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OCCURRENCE OF HEAVY METALS IN SELECTED FISH SPECIES OF RIVER OLI, KAINJI LAKE NATIONAL PARK, NIGERIA

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ABSTRACT: Heavy metals have long been documented as serious pollutants of the aquatic system because its contamination may have devastating effects on the ecological stability of the receiving environment. Therefore, this study assessed the concentration of heavy metals in three selected fish species from River Oli in Kainji Lake National Park to ensure continuous safety for sustainable production within the protected area. Nine sub-adult specimens, three each of *Lates niloticus* (Nile perch), *Hydrocynus forskalii*, (Tiger fish) and *Synodontis membranacea* (Upside-down catfish) were caught monthly using set gill nets for three months. All samples were labeled, processed and analyzed using Atomic Absorption Spectrophotometer. The result revealed that gills, bones, and muscles of the sample species contain significantly varying ($p<0.05$) concentration of Fe, Pb, Cu, Zn, Cr, and Cd. The highest mean concentration of Pb (4.80±0.12), Zn (24.46±4.33) and Cu (29.55±1.15) were found in *H. forskalii* flesh muscles also. There is significant ($p<0.05$) high level of Pb (2.65±0.04) bioaccumulation in the gill of *H. forskalii* while Cr (17.00±0.21) is higher in *S. membranacea* gills. The highest concentrations of Pb (4.05±0.03), Cr (11.55±0.56) and Cu (31.85±1.04) were again recorded in *S. membranacea* bones, while Fe (232.04±9.88) and Zn (39.35±1.24) highly accumulated in the vertebral bone of *L. niloticus* and *H. forskalii*, respectively. The concentrations of Pb and Fe in the whole fish of all sampled species are above maximum permissible limit according to the WHO standard for foods. Heavy metal elements in *L. niloticus and H. forskalii* have similar association pattern of Fe>Zn>Cu> Cr>Pb>Cd which slightly differ from Fe>Cu>Zn>Cr>Pb>Cd obtained for *S. membranacea*. This study revealed that fish can bio accumulate these heavy metals in different body parts from polluted water, whichmay lead to ecological adversity as result of impairment or loss of natural population.

Key words/phrases: Contamination; fishes; heavy metals; protected area; River Oli; wildlife

INTRODUCTION

Freshwater contamination with a wide range of pollutants has become a matter of urgent concern because the river system may be excessively contaminated with heavy metals released from both natural and anthropogenic activities (Burger *et al.*, 2002; Vutukuru, 2005) and accumulates in water, soil sediment and tissues and organs of aquatic organisms. Heavy metals are conservative pollutants because they are not easily degradable and they become permanent additions to the aquatic environment. However, since fish are located at the top of the aquatic food web, they accumulate metals in different tissues and organs which depend on the mode of exposure (water and diets) and metallic pathways. Heavy metals contaminant residues in fish may ultimately reach concentrations hundreds or thousands of times above permissible level (Goodwin *et al.*, 2003) which could threaten several endemic fisheries resources (Nwani *et al.*, 2010) leading to the depletion of fish resources (Srivastava and Srivastava, 2008).

This accumulation of heavy metals in fish depends upon species intake and elimination (Murtala *et al.*, 2012). Burger *et al.* (2002) also showed that the concentration of metals was a function of fish species as it accumulates more in some fish species than others due to substantial variation in pollution processes, hence more than one species of fish should be studied.

Moreover, contamination of fish tissues and organs could serve an important function as an early warning indicator of sediment contamination or related water quality problems (Mansour and Sidky, 2002; Barak and Mason, 1990) and enable us to take appropriate action to protect public health and environment.

In recent time, Borgu sector of Kainji Lake National Park major river (River Oli) that support the

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lives of aquatic and terrestrial wildlife species has been subjected to various forms of degradation due to pollution caused by anthropogenic activities from surrounding communities arising from artisanal mining, agricultural complexes, bush burning, untreated sewage discharge, wild animal feacals and decomposed carcass. Considering the importance of fish to ecological maintenance in the protected area, it is necessary that biological monitoring of fish should be done regularly to guarantee its unceasing ecological production for wildlife sustainability. Thus, this study assessed and evaluated the occurrence of selected heavy metals in three fish species as representative or components of the ecosystem in River Oli, Kainji Lake National Park to contribute toward finding the most appropriate model and related prospective organisms for trace metal pollution monitoring within the protected area.

