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Full Length Research Paper

Heavy metals concentrations in the offal, gill, muscle and liver of a freshwater mudfish (*Parachanna obscura*) from Ogba River, Benin city, Nigeria

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This study assessed and monitored the concentrations of Cu, Mn, Zn, Cd, Cr, Ni and Pb in the gills, offal, muscle and liver of a commercially important mudfish (*Parachanna obscura*) from Ogba River, Benin City, Nigeria between January and December, 2005. The same metals were also determined in the water of the river. The results revealed that the concentrations of all the metals in the tissues (offal, gills, muscle and liver) were higher than the concentrations of the metals in water and indicated bioaccumulation. The concentrations of all the metals in water were below WHO and FEPA recommended limits and suggested that the water of Ogba River was suitable for drinking, but the concentrations of Cu, Mn, Cr, Ni and Pb in all fish tissues exceeded these limits and indicated that the fishes of Ogba River, as far as these metals were concerned, were unfit for human consumption. Consequently, close monitoring of metals pollution and the consumption of the fishes of Ogba River is recommended with a view to minimizing the risks to health of the population that depend on the river for their water and fish supply.

Key words: Heavy metals, water, fish, Ogba River, Nigeria.

INTRODUCTION

The accumulation of toxic metals to hazardous levels in aquatic biota has become a problem of increasing concern (Dean et al., 1972; GESAMP, 1982; Manahann, 1994; Idodo–Umeh, 2002). Excessive pollution of surface waters could lead to health hazards in man, either through drinking of water and/or consumption of fish (Mathis and Cummings, 1973). The increasing importance of fish as a source of protein and the interest in understanding the accumulation of heavy metals at the trophic levels of the food chain, extend the focus towards finfish (Greig et al., 1978; Deb and Santra, 1997; Obasohan and Oronsaye, 2004). Pollution enters fish through five main routes: via food or non-food particles, gills, oral consumption of water and the skin. On absorption, the pollutant is carried in blood stream to either a storage point or to the liver for transformation and/or storage. Pollutants transformed in the liver may be stored there or excreted in bile or transported to other excretory organs such as gills or kidneys for elimination or stored in fat, which is an extra hepatic tissue (Heath, 1999; Nussey et al., 2000). The concentration of any pollutant in any given tissue therefore depends on its rate of absorption and the dynamic processes associated with its elimination by the fish.

The use of fish as bio-indicators of metal pollution of aquatic environments and suitability for human use from toxicological view point has been documented (Uthe and Bligh, 1971; Deb and Santra, 1997). Fish has also been extensively used in the study of physiological behavior of heavy metals in body organs (Suzuki et al., 1973; Goldberg, 1976; Oronsaye, 1989). Adeyeye et al. (1996) showed that the concentration of metals was a function of species and accumulate more in some fish tissues than in others.

Much has been documented about the sources, occurrence and toxicity of heavy metals (Kurland et al., 1960; Biney et al., 1991; Oronsaye and Ogunbor, 1998). Preliminary investigations in Ogba River revealed that the water, sediment and fishes (including shellfish) were contaminated with heavy metals (Kolade, 1998; Obasohan and Oronsaye, 2000; Wangboje and Oronsaye, 2001). Most of these studies were carried out using whole-fish samples without characterization of the metals in the tissues and organs. The objective of this study was to

