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Bioaccumulation of Lead, Cadmium and Chromium in Two freshwater Fish Species from River Kaduna (Nigeria)

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***Abstract:** There is increased global concern on the high rate of discharge of heavy metals into freshwater ecosystems from various anthropogenic sources due to their persistence, toxicity, bioaccumulation and biomagnification in the food chain. Fish are bioaccumulators of heavy metals hence; they are considered one of the key indicators of heavy metal pollution of freshwater systems. An investigation on the bioaccumulation of lead, cadmium and chromium in Clarias gariepinus and Oreochromis niloticus from river Kaduna was conducted. Sampling was done at seven different locations along the river. Muscle and liver tissues were collected from each of the fish species and analyzed for heavy metal concentration using atomic absorption spectroscopy. The muscle had higher levels of the heavy metals than the liver tissue. Both fish species are good bioaccumulators of these heavy metals however, O. niloticus is better than C. gariepinus. Furthermore, the muscle accumulated these heavy metals more than the liver. All heavy metals analyzed were above permissible limits hence, C. gariepinus and O. niloticus from river Kaduna are unsafe for human consumption. Therefore, there is an urgent need to regulate discharge of wastes into river Kaduna in order to prevent contamination by these heavy metals.*

Keywords: Bioaccumulation, Heavy Metals, *Clarias gariepinus*, *Oreochromis niloticus*, Freshwater ecosystem

1. Introduction

Pollution of freshwater ecosystems with heavy metals due to anthropogenic activities is receiving increasing attention [1][2]. This is due to their persistence, toxicity, bioaccumulation and biomagnification in the food chain [3]. Fish are good bioaccumulators of heavy metals hence; they are considered one of the key indicators of heavy metal pollution of freshwater systems [4]. Poor management of wastes containing heavy metals generated from various anthropogenic activities is a key reason for the rapid decrease in biodiversity of aquatic ecosystems in various parts of the world. This is severe in developing countries such as Nigeria and significantly contributes to the perceived short life expectancy of people in these regions [5].

Many factories in Nigeria are located on river banks and discharge their effluents into these aquatic environments. A significant proportion of the Nigerian populations still rely on this surface water for drinking, washing, fishing and swimming. River Kaduna (Figure 1) is one of the most polluted inland waters in Nigeria because it serves as a sink for all industrial effluents in Kaduna city [5]. It receives about 500,000 cubic meters of untreated effluent per day from various industries through 53 tributaries [6]. The current demand for fish food in Nigeria is estimated at little over 1 million tons per annum as against a supply of about 800,000 tons per annum [5]. Heavy metals accumulation in fish causes structural lesions, functional disturbances, physiological and chemical changes that can result into their death and could cause severe heavy metal toxicity and sometimes death of human consumers [7]. Two commonly found fish species in river Kaduna are *Clarias gariepinus* and *Oreochromis niloticus*.

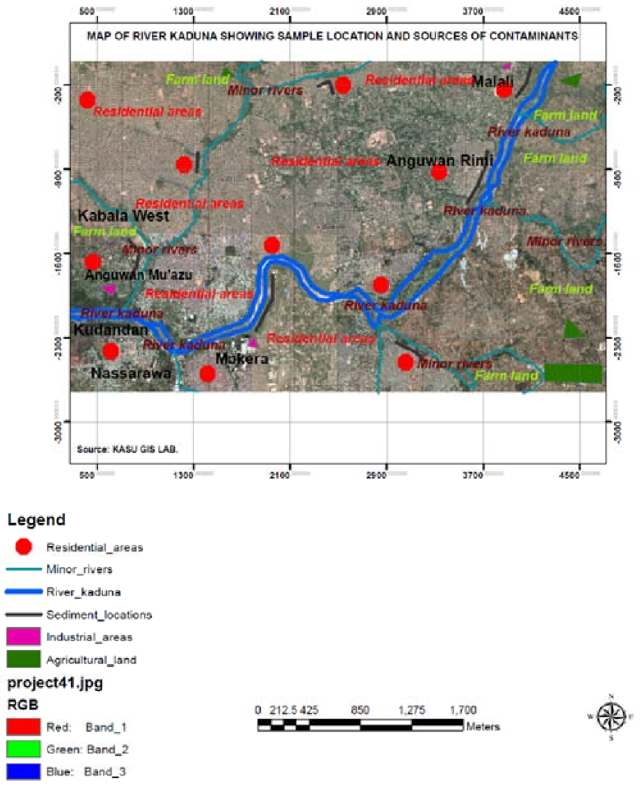

Figure 1: Map of river Kaduna showing sampling locations and sources of contaminants.