MATERIALS AND METHODS

Study location

Kainji Lake National Park is located in the North West-central part of Nigeria between latitude 9°45'N and 10°23'N and longitude 3°4'E and 5°47'E. It is made up of two sectors (Borgu and Zugurma) situated in Borgu and Kaima/Baruten Local Government Areas of Niger and Kwara State, respectively. It covers a total land area of 5,340.825 Km^2 (Ayeni, 2007).Kainji Lake National Park was established in 1979 by the amalgamation of two formal game reserves Borgu and Zugurma under decree 46 of 29th July 1997, thereby making Kainji Lake National Park the premier National Park in Nigeria (Ayeni, 2007).River Oli is the major river in the Park that supports the lives of aquatic and terrestrial wildlife species and domestic animals. The farmers and their families in the villages that share boundaries with the Park also depend on the river for their livelihood both in the dry and wet seasons.

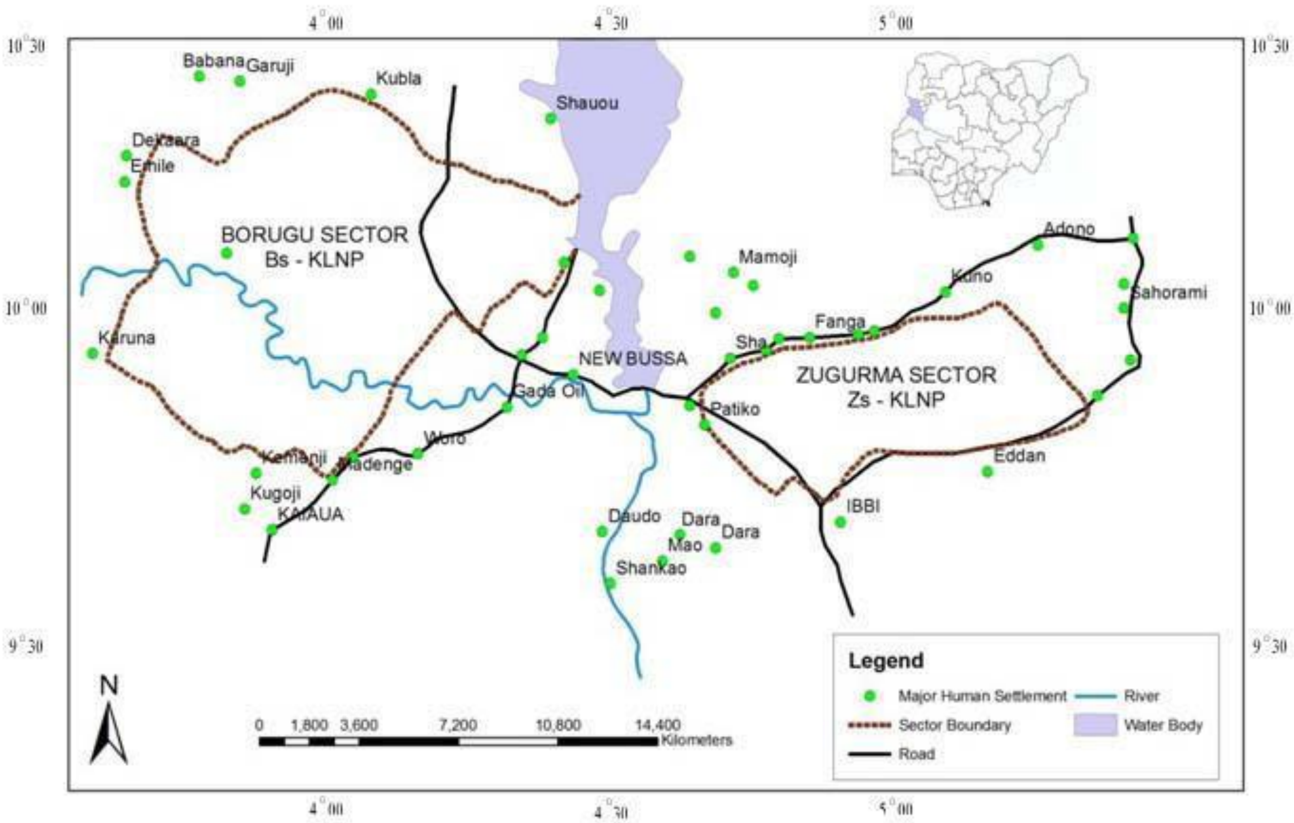

Figure 1. Kainji Lake National Park showing Oli river and major human settlements
Source: Adapted from Ayeni, 2007.