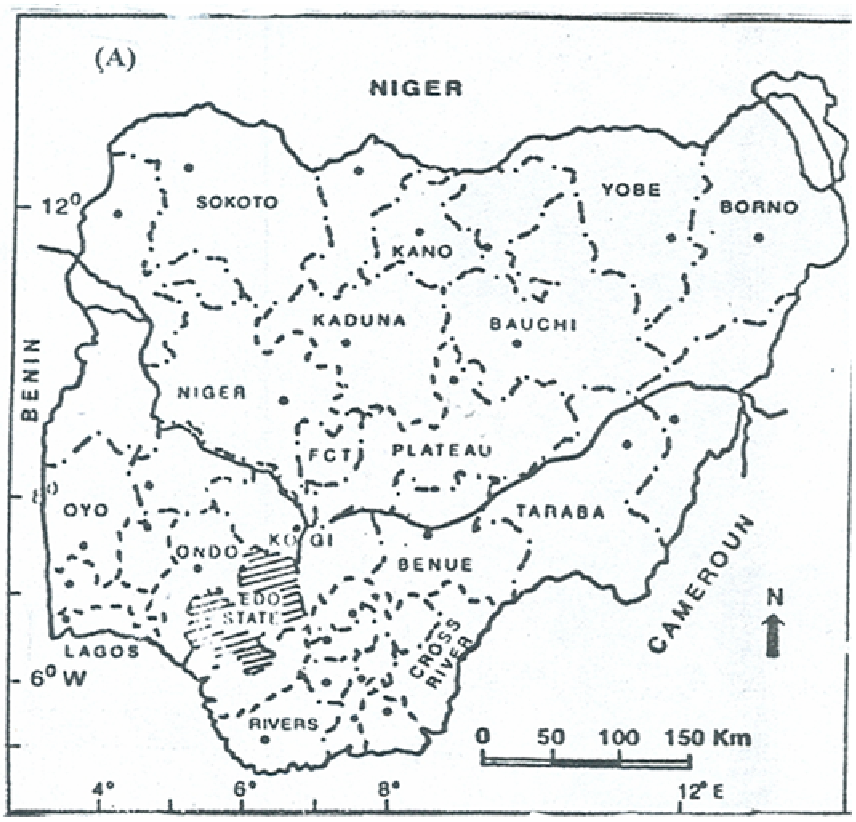

Figure 1a. Map of Nigeria showing position of Edo state.

determine the heavy metal accumulation levels in the water and tissues (gills, offal, muscle and liver) of a freshwater mudfish (***Parachanna obscura***) of the river, with a view to determining the pollution levels and ascertain the suitability of the water and fish for human consumption. The choice of fish (***P. obscura***) was based on its importance in the fisheries of the area for both food and economic purposes.

MATERIALS AND METHODS

Study Area

This investigation was carried out in Ogba River, a perennial rainforest river in Benin City, Edo State, Nigeria (latitude 6.5°N and longitude 5.8°E). The river takes its source from a spring in the south west part of the city and flows in a north-south direction before emptying into Benin River further south. The study area of the river is a 4.0 km stretch, beginning from the river source (Figure 1). In the area, the secondary rain forest has been subjected to extensive clearing and farming activities. Crops grown were mainly Cassava, Yams and Maize. Other agricultural activity in the area includes rubber (***Havea braziliensis***) and Oil palm (***Eleasis guinesis***) plantations, poultry, piggery, fish farming, wood treatment and rubber processing. A large underground drainage channel fed by the Benin City drainage system, introduces large volume of sewage into the river in the area.

The marginal vegetation was composed of ***Commelina ipomea, Emilia*** and ***Sonchifolia*** species (Kolade, 1998). The climate is typically tropical, with wet and dry seasons primarily regulated by rainfall. Annual temperatures ranged between 22 and 31°C, while humidity ranged between 69 and 96%.

Sample collection

For this study, two stations were established within a 4.0 km stretch of the upper reaches of the river (Figure 1c). Station 1 was established at about 500 m from the river source. The river at this point, has visible unidirectional flow, about 0.3 m deep and 1.5 m wide. It was shaded with fringing vegetation of mainly shrubs like ***Commelina*** and ***Sonchifolia spp***. The sediment was mainly coarse sand and granite. Human activities were limited to occasional swimming and traditional idol worshipping. The water at this point was relatively unpolluted. Station 2 was downstream at about 3.0 km from Station 1. The water at this point was about 5 m wide and 2 m deep, with no visible directional flow. The sediment was mainly sharp sand. The station was subjected to the influence of drainage effluents (sewage and runoffs from the surrounding agricultural fields). Station 2 was also a point source of effluents from a rubber processing factory, human activities which included sand excavation, bathing, laundering. Fishing and idol worshipping were also intense at the station.

The sample materials analyzed were water and fish (***P***. ***obscura***). Sampling was carried out monthly between January and December, 2005. On each occasion, samples were collected in three replicate spots at each station and the mean values recorded. Water samples were collected at 30 cm depth in 250 ml plastic bottles previously cleaned with detergent and soaked overnight in 5% nitric acid. All samples were stored frozen at -10°C. The fish samples were caught with set nets of various sizes, baited hooks and traps.