Clarias gariepinus is found in most parts of the African continent and it is probably the most widely distributed fish in Africa. *C. gariepinus* is widely tolerant of many different habitats, even the upper reaches of estuaries, but is considered to be a freshwater species. It favors floodplains, slow flowing rivers, lakes and dams [8]. It can tolerate waters high in turbidity and low in dissolved oxygen, and is often the last or only fish species found in remnant pools of drying rivers [9][10]. *Oreochromis niloticus* is native to central and North Africa and the Middle East. It is a tropical freshwater and estuarine species. It prefers shallow, still waters on the edge of lakes and wide rivers with sufficient vegetation [11]. The aim of this research was to assess the level of lead, cadmium and chromium in *Clarias gariepinus* and *Oreochromis niloticus* as indicators of contamination of river Kaduna.

2. Materials and Methods

2.1 Sample Collection

Water and fish samples were collected from river Kaduna at seven sampling locations (Malali, Anguwan Rimi, Makera, Nassarawa, Kudandan, Anguwan Mu'azu, and Kabala West) as shown in Figure 1. After which, 50 ml of thoroughly shaken water sample was measured accurately into a beaker and digested with 5 ml of conc. HNO_3. The solution was allowed to cool again then filtered with 125 mm filter paper into 100 ml standard flasks and made to the mark with de-ionized water. Fish samples were dissected and the muscle and liver were collected and washed with deionized water and sun dried for a week. Thereafter, dried in the oven for 3 hours at 80^{o}c. Fish samples (muscle and liver) weighing 2-10 g were transferred into 50 ml quartz crucible and dried in an oven at 120 ^{0}C. One gram of the dried sample was placed in a muffle furnace and ashed in a quartz crucible over night at temperature of 450 ^{0}C. The next day, the sample was removed from the furnace and cooled to room temperature, and then 1ml of concentrated nitric acid was added and dried on a hot plate. The sample was placed in a muffle furnace for the second time and the temperature was raised to 450 ^{0}C and kept for about 1 hour, until the ash became carbon free. The sample was removed from the muffle furnace and cooled at room temperature, and the ash was dissolved in 20 ml of 1 N hydrochloric acid and heated on a hot plate to further make the metals soluble. The residue obtained was dissolved in 50 ml de-ionized water, and filter into a 100 ml volumetric flask and made up to the mark with de-ionized water.

2.2 Analytical Procedure

Concentration of mercury, arsenic and copper in samples were determined in triplicates using atomic absorption spectroscopy (Thermo scientific iCE 3000 series AA spectrometers were used). Concentration each heavy metal was expressed in mg/kg dry weight.

2.3 Data Analysis

Data obtained were subjected to analysis of variance using SPSS software. Mean separation was done using least significant difference.

3. Results

3.1 Bioaccumulation of lead

Lead concentration in the muscle and in the liver of each of the two freshwater fish species were not significantly different ($P > 0.05$) as shown in Figure 2. Over-all concentration of lead in each of the two freshwater fish species were also not significantly different, values obtained were 0.89 mg/kg dry weight in *C. gariepinus* and 2.71 mg/kg dry weight in *O. niloticus* (Figure 3). Over-all mean concentration of lead in the muscle and in the liver were 1.82 mg/kg dry weight and 1.76 mg/kg dry weight respectively (Figure 4).

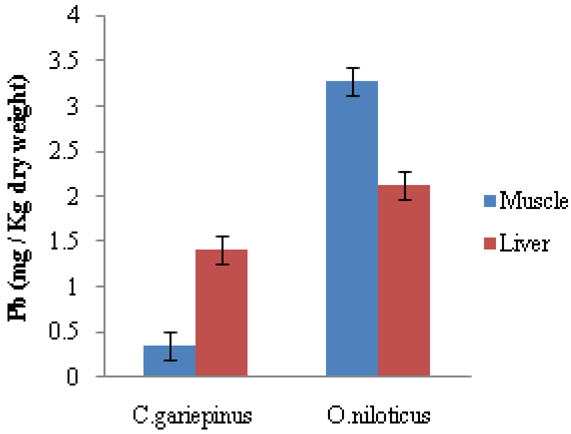

Figure 2: Concentration of lead (mg/kg dry weight) in different tissues of two freshwater species from river Kaduna.

