Bioaccumulation of Metals in Selected Aquatic Organisms in Lake Asejire, Nigeria.

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ABSTRACT

This study examined the concentration of Fe, Pb, Co, Ni, Cr, and Cd in water, Nile Tilapia (*Oreochromis niloticus*), and African river prawn (*Macrobrachium vollenhovenii*) samples from Lake Asejire, Nigeria. Fe had the highest mean concentration while the least concentration was recorded for Cr in both the Tilapia and prawn. The toxicity threshold of the metals is within the standard limits except for Fe. There is the need to preserve the lake from pollution in order to ensure that the metal levels do not exceed the regulated standards.

(Keywords: metals, aquatic organisms, Lake Asejire)

INTRODUCTION

Aquatic environments notably rivers and lakes, are considered as sites for disposal of wastes. Some levels of waste degradation take place in these water bodies before the remnants are drained into lagoons, seas and oceans. However, the increasing pollutant load and over-exploitation of the water resources for potable supplies, irrigation, industrial and power generation plants, significantly reduce the assimilative capacities and self-cleansing abilities of many rivers and lakes. Thus, the stress exerted on the water bodies is transferred to the biological communities inhabiting them. Among aquatic species, fishes are the inhabitants that cannot escape from the detrimental effects of heavy metal pollution. This is because of their intimate contact with water that carries the heavy metals in solution or suspension, and also fish have to extract oxygen from water passing over their gills (Muiruri *et al.,* 2013).

The delivery of pollutants in water bodies increases during the rainy season due to flood, run-off water, and atmospheric precipitation. During the dry season, the action of wind becomes more pronounced in the transport of hazardous substances which accumulate in inland water bodies (Oguzie and Okhagbuzo, 2010). The cumulative effects of the pollutants could cause severe physiological disorders, among other problems to aquatic organisms (Odiete, 1999). Fishes, one of the main aquatic organisms in the food chain, often accumulate large amounts of certain metals.

Heavy metals are natural trace components of the aquatic environment, but their levels have increased due to industrial wastes, geochemical structure, agricultural and mining activities (Dirican *et al.*, 2013). Fishes assimilate heavy metals through ingestion of suspended particles, food materials and/or by constant ion-exchange process of dissolved metals across lipophilic membranes, like the gills, or absorption of dissolved metals on tissue and membrane surfaces (Mallampati *et al.,* 2007). High concentration of heavy metals in fish may have direct detrimental effects on the fish or indirectly on those who eats the fish.

As reported by Gborade *et al*. (2015), the effect of heavy metal on fresh water ecosystem has generated global concern. These metals are persistent and once released into the environment, they are present for a prolonged period. The factors which contribute principally to the damaging effect of heavy metals as environmental pollutants are, firstly, their inadequate biological degradation to inert metals and secondly, the trend of metals to accumulate and largely remain in the aquatic environment (Olowu *et al.,* 2010).

Reactions of the metal elements depend on the concentration, physiochemical properties, chemical bonds and their solution on the absorption, accumulation distribution in the body of aquatic organisms (Gharib, 2003). Small amounts of absorbed heavy metals are either stored in a metabolically available form for essential biochemical processes or detoxified into metabolically inert forms and held in the body either temporarily or permanently (Hashmi *et al.,* 2002). Consequently, fish, prawns, and other aquatic organisms in polluted aquatic environments become enriched with the accumulated metal elements and compounds. Predatory fish generally displays higher levels of metal accumulation than their prey. Humans, having consumed such metal-containing fish and prawns, accumulate and inevitably suffer from the results of an enrichment taking place at each tropic level (Mazlin *et al.,* 2009).

In Nigeria, majority of the heavy metals that were previously occurring at very low concentrations in water bodies are now present in high concentrations; creating deleterious effects on aquatic life including fish (Adeyeye, 2000; Asaolu, 2002; Bala *et al*., 2008). According to Olowosegun *et al.* (2005), most of the fishing grounds in Nigeria have been rendered unproductive by oil exploration, dredging of water bodies and dumping of toxic industrial effluents and domestic wastes with highly toxic metals. The release of these pollutants poses significant threats to public health because of their persistence, biomagnification and accumulation in food chain.

Although some metals are essential for animal tissues metabolism, the range between beneficial and toxic levels is very narrow. There is an increasing concern about the health effects in humans due to continuous consumption of foods contaminated with heavy metals (Olowu *et al.,* 2010). Mazlin *et al*. (2009) affirm that fish and prawns are ideal species of aquatic organisms for assessment studies on effects of heavy metal contamination in aquaculture ponds, inland waters and coastal areas. They play an important role in human nutrition and therefore need to be carefully and routinely screened to ensure that there are no high levels of heavy metals being transferred to man through food consumption (Muiruri *et al.* 2013). Therefore, this study examined the bioaccumulation pattern of some heavy metals (Fe, Pb, Co, Ni, Cr, and Cd) in Nile Tilapia (*Oreochromis niloticus*) and African river prawn (*Macrobrachium vollenhovenii*) samples of Lake Asejire.