Fish sampling and processing

Nine sub-adult specimens, three each of *Lates niloticu s* (Nile perch), *Hydrocynus forskalii*, (Tiger fish) and *Synodontis membranacea* (Upside-down catfish) were caught monthly between April and July, 2019 using set gill nets for three months (9 fish sample per species) from Oli River at Oli camp of Kainji Lake National Park and transported to the laboratory. A clean-washed high-quality corrosion-resistant stainless knife was used to cut 1g wet weight of the fish tissue (muscle) along the lateral line. The operculum of each fish sample was opened and the gill removed while whole fish was dissected to remove vertebra bone. After dissection, all the samples were labeled accordingly. The entire samples (gills, muscles and vertebra bone) of each fish species were separately dried in a laboratory oven at 175˚C for 3 hours.

The dried samples were each ground with laboratory ceramic mortar and pestle to powder and sieved with 2mm sieve. After being ground, the samples were heated at the temperature of 45˚C in a muffle furnace till the aroma of the sample disappeared. The powdered samples were digested according to procedures described by Novozamsky *et al.* (1983). The digested samples were diluted with de-ionized distilled water appropriately and filtered using a 0.5micron filter membrane. The digested samples were poured into auto analyzer cups and concentration of Lead (Pb), Cadmium (Cd), Iron (Fe), Chromium (Cr), Zinc (Zn) and Copper (Cu) in each sample (mg/kg) were determined with Atomic Absorption Spectrophotometry (AAS) Perkin-Elmer spectrophotometer (A Analyst 200 model) using their respective lamps and wavelengths in the laboratory. Operational conditions (such as lamp selection and wavelength) were adjusted to yield optimal determination. The machine was standardized by aspirating distilled water to obtain zero absorbance. The samples were aspirated into the machine and absorbance value was read and recorded.

Data analysis

Data obtained were statistically analyzed using ANOVA in SPSS 18 and $p<0.05$ were considered to indicate statistical significance while the means were compared andseparated using Duncan's Multiple Range Test (DMRT) as a post-hoc test (Steele and Torrie, 1980).

RESULTS

Table 1 shows the mean concentration (µg/g dry weight) of heavy metals in the flesh muscles of different fish species from River Oli in Kainji Lake National Park, Nigeria. The result revealed that there were significant differences ($p<0.05$) in the values recorded for all metals across fish species except for Cd levels. There are relatively more Pb (4.80±0.12), Zn (24.46±4.33) and Cu (29.55±1.15) in *H. forskalii* flesh muscles while Cr (8.59±2.16) accumulated more in *L. niloticus* and Fe (264.33±29.76) is significantly ($p<0.05$) higher in *S. membranacea*.

Table 1. Mean (±) concentration of heavy metals in fish species flesh muscles from the study area (µg/g dry weight).

Fish species	The mean concentration of heavy metals in fish flesh (µg/g)					
	Pb	Cr	Zn	Cu	Fe	Cd
L.niloticus	2.85±0.02^{b}	8.59±2.16^{c}	11.39±0.04^{b}	22.45±0.56^{a}	194±4.68^{a}	0.002±0.001^{a}
H.forskalii	4.80±0.12^{c}	4.80±0.04^{a}	24.46±4.33^{c}	29.55±1.15^{b}	201±11.50^{a}	0.001±0.001^{a}
S.membranacea	2.30±0.15^{a}	7.35±0.22^{b}	8.50±0.64^{a}	24.15±4.06^{a}	264.33±29.76^{b}	0.003±0.001^{a}

Means followed by the same letter within a column are not significantly different from each other at 5%, HSD

Table 2 also shows the concentration (µg/g dry weight) of metals in the gills of different fish species from the study area. The gills of the sampled species were found to contain significantly ($p<0.05$) varied concentration of metal elements analyzed except for *S. membranacea* in which its Cd level is below detectable, though has a relatively high concentration of Cr (17.00±0.21) and Cu (29.25±0.03) with the lowest level of Pb (0.80±0.02). There is no significant ($p>0.05$) difference in the concentration of Fe across the species as well as Zn and Cd level for both carnivorous fishes (*L. niloticus* and *H. forskalii*), however *H. forskalii* has the highest level of Pb (2.65±0.04) deposited in its gills (table 2).

Table 2. Mean (±se) concentration of heavy metals in fish species gills from the study area (µg/g dry weight).

