

Bioaccumulation of Heavy Metals in *Clarias gariepinus* from Lake Njoboliyo, Yola-South L.G.A, Adamawa State, Nigeria

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Abstract

A study on the bioaccumulation of heavy metals was carried out monthly using standard methods for the period of four months (i.e from March to June.). Bioaccumulation of heavy metals including Cadmium (Cd), Zinc (Zn), Copper (Cu) and Iron (Fe) in Catfish (*Clarias gariepinus*) organs (muscles, gills and Liver) were investigated. Iron, Zinc, Copper and Cadmium (Cu, Fe, Zn and Cd) at station A, B and C recorded concentration (4.02 mg/kg, 0.23 mg/kg, 1.14 mg/kg, 0.09 mg/kg) within the international permissible limits in fish organs except cadmium. Gills and Liver of *Clarias gariepinus* contained the highest concentration of most of the detected heavy metals, while the edible part (muscle) of *Clarias gariepinus* showed appreciable concentration of the heavy metals investigated. This may be due to bioaccumulation over a period of time in the muscle *Clarias gariepinus*. The present results shows that the Fish at Lake Njoboliyo is polluted with Cadmium (Cd) and it can risk getting polluted with other heavy metals and may pose a health challenges to human and fish species.

Introduction

The global consumption of fish and derived fish products has generally increased during recent decades (Wim *et al.*, 2007, Nzeve *et al.*, 2014). Fish provide high quality animal protein, vitamins, minerals and omega-3 fatty acids which have been associated with health benefits due to their cardio-protective effects (Wim *et al.*, 2007, Gamal and Shamery, 2010). Despite the benefits, there are health risks related to fish consumption, mainly due to potential adverse effects of heavy metal contamination. Heavy metals are well known environmental pollutants that cause serious health hazards to human beings (Jarup, 2003, Nzeve *et al.*, 2014). Bio-concentration is the net accumulation of a substance from water into an aquatic organism resulting from the simultaneous uptake and elimination of the substance. Fish and bivalve molluscs are used in bioaccumulation tests because they are higher tropic level organisms and are usually eaten by man. Tissues such as liver, kidney, muscle, viscera and whole organisms are analyzed to determine the concentration of the metals (Olaifa *et al* 2004).

Anthropogenic activities continuously increase the amount of heavy metals in the environment, especially in aquatic ecosystems. Increase in population, urbanization, industrialization and agricultural practices as well as lack of environmental regulations have further aggravated the situation (Gupta *et al.*, 2009). As the metal levels increase in aquatic ecosystems, they raise the concern of metal bioaccumulation through the food chain and related human health hazards (Wright and Welbourn, 2002). Heavy metal contamination in aquatic ecosystems can be expressed by its high concentration in water, as well as in sediments and aquatic organisms (Pham *et al.*, 2007). Fish assimilate metals by ingestion of particulate materials suspended in water, ingestion of food, ion exchange of dissolved metals across lipophilic membranes for example the gills, and

adsorption on tissue and membrane surfaces (Allinson *et al.*, 2009).

The presence of toxic heavy metals in fish can invalidate their beneficial effects. Several unfavorable effects of heavy metals to human health have been known for long time (Castro-González and M'endez-Armenta, 2008). This includes serious threats like renal failure, liver damage, cardiovascular diseases, and even death (Al-Busaidi *et al.*, 2011). Thus, many local and international monitoring programs have been established in order to assess the quality of fish for human consumption and to monitor the health of the aquatic ecosystem (Rahman *et al.*, 2011). The contaminations were taken up through organisms such as fish and domestic use water. Nigeria is witnessing industrialization in recent years, the result is the contamination and deterioration of her natural environment due to the problems of waste disposal in the city centres (Ademoriti, 1996). It is in this context that the above study would assess the Bioaccumulation of heavy metals in a commercially important fish species (*Clarias gariepinus*) in Lake Njoboliyo of Adamawa state.

Materials methods

Study Area

Njoboliyo Lake lies within the latitude 9.12⁰ to 16.15⁰N and longitude 12.28⁰ to 12.43⁰E. The Lake is found in eastern part of Yola south Local Government (Fig.1). The major ethnic groups of the area are Bwatiye, Fulbe, Mbula and few migrant fishers that comprises of Hausa, Jukum and Agatu. Some of these migrant fishers have over the years become indigene to that area (Adebayo and Tukur, 1999).

The Lake is wet flooded plain lake found adjacent to river Benue; this Lake has its course from river Nafari and Chigari as inlet and empties into river

Benue. The Lake is perennial; Chigari and Nafari take their course from the Mandara highland on entering Nigeria. They meanders along their ways with continues deposition of alluvia's and sands, leading to formation of many oxbow lakes within the geographical location of the Benue (Adebayo and Tukur, 1999). Three sampling sites along the stretch of the lake during the period of the study, in choosing the point, preference was given to such factors as point of intense discharge into the lake from the Agricultural and domestic waste as Lower lake Njoboliyo (LLN) Station (A.) and upper Lake Njoboliyo (ULN) Station (B.) As point of less discharge from the urban domestic, agricultural wastes, and as well middle Lake Njoboliyo (MLN) Station (C) which is the centre of the Lake Njoboliyo.