MATERIALS AND METHODS

The study was conducted on an artificial lake, Lake Asejire, in Southwest Nigeria. The lake lies on 04°07' East and 07°21' North at an altitude of 137 meters above sea level, covering a length of 19.5 km (Ayoade *et al.,* 2007). The lake is made out of River Osun, on which Asejire Dam was situated to provide portable water supply to Ibadan and surrounding cities in Oyo State, southwest Nigeria (Ogunleye, 1982). The lake has other numerous adjoining inflows at different points (Egborge, 1977); with an approximate gross storage of 7,403 million liters of water. Despite identifying twenty-five (25) fish species inhabiting the lake, Ogunleye (1982) describes the lake as Tilapia and Chrysichthys fisheries due to their dominant population.

Samples were collected over a period of 5 months (December 2014 to April 2015) from 3 sampling locations distributed with reference to the point of damming the River. Each sampling location had 4 sampling points from where samples were obtained. Water, Tilapia and African River Prawn samples were collected in the early hours (between 7.00 and 10.00 hours).

Water samples were collected in 2-liter plastic sampling bottles in line with APHA (1992) procedures while the Tilapia and Prawns samples were obtained using cast nets of various mesh sizes and transported to the laboratory under iced condition. Weight ranges of 100-150g and 50-75g were sampled for Tilapia and African river prawn, respectively. These organisms were selected because of their huge socio-economic value and availability as pollution bio-indicators. Also, they were chosen with the consideration of the sensitivity of aquaculture organisms in terms of heavy-metal contamination and accumulation (Agbozu *et al.,* 2007).

Metal concentration in samples of the water and the aquatic organisms were determined using VGP 210/211 model of Buck Scientific Atomic Absorption Spectrophotometer. Oven-drying of Tilapia and prawn samples was done to constant weight at 105^oC, prior to grinding into powdery form, digestion and determination of metal content. The data were subjected to both descriptive and inferential analysis using SAS statistical package.

RESULTS

The mean concentration of the metals in the water, fish and prawn samples are presented in Tables 1, 2, and 3. Table 1 shows the monthly mean concentration of metals in the water samples. Only Fe and Pb were found in detectable quantities in the first 2 months.

As shown in Table 2, the metals had varying concentrations throughout the study period. All the metals were present except for cobalt (Co) and chromium (Cr) which were not detected in the fish samples obtained during the later period of the study. Iron (Fe) had the highest mean concentration while chromium recorded the least concentration.

For each of the metals, the mean concentration showed varying significant differences across the period of study (months). There were significant differences ($P<0.05$) in mean concentration of iron (Fe) across all the months of the study period. A similar significance ($P<0.05$) was recorded in lead (Pb) except for March which showed no significant difference with all other months. Mean concentration of cobalt (Co) showed significant differences ($P<0.05$) among the 3 months wherein the metal was present in detectable quantities.

Nickel (Ni) showed no significant difference among all the months except for January ($P<0.05$); chromium (Cr) showed no significant difference except for December ($P<0.05$) while January and April showed significant differences ($P<0.05$) from other months.

Mean concentration of metals in the prawn sample are presented in Table 3. Like in Tilapia, African River prawn had varying concentrations of the metals with the highest being iron (Fe) while the least is chromium (Cr). All the metals showed varying concentrations during the months of study except for cobalt (Co) which had non-detectable concentrations in March and April.

There were no significant differences between iron (Fe) concentration observed in January and February, and March and April. Similarly, lead (Pb) concentration in December and April had significant differences ($P<0.05$) while other months showed no significant differences among each other. Mean concentrations of cobalt (Co) displayed no significant differences across the months. Nickel (Ni) concentrations in December and January were significantly different from other months. Chromium (Cr) displayed no significant differences between December and February; and among January, March and April. Cadmium (Cd) concentration recorded in December was significantly different ($P<0.05$) from other months except April.

Table 1: Mean Concentration (mg/l) of Metals in Water Samples.

