ND	Whole fish: 2.22 Muscle: ND Liver: ND Gills: ND	Whole fish: 4.93 Muscle: ND Liver: ND Gills: ND	Obasohan *et al.* (2007)
Ogba River (*Erpetoichthys calabaricus)*	Whole fish: 6.26 Muscle: ND Liver: ND Gills: ND	Whole fish: 0.14 Muscle: ND Liver: ND Gills: ND	Whole fish: 4.79 Muscle: ND Liver: ND Gills: ND	Whole fish: 0.95 Muscle: ND Liver: ND Gills: ND	Whole fish: 4.79 Muscle: ND Liver: ND Gills: ND	Obasohan *et al.* (2005)
Okumeshi River (*Tilapia nilotica*)	Whole fish: ND Muscle: ND Liver: ND Gills: ND	Whole fish: ND Muscle: 0.62 Liver: 0.31 Gill: 0.21 Bone: 0.04	Whole fish: ND Muscle: 0.06 Liver: 0.17 Gill: 0.06 Bone: 0.04	Whole fish: ND Muscle: <0.01 Liver: 0.01 Gill: <0.01 Bone: <0.01	Whole fish: ND Muscle: ND Liver: ND Gills: ND	Ekeanyanwu *et al.* (2011)
WHO Limit	10-75	2.0	0.15	2.0	30	WHO (1994)

Table 6: Comparison of trace metal concentration (mg/kg) in sediment with some other studies

Water body	Zn	Cd	Cr	Pb	Cr	Reference
Ogba River	12.40	0.58	0.44	2.30	8.72	This study
Ikpoba Reservoir	28.48	ND	0.60	8.88	21.50	Fufeyin, 1998
Ikpoba River	1.475-1.663	ND	0.024-0.033	0.660-12.98	0.283-4.755	Obasohan *et al.* 2007
Madivala lake	ND	1.52-5.42	0.75-2.455	1.10-7.9	ND	Begum *et al.* 2009
Unpolluted sediment for African inland waters	0.095	0.011	ND	0.019	0.033	GESAMP 1982

liver, with mean concentration values of 20.00 mg/kg, 20.56 mg/kg, 11.16 mg/kg and 7.04 mg/kg, respectively. This observation was in agreement with Kotze *et al.* (1999) and Nussey *et al.* (2000) who indicated that the liver is associated with storage and detoxification functions. The highest concentration of Cu, was recorded in the muscle tissue, with a mean concentration of 15.49 mg/kg. According to Seymore *et al.* (1996), Cu and Zn accumulate mainly in the muscle, kidney, heart, liver, bone, skin and gills of fish. Furthermore, fish in an ecosystem contaminated by trace metals are known to accumulate significantly more metals in edible muscle tissues than do fish in an uncontaminated ecosystem (Du Preez *et al.,* 1993). With regard to health risk to man, the concentration of Zn in the tissue of *Crysichthys nigrodigitatus,* fell below the World Health Organisation (WHO) maximum allowable limit of 10 – 75 mg/kg for food and fish. The concentration of Cu in the fish tissues were also below the WHO limit of 30 mg/kg for food and fish. Zn and Cu may therefore not pose immediate health hazard to man The Cr concentrations in the fish tissues exceeded the WHO limits of 0.15 mg/g. The concentration of Cd in the fish tissues were generally below the WHO limit of 2.0 mg/g. The only exception was in the liver, with a mean value of 20.56 mg/kg and this could be attributable to the fact that Cd had the highest distribution co-efficient value of 0.069 compared to the other trace metals investigated. The presence of Cr, Cd and Pb at low concentrations, inhibit photosynthesis and phytoplankton growth (Florence and Stauber, 1986). At higher concentrations of these elements, delayed embryo development, tissue damage, reduced growth and fish kill have been reported (Siem *et al.,* 1984; Oronsaye, 2001). The Zn, Cd, Cr and Cu concentrations in water did not exceed the WHO maximum allowable limits for drinking water. The only exception was Pb (mean value of 0.06 mg/l) which was above the 0.05 mg/l WHO limit. The mean concentrations of the investigated metals in sediment were all above the benchmark for unpolluted sediment for African inland waters. In the sediments, Zn had the highest concentration of 12.40 mg/kg. This value was exceeded by values for Zn from the sediments of the Lagos Lagoon (Okoye, 1991) and the Ikpoba reservoir (Fufeyin, 1994), with values at 147 mg/kg and 193.08mg/kg respectively. It has been reported that sediments are sinks for both inorganic and organic pollutants and are thus a potential source of toxicity to aquatic biota (Fernandes, 1997; Long *et al.,* 1998).

Conclusion: This study has revealed that Zn, Cd, Cr, Pb and Cu were present in the tissues of the fish, *Crysichthys nigrodigitatus,* water and sediment of the Ikpoba River Dam. In other to produce sufficient information to implement better management strategies which would alleviate negative impacts, there is the need for regulatory agencies and other concerned parties to further monitor the Ikpoba River Dam. This study is considered to be a part of such monitoring efforts and will contribute to the data base regarding heavy metal pollution in the Ikpoba River Dam.

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