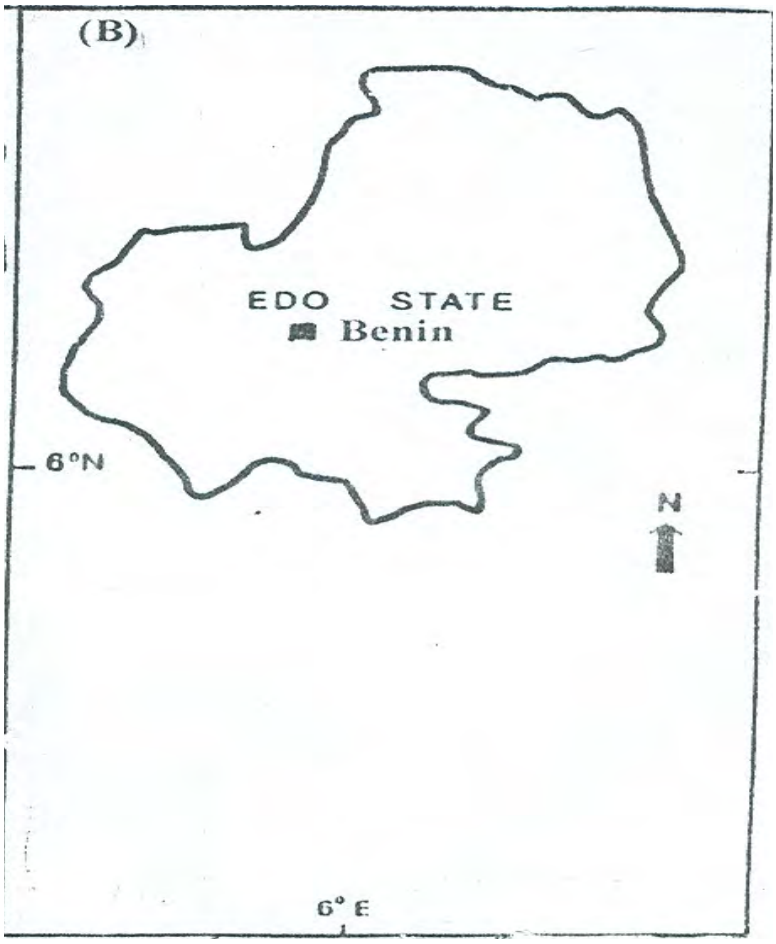

Figure 1b. Edo state showing position of Benin City.

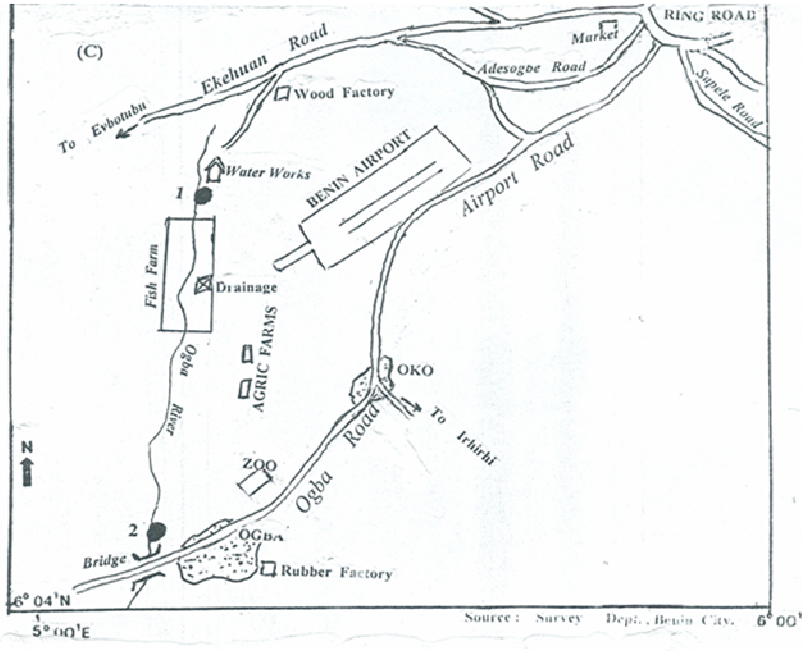

Figure 1c. Benin City showing Ogba River and study stations.

Table 1. Monthly mean variations of heavy metals in Ogba River (mg/kg).