Fish species	The mean concentration of heavy metals in Gills (µg/g)					
	Pb	**Cr**	**Zn**	**Cu**	**Fe**	**Cd**
L.niloticus	2.04±0.03[b]	6.15±0.032[b]	42.92±1.62[b]	21.25±1.22[a]	223±16.87[a]	0.001±0.001[a]
H.forskalii	2.65±0.04[c]	4.70±0.05[a]	40.30±4.78[b]	24.20±0.09[b]	241.83±39.00[a]	0.001±0.001[a]
S.membranacea	0.80±0.02[a]	17.00±0.21[c]	28.85±2.43[a]	29.25±0.03[c]	232.33±8.75[a]	0.00±0.00a

Means followed by the same letter within a column are not significantly different from each other at 5%, HSD

The mean values of the heavy metals present in the vertebra bones of the fish samples (table 3) show a significantly ($p<0.05$) high concentration of Pb (4.05±0.03), Cr (11.55±0.56) and Cu (31.85±1.04) in *S. membranacea*, Fe (232.04±9.88) in *L. niloticus* and Zn (39.35±1.24) in *H. forskalii*. However, there is no significant ($p>0.05$) variation in the 0.001±0.001 recorded for Cd in all species sampled.

Table 3. Mean (±) concentration of heavy metals in fish species vertebra bones from the study area (µg/g dry weight).

Fish species	The mean concentration of heavy metals in Vertebra Bones (µg/g)					
	Pb	**Cr**	**Zn**	**Cu**	**Fe**	**Cd**
L.niloticus	1.80±0.02[a]	6.44±0.35[b]	31.35±1.90[b]	23.30±2.66[a]	232.04±9.88[b]	0.001±0.001[a]
H.forskalii	3.18±0.09[b]	4.65±0.07[a]	39.35±1.24[c]	23.58±1.17[a]	186±21.50[a]	0.001±0.001[a]
S.membranacea	4.05±0.03[c]	11.55±0.56[c]	25.15±0.04[a]	31.85±1.04[b]	195.5±2.50[a]	0.001±0.001[a]

Means followed by the same letter within a column are not significantly different from each other at 5%, HSD

The mean levels of the various metals recorded in different fish tissues of the three fish species were compared with the World Health Organization (WHO) standard (table 4). The concentrations of Pb and Fe in the whole fish of all sampled species are above maximum permissible limit according to the WHO standard for foods.

Table 4. Mean (±) concentration of heavy metals in whole fish species from the study area against standard maximum permissible limit (µg/g dry weight)

Fish species	Mean concentration of heavy metals in different whole sampled fish species (µg/g)					
	Pb	**Cr**	**Zn**	**Cu**	**Fe**	**Cd**
L.niloticus	2.23±0.48[a]	7.06±1.60[a]	28.72±13.64[ab]	22.33±1.74[a]	216.34±19.93[a]	0.001±0.001[a]
H.forskalii	3.54±0.97[b]	4.72±0.08[a]	34.70±8.36[b]	25.78±2.96[b]	209.61±33.99[a]	0.001±0.001[a]
S.membranacea	2.38±1.41[a]	11.97±4.02[b]	20.83±9.47[a]	28.42±3.99[b]	230.72±33.64[a]	0.001±0.001[a]
Maximum Permissible limit (WHO, 2008)	2	50	75	30	100	<1

Means followed by the same letter within a column are not significantly different from each other at 5%, HSD

The pattern of accumulation of all metal elements in the whole fish of the investigated fish species varied across the trophic level. Heavy metals elements in *L. niloticus* and *H. forskalii* (both carnivorous fishes) has similar association pattern of Fe>Zn>Cu> Cr>Pb>Cd which slightly differ from Fe>Cu>Zn>Cr>Pb>Cd obtainable for *S. membranacea*; an omnivorous fish in the study area (table 5).

Table 5. patterns of association of heavy metals in a whole fish sample of fish speciesfrom oli river, kainji lake national park

Fish species	Feeding habits	Patterns of accumulation of metals
Latesniloticus	Carnivorous	Fe>Zn>Cu>Cr>Pb>Cd
Hydrocynusforskalii	Carnivorous	Fe>Zn>Cu>Cr>Pb>Cd
Synodontismembranacea	Omnivorous	Fe>Cu>Zn>Cr>Pb>Cd

DISCUSSION

Heavy metals are easily absorbed by aquatic life forms and accumulation may occur in higher concentrations than in water bodies (Omoregie *et al.*, 2002). The presence of heavy metals in all samples confirmed that fish can take up heavy metals either in their diets or water through their gills and bio-accumulate them at different rates in their muscles and organs as earlier reported by Agbon and Omoniyi (2010).