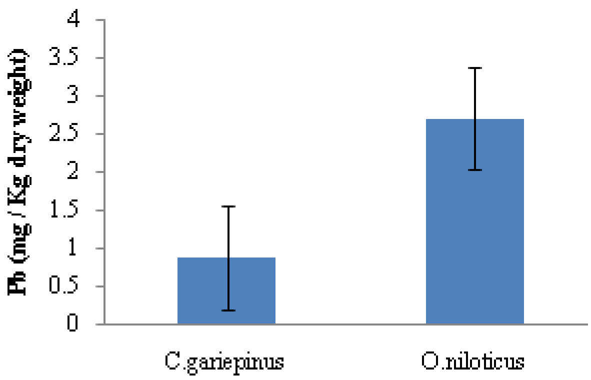

Figure 3: Concentration of lead in two freshwater fish species from river Kaduna.

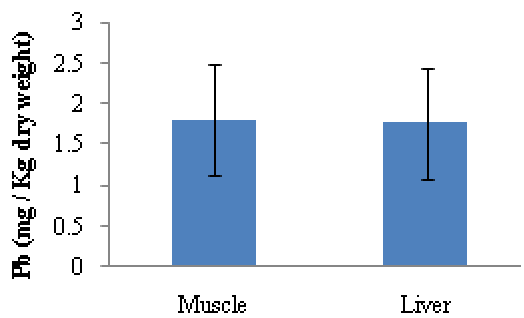

Figure 4: Concentration of lead in different tissues of two freshwater species from river Kaduna.

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3.2 Bioaccumulation of Cadmium

Cadmium levels in the muscle and in the liver of each of the two freshwater species were not significantly different at 5 % probability level (Figure 5). The over-all concentration of cadmium in the each of the two fish species was likewise not significantly different. Mean values obtained were 0.74 mg/kg dry weight in *C. gariepinus* and 0.53 mg/kg dry weight in *O. niloticus* (Figure 6).

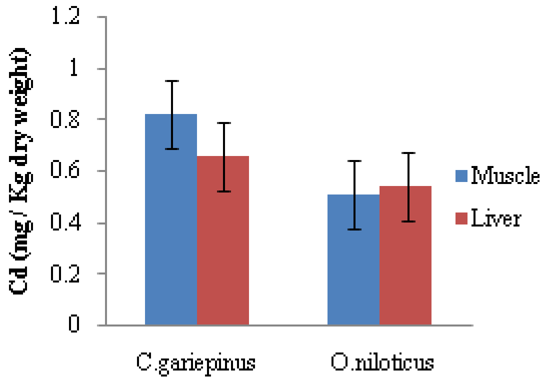

Figure 5: Concentration of cadmium (mg/kg dry weight) in different tissues of two freshwater species from river Kaduna.

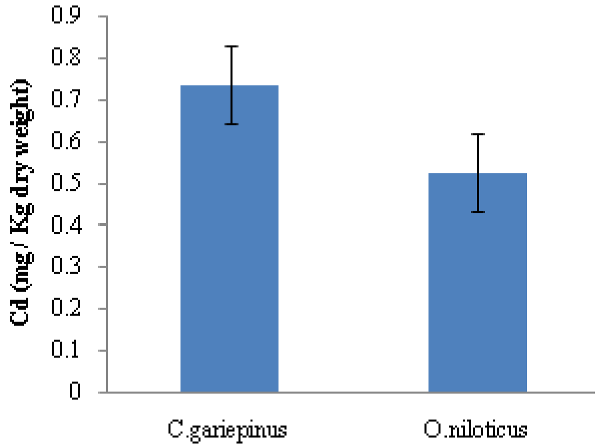

Figure 6: Concentration of lead in two freshwater fish species from river Kaduna.

Over-all cadmium levels in the muscle and in the liver of the two fish species were 0.67 mg/kg dry weight and 0.60 mg/kg dry weight respectively (Figure 7). These mean values were not significantly different.