Station 1							
Metal	**Cu**	**Mn**	**Zn**	**Cd**	**Cr**	**Ni**	**Pb**
January	0.007	0.002	0.001	0.003	0.001	0.001	0.002
February	0.006	ND	0.002	0.001	0.001	0.002	0.001
March	0.004	ND	0.002	ND	ND	0.001	0.001
April	0.001	ND	0.004	ND	ND	0.001	ND
May	0.001	0.001	0.003	0.003	0.001	0.004	ND
June	0.006	0.001	0.002	ND	0.001	0.002	ND
July	0.009	0.002	0.001	0.002	0.002	0.002	0.001
August	0.007	0.002	0.002	ND	ND	0.001	ND
September	0.009	0.001	0.002	0.001	0.001	0.001	0.001
October	0.009	0.002	0.004	0.001	0.001	0.001	0.002
November	0.004	0.001	0.003	0.002	0.001	0.001	0.001
December	0.006	0.001	0.004	0.001	0.007	0.002	0.001
Mean	**0.007**	**0.001**	**0.003**	**0.002**	**0.001**	**0.002**	**0.001**
Station 2							
Metal	**Cu**	**Mn**	**Zn**	**Cd**	**Cr**	**Ni**	**Pb**
January	0.002	0.007	0.089	0.001	0.003	0.012	0.005
February	0.001	0.004	0.093	0.002	0.001	0.013	0.004
March	0.002	0.003	0.076	0.003	0.003	0.009	0.002
April	0.001	0.003	0.082	0.001	0.002	0.012	0.003
May	0.002	0.004	0.090	0.002	0.002	0.013	0.004
June	0.002	0.002	0.086	0.002	0.001	0.014	0.002
July	0.001	0.003	0.079	0.001	0.002	0.009	0.004
August	0.001	0.004	0.086	0.002	0.002	0.009	0.003
September	0.002	0.005	0.089	0.003	0.002	0.014	0.004
October	0.003	0.005	0.091	0.003	0.002	0.014	0.005
November	0.003	0.006	0.094	0.002	0.001	0.010	0.003
December	0.003	0.006	0.092	0.002	0.003	0.009	0.002
Mean	**0.002**	**0.004**	**0.086**	**0.002**	**0.002**	**0.012**	**0.004**

They were placed in plastic bags and were stored frozen at -10^{o}C after cleaning with distilled water to remove adhering dirt (Ademoroti, 1996).

Sample treatment

All frozen samples were allowed to thaw at room temperature (27 ± 2^{o}C). Water samples were mixed vigorously and aspirated in an Atomic Absorption Spectrophotometer (Vivian Techtron Spetra B) for trace metal determination (APHA, 1989).

The fish samples after defrosting were dissected into offal, gills, muscle and liver. After dissection, all the tissue samples were separately oven-dried to constant weight at 105 ± 20^{o}C and were each ground to powder. The powdered samples were digested according to Sreedevi et al. (1992). 1 g of each sample was digested using 1.5.1 mixture of 70% perchloric acid, concentrated nitric acid and concentrated sulphuric acid at 80 ± 5^{o}C in a fume chamber, until colorless liquid was obtained. Each digested sample was made up to 20 ml with de-ionized water and analyzed for heavy metals in a Varian Techtron Spectra B Atomic Absorption Spectrophotometer (APHA, 1989). Values of heavy metals were recorded in mg/kg.

Tests of significance between the stations were carried out using the Student t-test, while the CRD statistical model was used for the analysis of the fish tissues.

RESULTS

The monthly mean concentrations of the heavy metals (Cu, Mn, Zn, Cd, Cr, Ni and Pb) in water at the sample stations are presented in Table 1, while the annual variations in concentrations of the metals in offal, gills, muscle and liver samples are in Table 2. In Tables 3 and 4, metal levels in water and fish are compared with WHO and FEPA recommended limits and levels in some fishes of other water bodies.

The monthly concentrations of Cu in water ranged between 0.001 and 0.009 mg/l at Station 1, while at Station 2, the values ranged between 0.001 and 0.003 mg/l. Mn values ranged from ND (Non Detectable) level to 0.002 mg/l at Station 1, while at Station 2, the values were between 0.002 and 0.007 mg/l. The corresponding ranges for the other metals were Zn (0.001 - 0.004 mg/l) at Station 1 and (0.07 - 0.094 mg/l) at Station 2; Cd (ND -

Table 2. Annual variations in the concentrations of heavy metals in the offal, gills, muscle and liver of fish (***P. obscura***) from Ogba River (concentration in mg/kg).