Month	Iron (Fe)	Lead (Pb)	Cobalt (Co)	Nickel (Ni)	Chromium (Cr)	Cadmium (Cd)
Dec.	0.033±0.057	0.057±0.098	Nd	Nd	Nd	Nd
Jan.	Nd	0.018±0.044	Nd	Nd	Nd	Nd
Feb.	Nd	Nd	Nd	Nd	Nd	Nd
Mar.	Nd	Nd	Nd	Nd	Nd	Nd
April	Nd	Nd	Nd	Nd	Nd	Nd

Data are expressed as mean ± standard deviation (n = 5). Nd = Not detected

Table 2: Mean Concentration (mg/kg) of Metals in Fish Samples.

Month	Iron (Fe)	Lead (Pb)	Cobalt (Co)	Nickel (Ni)	Chromium (Cr)	Cadmium (Cd)
Dec.	7.300^{c}±0.100	0.063^{a}±0.006	0.010^{b}±0.000	0.023^{a}±0.006	0.017^{a}±0.006	0.060^{b}±0.010
Jan.	6.680^{d}±0.072	0.060^{a}±0.010	0.001^{c}±0.000	0.002^{b}±0.001	0.001^{b}±0.0001	0.040^{c}±0.000
Feb.	5.960^{e}±0.140	0.047^{b}±0.006	0.017^{a}±0.006	0.017^{a}±0.006	0.001^{b}±0.000	0.060^{b}±0.000
Mar.	8.400^{b}±0.200	0.053^{ab}±0.006	Nd	0.023^{a}±0.006	Nd	0.073^{b}±0.012
April	8.817^{a}±0.375	0.043^{b}±0.006	Nd	0.013^{a}±0.006	Nd	0.087^{a}±0.006
	7.431±1.184	**0.053±0.008**	**0.006±0.008**	**0.016±0.009**	**0.004±0.007**	**0.064±0.017**

Data are expressed as mean ± standard deviation (n = 5). Nd = Not detected
Means with the same superscript along the vertical row are not significantly different ($P<0.05$).

Table 3: Mean Concentration (mg/kg) of Metals in Prawn Samples.

Month	Iron (Fe)	Lead (Pb)	Cobalt (Co)	Nickel (Ni)	Chromium (Cr)	Cadmium (Cd)
Dec.	$1.753^{a}\pm0.070$	$0.120^{a}\pm0.010$	$0.007^{a}\pm0.006$	$0.027^{a}\pm0.006$	$0.002^{a}\pm0.001$	$0.060^{a}\pm0.000$
Jan.	$1.553^{b}\pm0.075$	$0.117^{ab}\pm0.025$	$0.010^{a}\pm0.010$	$0.030^{a}\pm0.000$	$0.0003^{b}\pm0.001$	$0.033^{c}\pm0.006$
Feb.	$1.487^{b}\pm0.057$	$0.097^{ab}\pm0.006$	$0.010^{a}\pm0.000$	$0.017^{b}\pm0.006$	$0.002^{a}\pm0.000$	$0.033^{c}\pm0.006$
Mar.	$1.637^{ab}\pm0.091$	$0.097^{ab}\pm0.015$	Nd	$0.010^{b}\pm0.000$	$0.0003^{b}\pm0.001$	$0.047^{b}\pm0.006$
April	$1.620^{ab}\pm0.090$	$0.087^{b}\pm0.015$	Nd	$0.010^{b}\pm0.000$	$0.0003^{b}\pm0.001$	$0.050^{ab}\pm0.010$
	1.610±0.010	**0.104±0.014**	**0.005±0.001**	**0.019±0.009**	**0.001±0.001**	**0.045±0.002**

Data are expressed as mean ± standard deviation (n = 5). Nd = Not detected
Means with the same superscript along the vertical row are not significantly different (P<0.05).

DISCUSSION

Water samples obtained from the lake showed that only iron (Fe) and lead (Pb) were present in detectable amounts. Lack of detection does not totally imply that other metals were not present in the water; however, their concentration may be so low that they were not detected spectrophotometrically.

The presence of Fe and Pb can be traced to the agrochemicals used by farmers in crop farms adjacent to the lake. The mechanism of Pb accumulation in water is likely to be through adsorption and complexing of free Pb ions (Denny and Welsh, 1979). Fe and Pb compounds transported during rainfall and erosion especially from household sources, where domestic wastes are deposited along the courses of the water body, may have also contributed to the presence of these metals in the water column. Reports obtained from the fishermen and the members of staff of Asejire Water Processing Unit corroborated disposal of household wastes along the courses of the water body, as evident especially during the rainy season. The contribution of metallic rusts and chemical degradation of abandoned machine parts, metallic pipes and equipment cannot be overlooked, as various damaged machines and equipment were found littering the lake vicinity.