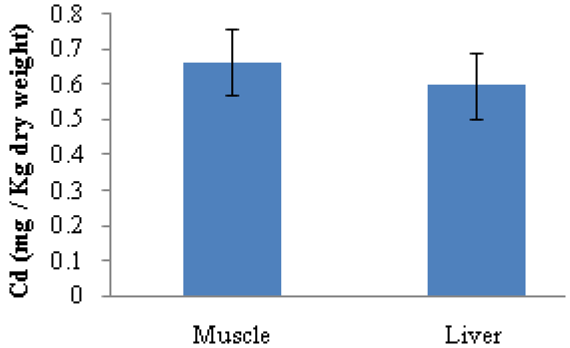

Figure 7: Concentration of cadmium in different tissues of two freshwater species from river Kaduna.

3.3 Bioaccumulation of Chromium

Chromium levels in the muscle and in the liver *C gariepinus* were not significantly different. However, values obtained in *O. niloticus* were significantly different ($p < 0.05$) as shown in Figure 8.

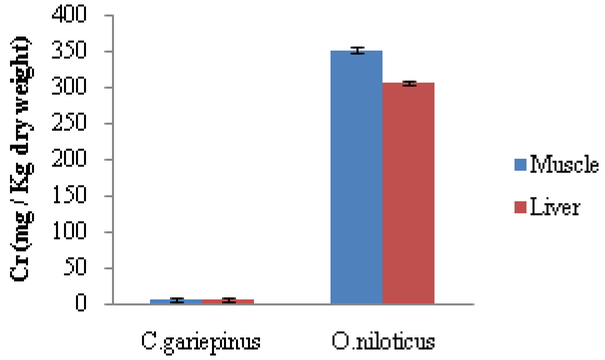

Figure 8: Concentration of chromium (mg/kg dry weight) in different tissues of two freshwater species from river Kaduna.

Over-all chromium concentration in each of the fish species were significantly different ($p < 0.05$). Mean values obtained were 1.41 mg/kg dry weight in *C. gariepinus* and 329.71 mg/kg dry weight in *O. niloticus* (Figure 9).

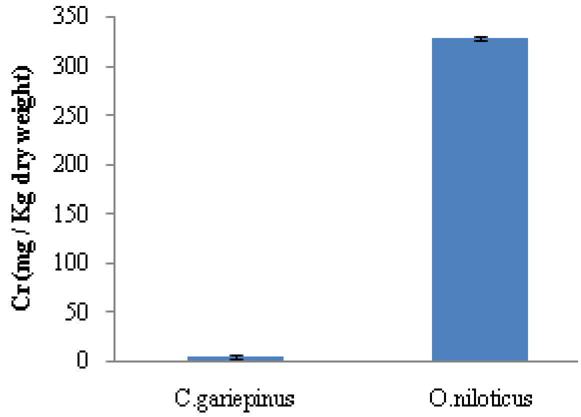

Figure 9: Concentration of chromium in two freshwater fish species from river Kaduna.

Over-all concentration of chromium in the muscle and in the liver of the fish species were 177.10 mg/kg dry and 154.00 mg/kg dry weight respectively (Figure 10). These mean values were significantly different at 5 % probability level.

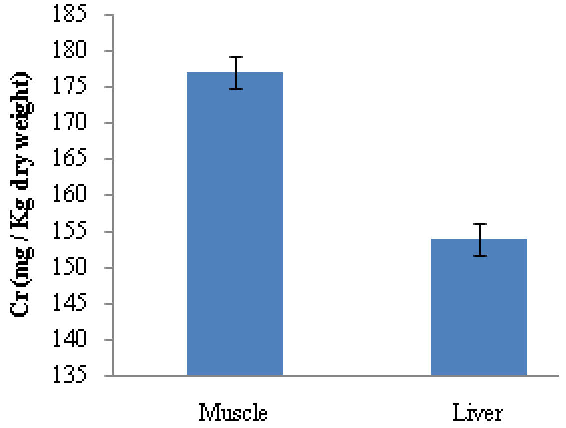

Figure 10: Concentration of chromium in different tissues of two freshwater species from river Kaduna.