Fish	Station	Heavy metals	Offal	Gills	Muscle	Liver
P. obscura	1	Cu	7.42	6.18	18.04	10.54
		Mn	2.71	0.67	0.94	1.44
		Zn	12.32	11.34	15.16	12.94
		Cd	0.13	0.17	0.11	0.14
		Cr	2.01	0.40	1.02	1.14
		Ni	0.29	0.07	0.28	0.22
		Pb	5.00	3.33	2.67	3.67
	2	Cu	5.68	4.01	14.53	19.71
		Mn	3.48	0.70	3.50	1.32
		Zn	10.18	13.19	14.93	15.28
		Cd	0.05	0.19	0.10	0.19
		Cr	5.61	2.64	3.96	2.97
		Ni	0.28	0.21	0.86	0.10
		Pb	7.33	4.00	4.00	4.00

Table 3. Comparison of mean metal levels in water of Ogba River with those of some other water bodies (conc. in mg/l).

Water body		Cu	Mn	Zn	Cd	Cr	Ni	Pb	Reference
Ogba River	Station 1	0.006	0.001	0.003	0.002	0.001	0.002	0.001	This study
	Station 2	0.002	0.004	0.086	0.002	0.002	0.012	0.004	
Ikpoba River		0.147	0.417	0.316	0.214	0.108	0.244	0.095	Oguzie, 2003
River Niger		-	0.035	-	0.112	-	-	0.050	Okoronkwo,1992
Olomoro water bodies		0.07	0.07	2.01	0.098	0.007	0.040	0.039	Idodo-Umeh, 2002
WHO (1985)		1.0	0.01	5.0	0.05	0.05	0.05	0.05	
FEPA (2003)		< 1.0	0.05	20	< 1.0	< 1.0	< 1.0	< 1.0	

0.003 mg/l) at Station 1 and (0.001 - 0.003 mg/l) at Station 2; Cr (ND - 0.007 mg/l) at Station 1 and (0.001 - 0.003 mg/l) at Station 2; Ni (0.001 - 002 mg/l) at Station 1 and (0.009 - 0.014 mg/l) at Station 2 and Pb (ND - 0.002 mg/l) at Station 1 and (0.002 - 0.005 mg/l) at Station 2 respectively (Table 1). Analysis of variance (ANOVA) of metals levels, showed no significant differences ($P > 0.05$) among the stations, except for Zn and Ni.

In fish tissues, the mean concentrations of the metals were as presented in Table 2. Cu values ranged from 6.18 in gills to 18.04 mg/kg in muscle (Station 1) and from 4.01 in gills to 19.71 mg/kg in liver (Station 2). The ranges for Mn were 0.67 in gills to 2.71 mg/kg in offal (Station 1) and 0.70 in gills to 3.50 mg/kg in muscle at Station 2. The values for the other metals were 11.34 (gills) to 15.16 mg/kg (muscle) at Station 1 and 10.18 (offal) to 15.28 mg/kg (liver) at Station 2 for Zn; 0.11 (muscle) to 0.17 mg/kg (gills) at Station 1 and 0.10 (muscle) to 0.19 mg/kg (liver and gills) at Station 2 for Cd; 0.40 (gills) to 2.01 mg/kg (offal) at Station 1 and 2.64 (gills) to 5.61 mg/kg (offal) at Station 2 for Cr; 0.07 (gills) to 0.29 mg/kg (offal) at Station 1 and 0.10 (liver) to 0.28 mg/kg (muscle) for Ni at Station 2 and 2.67 (muscle) to 5.00 mg/kg (offal) at Station 1 and 4.00 (gills, muscle, liver) to 7.33 mg/kg (offal) at Station 2 for Pb respectively.

Statistical analysis (ANOVA) showed that there were significant differences ($P < 0.05$) between the tissues for all the metals analyzed. Among the stations, there were no significant differences ($P > 0.05$) except Cr and Mn in muscle.

DISCUSSION

The process whereby an organism concentrates metals in its body from the surrounding medium or food, either by absorption or ingestion is known as bioaccumulation (Forstner and Wittman, 1981; Ademoroti, 1996). According to Heath (1991), fish can regulate metal concentration to a certain limit after which bioaccumulation occurs. The concentrations of metals in an organism‘s body, vary from organ to organ and is the product of an equilibrium between the concentration of the metal in an organism’s environment and its rate of ingestion and excretion (Oronsaye, 1987; Gerhardt, 1992; Adeyeye et al., 1996). The ability of each organ or tissue to either regulate or

Table 4. Comparison of mean metal levels in fish from Ogba River with those in fish of some other water bodies (mg/kg).