Duration of sampling

The study was conducted for four months (March to June). The concentration of heavy metals in *C. gariepinus* organs (muscles gills and liver) were evaluated in the laboratory for the period of this study by taking the sample monthly.

Sampling methods

Fishing was done late at night with the help of professional local fishermen. Fish samples were collected from site A, site B and site C during the period of this study for evaluation of heavy metals concentration. The fish samples were kept refrigerated and transferred cold to the laboratory for analysis.

Digestion and determination of heavy metals in fish samples

Fish species (*C. gariepinus*) were collected monthly from each site for heavy metals analysis. The fish samples were separated and washed with running water before dissecting with sterile scissors to remove gills, liver and muscles. The wet digestion technique was used as described by AOAC (1990). The digests were kept in plastic bottles and heavy metal Zinc (Zn), Iron (Fe), Cupper (Cu), and Cadmium (Cd) concentrations were determined using an Atomic Absorption Spectrophotometer (AAS)-VGP210.

Data Analysis

Data of the bioaccumulation of heavy metals that was obtained in the gill, liver and muscle was expressed as mean + standard deviation (SD) and was analysed using one-way ANOVA and Duncan multiple ranged test was used to determine the monthly mean significant differences of bioaccumulation at the various sampling stations.

Results

Accumulation of Heavy metals in *Clarias gariepinus* Organs (Muscles, gills and liver)

The mean concentration of heavy metals in *clarias gariepinus* organs (muscles, gills and liver) for the period of four months (March to June) from Lake Njoboliyo as shown below:

Cadmium (Cd)

The monthly mean concentration of cadmium (Cd) in muscles ranged between $(0.01 \pm 0.00 \text{ mg/kg})$ and $(0.44 \pm 0.36 \text{ mg/kg})$. The highest concentration of cadmium $(0.44 \pm 0.36 \text{ mg/kg})$ was recorded in March at station C while the lowest concentration $(0.01 \pm 0.00 \text{ mg/kg})$ was recorded at station A and C in April and June respectively. There was no significant difference in cadmium (Cd) concentration in muscle ($P > 0.05$) in station B and C during the study period, but there was significant different in station A in April to June ($P < 0.05$).

The monthly concentration of cadmium (Cd) in Gills ranged from $(0.01 \pm 0.00 \text{ mg/kg})$ to $(0.09 \pm 0.04 \text{ mg/kg})$. The highest concentration of Cadmium $(0.09 \pm 0.04 \text{ mg/kg})$ was recorded at station A in the month of March while the lowest $(0.01 \pm 0.00 \text{ mg/kg})$ was observed at station A in the month of May. The concentration of cadmium (Cd) in gills indicated that there was no statistical difference ($p > 0.05$).

The monthly mean concentration of cadmium (Cd) in the liver ranged from $(0.02 \pm 0.02 \text{ mg/kg})$ to $(0.09 \pm 0.03 \text{ mg/kg})$ in the month of March and April respectively. The lowest concentration of Cadmium $(0.02 \pm 0.02 \text{ mg/kg})$ was detected in the month of April and June at station A While the highest concentration $(0.09 \pm 0.03 \text{ mg/kg})$. There was statistical difference in station A and B in the months of March and April respectively ($p < 0.05$).

Copper (Cu)

The monthly mean concentration of Copper ranged from $(0.09 \pm 0.04 \text{ mg/kg})$ to $(0.27 \pm 0.04 \text{ mg/kg})$. The highest concentration of Copper $(0.27 \pm 0.04 \text{ mg/kg})$ was detected in the month of April at station A and the lowest concentration of Copper $(0.09 \pm 0.04 \text{ mg/kg})$ was recorded in the month of March at station A. The concentration of copper (Cu) in the muscle were statistically different from each other at station A, but station B and C are not statistically different from each other ($p > 0.05$).

The monthly mean concentration of copper in the gills ranged from $(0.15 \pm 0.07 \text{ mg/kg})$ to $(0.35 \pm 0.09 \text{ mg/kg})$. The lowest concentration $(0.15 \pm 0.07 \text{ mg/kg})$ was obtained in the month of April at station C while the highest concentration $(0.35 \pm 0.09 \text{ mg/kg})$ was at station A during the month of March. There was no significance different in station B and C. ($p > 0.05$). But there was statistical difference at station A ($p < 0.05$).

The concentration of copper (Cu) in liver, during the period of the study period indicated that the level of concentration in station A, B and C are significantly different from each other at ($p > 0.05$) from the months of April to June. The highest concentration of Copper $(1.14 \pm 1.18 \text{ mg/kg})$ was detected at station C in the month of May while the lowest concentration $(0.18 \pm 0.03 \text{ mg /kg})$ was detected at station A in the month of April.