According to Rainbow *et al.* (1990), the rate of accumulation and the ability of the fish to detoxify particular metals differ greatly. This is probably responsible for the disparity in various fish species sampled and this will eventually affect their key enzymes activities including biotransformation enzymes (Stramc and Braunbeck, 2000). Discrepancies in the concentration of metals found in different body parts (flesh muscles, gills, and bones) could be attributed to their different roles in the bioaccumulation process (Evans *et al.*, 1993), the mode of exposure and metallic pathways (Maheswari *et al.*, 2006), the ability of each body part to regulate or accumulate metals as well as the physiological difference of the body parts of the fish (Nussey *et al.*, 2000). Fish muscles are typically the major target for metal storage (Reinderfelder *et al.*, 1998), this confirmed reason for relative absorption of metals in the flesh muscles of fish samples while the high occurrence of metalsin the gills established that fish exposed to elevated levels of heavy metals can absorb the available metals through the gills in the process of ingestion of contaminated water and food (Nussey*et al.,* 2000). The high level of some metals found in the whole fish samples could be attributed to the fact that concentration represents the aggregate of all the total concentrations of the metals in the fish (Idodo-Umeh and Oronsaye, 2006). Iron (Fe) was the most bio-accumulated of all the metals by all fishes. Similarly, high levels of Fe in *Chrysichthy nigrodigitatus* and *Parachanna obscura* were reported from Ibiekuma stream (Erhabor*et al.*, 2010). This is expected because the metal is an essential element required in an organism's blood hemoglobin for oxygen transportation. The pattern of accumulation is similar for the carnivorous fishes (*L. niloticus* and *H. forskalii*) which imply that the fish species accumulate heavy metals relative to their position in the food web (Dusek*et al.*, 2005) and also confirmed that metal ions are moving along the food chain from prey to predator (Hossain, 2002). The mean levels of Pb and Fe concentration found in the whole fish for all species exceeded the maximum permissible limit thereby making the fishes from the study area an object of ecological concerns (WHO, 2008). Cd; a non-essential metal for biological systems and toxic, was the least bio-accumulated of all the metals detected all samples. This probably could be attributed to the presence of a low level of Cd in the water in the study area due to the non-existence of metallurgical and electroplating industries within the river catchment area. Kaoud *et al* (2011) opined that cadmium as an extremely toxic metal is widely used in mining, metallurgical operations and electroplating industries. This similar observation has earlier been reported from majors rivers (Umeh and Oronsaye, 2006; Oguzie, 2003 and Nussey *et al.*, 2000). The highest concentration Cd was found in the flesh muscles of *S. membranacea* probably because the specie is a benthic feeder (Owolabi, 2011) that feeds majorly on detritus and organism closer to river sediment where Cd may accumulate.

CONCLUSION

Heavy metals are readily dissolved in water and can be easily taken up by fish and other aquatic organisms, thus causing concern on the animals and the entire food chain.

The levels of metals measured in the fish species are the net effects of accumulation, metabolism, storage and elimination processes in River Oli. All fish species and their body parts investigated bio-accumulated tested heavy metals and some metals (Pb, Cr, Fe) are even above the maximum permissible limit set by World Health Organization and Federal Environmental Protection Agency.

Pb, Cr and Cd are important toxic metals of global concern because both elements physiological role in living organisms is yet to be ascertained; hence their accumulation could be detrimental to the health of these fish species. Continuous exposure of fish to even low concentrations Cd may result in bioaccumulation and subsequent pollution of the entire ecological system through the food web. On the other hand, Fe; an essential mineral element that plays an irreplaceable role in living organisms including fish blood hemoglobin for oxygen transportation has the potential to become harmful as it was detected at high concentrations in the study area.

The mode of accumulation of heavy metals is similar for *L. niloticus* and *H. forskalii* in the study because of their similar trophic position and this connotes that carnivorous fishes have peculiar bioaccumulation pattern.

Considering the human and ecological health, the presence of heavy metals especially high concentration found in PbCr and Fe as well as the presence of Cd in the samples implies that the fish species inhabiting Oli River of Kainji Lake National Park could be unhealthy for wildlife ecological balance as well as human consumption for fear of heavy metals induced health risks pending any serious ameliorative interventions.

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