Water Body	Cu	Mn	Zn	Cd	Cr	Ni	Pb	Reference
Ogba River	4.01 - 19.71	0.67 - 3.50	10.18 - 15.28	0.02 - 0.19	0.40 - 5.61	0.07 - 0.86	2.67 - 7.33	This study
Ikpoba River	0.098 - 0.141	0.016 - 0.043	0.104 - 0.163	1.32 - 1.37	0.13 - 0.22	0.035 - 0.464	0.007 - 0.03	Oguzie, 2003
River Niger	0.23 - 2.43	0.193 - 0.435	-	0.270	-	-	-	Okoronkwo1992
Olomoro water bodies	1.28 - 1.57	2.81 - 4.61	40.06 - 43.7	0.576 - 1.257	0.28 - 0.33	1.64 - 3.58	0.62 - 1.60	Idodo-Umeh, 2002
WHO (1985)	3.0	0.5	10 - 75	2.0	0.15	0.6	2.0	
FEPA (2003)	1-3	0.5	75	2.0	0.15	0.5	2.0	

accumulate metals can be related to the total amount of metal accumulated in the specific organ or tissue. Kotze (1997) reported that physiological differences among tissues influence the bioaccumulation of a particular metal.

The levels of heavy metals recorded in water in this study were generally low, when compared to WHO and FEPA recommended levels in drinking water. In comparison with levels recorded in some other water bodies in the area, the levels in Ogba River where also low. Okoronkwo (1992) recorded higher metal levels in the Niger River, while Idodo-Umeh (2002) and Oguzie (2003) recorded similarly higher levels in Olomoro water bodies and Ikpoba River, Benin City respectively (Table 1). Among the stations, metal levels though generally more elevated at Station 2 than Station 1 (except Cu), the differences were not significant. The high level of Cu at Station 1 could be due to local sources. The low levels in water in comparison to WHO and FEPA recommended limits for drinking water, indicated that the water of Ogba River was suitable for drinking.

In fish, metal levels were significantly higher ($P < 0.05$) than the levels in water, indicating bioaccumulation. Metal levels in fish tissues were generally higher at Station 2 when compared to Station 1. This could be as a result of exposure to higher concentrations of the metals at Station 2. Station 2 was subjected to the influence of sewage and rubber processing effluents, which could have increased metals load to the river at the point.

The concentrations of Cu in the offal, gills, muscle and liver varied from a minimum of 4.01 mg/kg in gills to a maximum of 19.71 mg/kg in liver (Station 2). Cu concentrations profile at Station 1 was gills < offal < liver < muscle, while at Station 2, the profile was gills < offal < muscle < liver. The high levels in liver, was expected in view of its storage and detoxification functions. Cu levels recorded were higher than the 3.0 mg/kg maximum recommended standards in food (WHO, 1985; FEPA, 2003) and indicated that the fish of Ogba River might not be suitable for consumption as far as Cu levels were concerned.

Mn levels (0.67 - 3.48 mg/kg) in fish samples were high when compared to the 0.5 mg/kg WHO (1985) and FEPA (2003) recommended standards. The levels were also high when compared to the 0.193 - 0.435 mg/kg recorded in fish of River Niger (Okoronkwo, 1992) and the 0.016 - 0.043 mg/kg in fish of Ikpoba River (Oguzie, 2003) (Table 4). Mn levels profile in the fish samples were gills < muscle < liver < offal at Station 1 and gills < liver < offal < muscle at Station 2. Mn has been reported to be taken up directly through the gills or indirectly from food and ingested sediments via gut (Bendell-Young and Harvey, 1986). High levels of Mn in offal, recorded in this study, indicated possible uptake in food. This finding was not unexpected because of the bottom feeding habit of the fish.