The dissimilarity in iron (Fe) concentration observed in the fish and prawn samples shows the differences in the accumulative capacities of these organisms. Similarly, the variation may be described as a function of individual organism homeostatic control mechanism (Glenn, 2009). The relatively high concentration of iron (Fe) in the fish and prawn samples, as against the minute quantities of other metals, may be attributed to the fact that it is an essential micronutrient associated with many proteins and enzymes (Gill *et al.,* 1997). Relatively low concentration of other metals in the Tilapia and African River Prawn may be accredited to effective release of these metals from the body system and low concentration of the metals in the water column. In general, species differences play major roles in the absorptive capacities of organisms, as it concerns metals and even nutrient elements.

In addition to being a nutrient element, the high concentration of Fe in Tilapia and African River Prawn is not unexpected. This is due to the abundance of Fe in most soils in Nigeria on which the inland waters flow. This is in line with the submissions of Olowu *et al.* (2010), which opined that Nigerian soils belong to the group, known as 'ferruginous' tropical soils, formed from basement rock minerals which are rich in iron oxides. Pb and Cd sources could be traced to wastes which emanated from domestic wastes as well as ores of zinc, copper and lead, which may be present in the minerals of surrounding rocks.

Report of Omitoyin and Ajani (2007) reveals that the gills are the major body parts where Pb is accumulated while lower concentrations can be found in the fish muscles. According to Obasohan (2008), Cd is considered as one of the most toxic metals in aquatic environments, with no known physiological role in the body of aquatic organisms. Cobalt (Co) is a constituent of vitamin B_{12}, which is required by animals; hence, its deficiency causes nutritional defects (Oduwole, 1997), while high concentration in levels above the threshold poses great danger as a potential source of food poisoning. Tilapia, among other fish species, is known to accumulate Ni in different tissues when exposed to elevated levels in their environment.

Comparison of Mean Metal Concentration in Fish and Prawn Samples with Standard Limits

The comparison between metal concentration in the fish and prawn samples with National and International standards (Federal Environmental Protection Agency (FEPA) and World Health Organization (WHO) respectively) revealed that all the metals except Fe are within the allowable limits. This is evident in Table 4. The Comparison allowed for determining the safety status of the lake organisms, represented by Tilapia and African Rivers Prawn, as food organisms.

In contrast to other metals, the mean concentration of iron (Fe) in the fish and prawn samples exceeded 1mg/kg; however, the concentration of Fe in the prawn was still within the limits (3mg/kg). On the other hand, the concentration of Fe in fish exceeded the limit, with a concentration 7.431mg/kg. With respect to the limits, it can be implied that African River Prawn from the water body is safe for consumption as food organism while Tilapia may be considered as unsafe due to the notably high Fe accumulation. This disparity could be attributed to the fact that the accumulation of metals in organisms is species independent, and is determined by the rates of uptake, metabolism and elimination (Oguzie and Okhagbuzo, 2010).

The reason for lower Fe concentration in the African River Prawn can, hence, be ascribed to a more effective iron elimination mechanism than Tilapia. Relatively low concentration of other metals, in the Tilapia and African River Prawn, observed in the study area is in consonance with the findings of Omitoyin and Ajani (2007), that fish muscle like mammalian muscle, does not become heavily contaminated except perhaps when exposed to very high doses of heavy metals.

CONCLUSION

Non-detection of most of the metals in the water indicates low levels of these metals. This may have been affected by physico-chemical parameters which could have aided the conversion of the metals into biodegradable compounds. The continuous flow of the water may also have assisted in self-purification of the water body.

A similar trend of relatively low metal concentration in the fish and prawn samples, especially as found to be within the limits of national and international standards, indicated that water and food organisms from the lake are safe for use by man. Also, the pollution level of the lake can be considered as relatively low. Therefore, Tilapia and African River Prawn, among other edible aquatic organisms inhabiting the lake, are deemed suitable for human consumption as safe food products in line with local and international standards. Hence, adequate measures should be put in place to ensure that the metal levels do not exceed the threshold limits nor become higher than the regulated standards. Future research work geared towards monitoring the pattern of metal concentration in the lake should be carried out on a time to time basis to alert the government and the public of any imminent danger on the consumption of fauna resources obtained from the lake.

Table 4: Comparison of Metal Concentration (mg/kg) in Fish and Prawn Samples with FEPA and WHO Limits.

Sample	Fe	Pb	Co	Ni	Cr	Cd
Fish	7.431	0.053	0.006	0.016	0.004	0.064
Prawn	1.610	0.104	0.005	0.019	0.001	0.045
*FEPA (2003)	3	2	-	0.5 – 0.6	0.15	1
*WHO (1989)	3	2	-	0.5 – 0.6	0.15	1

*FEPA and WHO Maximum Allowable Limits

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