4. Discussion

4.1 Bioaccumulation of Lead, Cadmium and Chromium in the Muscle and Liver of Each Fish Species

Bioaccumulation of lead and cadmium in the muscle and in the liver of each of the two fish species was not significantly different implying that these tissues contain similar levels of the metal binding protein called metallothioneins. These proteins play an important role in the homeostasis of metals and protection against heavy metal toxicity [2]. Imam *et al.* [12] reported that a positive correlation occurred between metallothioneins levels and cadmium levels in tilapia obtained from selected farms in Egypt. Significant variation in chromium levels in the tissues of *O. niloticus* was observed implying that it accumulates this heavy metal in a tissue-dependent manner which could be attributed to variation in metallothioneins level among the two tissues analyzed.

4.2 Over-all Mean Concentration of Each Heavy Metal in Each Fish Species

It is noteworthy, to mention that the over-all mean concentration of lead and cadmium were beyond permissible limits as recommended by Codex alimentarius commission (≤ 0.5 mg/kg for lead) and heavy metals regulations legal notice no. 66 (≤ 0.05 mg/kg for cadmium). Over-all chromium level in each of the fish species was significantly different. This could be due to interplay of a number of factors which include: habitat, seasonal variations, and individual affinity for metal uptake, differences in life history patterns that influence exposure (including trophic levels and geographic distribution of life stages), biomagnifications, seasonal changes in the taxonomic composition of the different trophic levels affecting the concentration and accumulation of heavy metals in the body of the fish, adaptation capacity of the fish to heavy metal load and distance of the organism from the contamination source. Over-all chromium level in each fish species was also above permissible limit set by FAO [13] and FEPA [14] (0.15 mg/kg). High level of these heavy metals in these fish species did not only signify contamination of river Kaduna with these metals but also show that *C. gariepinus* and *O. niloticus* from this river are not safe for consumption. Short-term exposure to high levels of lead can cause brain damage, paralysis (lead palsy), anaemia and gastrointestinal symptoms. Long-term exposure can cause damage to the kidneys, reproductive and immune systems in addition to effects on the nervous system. The most critical effect of low-level lead exposure is on intellectual development in young children and, like mercury, lead crosses the placental barrier and accumulates in the foetus. Infants and young children are more vulnerable than adults to the toxic effects of lead, and they also absorb lead more readily. Even short-tem, low-level exposures of young children to lead is considered to have an effect on neurobehavioural development [15]. The principal toxic effect of cadmium is its toxicity to the kidney, although it has also been associated with lung damage (including induction of lung tumours) and skeletal changes in occupationally exposed populations Food Safety Authority of Ireland [16]. Bioaccumulation of chromium in fish has been reported to cause impaired respiratory and osmoregulatory functions through structural damage to gill epithelium [17].

4.3 Over-all Mean Concentration of Heavy Metals in Each Fish Tissue

Results of this study show that the muscle is more bioaccumulative for chromium than the liver which could be explained in terms of variation in metallothioneins level. Metallothioneins have been discovered in varying amounts in different tissues including muscle [18], kidney, liver and brain [2].

4.4 Sources of Contaminants

The presence of high levels of lead, cadmium, and chromium in *C. gariepinus* and *O. niloticus* shows that river Kaduna is highly polluted with these heavy metals as earlier mentioned. This is not surprising because farmlands and industries are cited close to the river (Figure 1). Run-off from farmlands could be a contributing factor to the pollution of this river due to application of inorganic fertilizers, pesticides and herbicides on these farmlands. Improper discharge of industrial wastes could also be one of the major causes of pollution of river Kaduna [5]. One of the ways to circumvent this challenge is by judicious use of chemicals on farmlands which can be achieved by using more of organic materials (organic manure, organic pesticides, biological control of pests and diseases, cultural practices in weed control) and proper industrial wastes management.

5. Conclusion

This research has established that River Kaduna is polluted with lead, cadmium, and chromium. Both fish species contain these heavy metals at levels above permissible limits hence, are unsafe for human consumption. Both fish species are good bioaccumulators of these heavy metals however, *O. niloticus* is better than *C. gariepinus*. Furthermore the muscle accumulated these heavy metals more than the liver. Therefore, there is an urgent need for development and implementation of policies to reduce the pollution of river Kaduna for the good wellbeing of consumers of these two fish species.

6. Future Studies

Future research will focus on the effect of these heavy metals on consumers of the fish species. Also, relationship between these heavy metals and metallothionein levels will be investigated.

7. Acknowledgements

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