The range of Zn levels (10.18 - 15.28 mg/kg) recorded in fish in this study was low when compared to Zn levels recorded in some other fishes of the river. Obasohan and Oronsaye (2004) recorded Zn levels of 21.83 mg/kg in ***Hemichromis fasciatus*** and 23.32 mg/kg in ***Oreochromis niloticus*** from the river. The possible explanation for this could be differences in fish species; sizes, ages and sampling periods. Adeyeye et al. (1996) reported that differences in metal concentrations in fish were a function of species, while Idodo-Umeh (2002) reported that bigger fishes tended to accumulate higher concentrations of metals than smaller ones. Zn profile in the tissues was gills < offal < liver < muscle at Station 1, while at Station 2, the profile was offal < gill < muscle < liver. In comparison to the 1000 mg/kg recommended maximum limits in fish (WHO, 1985), the levels recorded in fish samples in this study were low. Consequently, consumption of fish of Ogba River could not pose any Zn induced health hazards.

Cd levels (0.05 - 0.19 mg/kg) recorded in fish samples were low, when compared to WHO (1985) and FEPA (2003) maximum recommended limits of 2.0 mg/kg in fish food. The levels were also low in comparison to the 0.576 - 1.257 mg/kg recorded in fishes of Olomoro water bodies (Idodo-Umeh, 2002) and 0.270 mg/kg reported for fishes of the River Niger (Okoronkwo, 1992). Cd profiles recorded in this study were muscle < offal < liver < gills (Station 1) and offal < muscle < gills = liver (Station 2). The gills and liver showed the greatest accumulation of

Cd. Similar patterns of Cd accumulation have also been reported in similar studies in fish (Allen, 1995). The high levels in the gills showed that the main uptake route was through gills. Cd absorption via gills has been reported by Oronsaye, 1987; Shah and Altindag, 2005. Cd is known to cause damage to fish gills (Oronsaye, 1989). In man, Cd poisoning could lead to anaemia, renal damage, nerve damage, bone disorder (Osteoporosis and Osteomalacia) and lung cancer (Manahann, 1984; Ademoroti, 1996). However, judging from the low levels of Cd recorded in this study, consumption of fish from Ogba River, could not pose any Cd induced health hazards for now.

Cr levels (0.40 - 5.61 mg/kg) were high when compared to WHO and FEPA limits of 0.05 - 0.15 mg/kg in food fish. At both stations, Cr levels were highest in fish offal, suggesting that food was probably the major source of uptake, rather than absorption through gills and skin. It has been reported that enhanced metal levels in fish tissues arise through bio-magnification at each trophic level and carnivorous bottom feeders concentrate higher metal levels (Porter et al., 1975; Forstner and Wittmann, 1981). ***P. obscura*** is a known voracious bottom feeder (Reed et al., 1967) and could thus have bio-accumulated high metal (Cr) levels from the river sediment. In view of the higher levels of Cr, when compared to WHO limits, it could be inferred that consumption of the fish could lead to health hazards in man.

The range of Ni levels (0.07 - 0.86 mg/kg) in the fish tissues recorded in this study was equally high in comparison to WHO and FEPA maximum recommended limits of 0.5 - 0.6 mg/kg. Ni levels recorded were also high when compared to the levels of 0.035 - 0.464 mg/kg recorded for fishes of Ikpoba River (Oguzie, 2003). The levels were however lower than the 1.636 - 3.580 mg/kg recorded by Idodo–Umeh (2002) for fishes of Olomoro Water bodies (Table 4). Ni accumulation profiles were gills < liver < muscle < offal at Station 1 and liver < gills < offal < muscle at Station 2. As explained earlier high Ni levels in offal could be linked to bottom feeding habit of the fish. Arising from the high levels recorded in fish in this study, Ogba River fish were deemed unfit for human consumption.

Pb levels recorded in this study ranged between 2.67 - 7.33 mg/kg. Pb profiles among the tissues were muscle < gills < liver < offal at Station 1 and gills = muscle = liver < offal at Station 2. The high levels of Pb in offal at both stations suggested uptake via gut. The levels were high when compared to the maximum allowable limit of 2.0 mg/kg for food fish, recommended by WHO (1985) and FEPA (2003). Consequently, it could be inferred that consumption of fish could induce health hazards in consumers.

Conclusion

The results of this investigation showed that the water and fish of Ogba River were contaminated by the heavy metals Cu, Mn, Zn, Cd, Cr, Ni and Pb. The results further showed that whereas the water of the river could be considered safe for drinking, the fishes, based on the higher levels of metal bioaccumulation in all fish tissues, could be unsafe for human consumption. The finding is worrisome in view of the health implications for the population that depend on the river for their water and fish requirements. Consequently, very close monitoring of heavy metal loads in Ogba River system is recommended in view of the possible risks to health of consumers.

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