Iron (Fe)

The monthly mean concentration of iron (Fe) in the muscle of *Clarias gariepinus* ranged from $(2.20 \pm 0.50 \text{ mg/kg})$ to $(4.02 \pm 0.35 \text{ mg/kg})$. The highest concentration $(4.02 \pm 0.35 \text{ mg/kg})$ was detected at station A in the month of May while the lowest concentration of iron (Fe) $(2.20 \pm 0.50 \text{ mg/kg})$ was obtained at station A in the month of March. There was no significant difference between each other at station B and C ($p > 0.05$).

The mean concentration of iron (Fe) in gills of *Clarias gariepinus* during the period of the study indicated that the highest concentration $(3.84 \pm 0.84 \text{ mg/kg})$ was observed in the month of May at station B while the lowest concentration $(2.18 \pm 0.85 \text{ mg/kg})$ was also recorded at station B in the month of March. There was statistical different at station A during the study period ($p < 0.05$) but there was no statistical difference between each other at station B and C ($p > 0.05$).

The mean concentration of iron (Fe) in the liver of *Clarias gariepinus* shows that Station A recorded the highest concentration of $(3.19 \pm 0.71 \text{ mg/kg})$ in the month of June and the lowest concentration $(1.68 \pm 0.08 \text{ mg/kg})$ was detected at station B in the month of March. Station A was statistically

different with stations B and C during the study period ($p < 0.05$).

Zinc (Zn)

The mean concentration of zinc (Zn) in the muscle ranged from $(0.12 \pm 0.02 \text{ mg/kg})$ to $(0.20 \pm 0.03 \text{ mg/kg})$. Station A and B has the highest concentration of $(0.20 \pm 0.30 \text{ mg/kg})$ in the month of April and June while the lowest concentration of Zinc $(0.12 \pm 0.02 \text{ mg/kg})$ was recorded at station A in the month of May. Stations B and C were not statistically different from each other ($p < 0.05$).

The mean concentration of zinc (mg/kg) in the gills of *Clarias gariepinus* ranged from $(0.13 \pm 0.02 \text{ mg/kg})$ to $0.23 \pm 0.02 \text{ mg/kg}$. Station B and C are not significantly different from each other but station A in the month of May was statistically different ($p > 0.05$). The concentration of zinc (Zn) in the liver of *Clarias gariepinus* ranged between $(0.12 \pm 0.03 \text{ mg/kg})$ and $0.20 \pm 0.03 \text{ mg/kg}$. The highest concentration $(0.20 \pm 0.03 \text{ mg/kg})$ was observed at station B in the month of April while the lowest concentration $(0.12 \pm 0.03 \text{ mg/kg})$ was recorded at station C in month of June. There was no statistical different between each other at station B and C ($p < 0.05$).

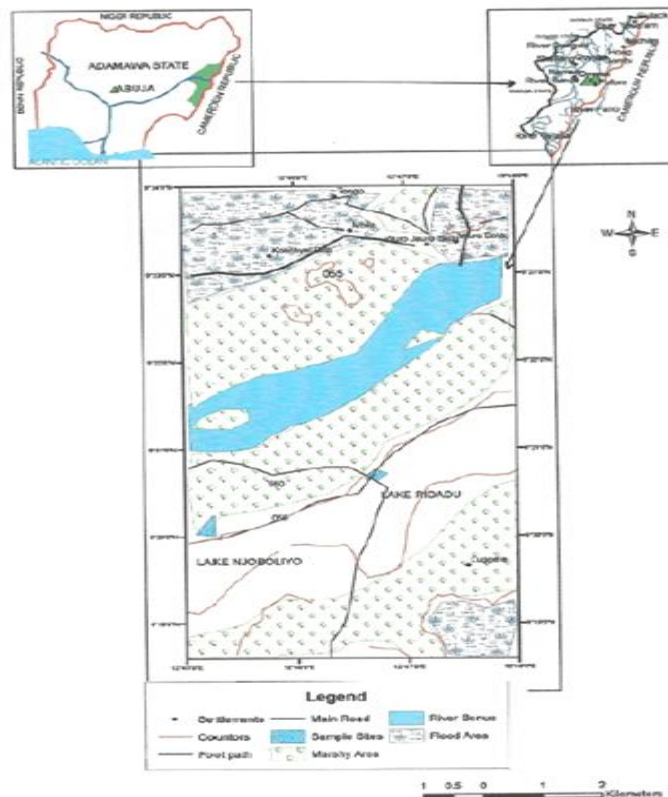


Figure 1: map showing study area (Lake Njoboliyo)

Table 1. Mean ± SD error of Cadmium (Cd) concentration in the Muscles, Gills and liver of *Clarias gariepinus* in Lake Njobiliyo

Months	Sites A Muscle	B	C	Sites A Gills	B	C	Sites A Liver	B	C
March	0.27 ^a ±0.25	0.27 ^a ±0.36	0.44 ^a ±0.36	0.09 ^a ±0.04	0.07 ^a ±0.05	0.05 ^a ±0.05	0.09 ^b ±0.03	0.04 ^a ±0.04	0.02 ^a ±0.04
April	0.01 ^b ±0.00	0.02 ^a ±0.01	0.02 ^a ±0.01	0.05 ^a ±0.03	0.06 ^a ±0.04	0.01 ^a ±0.04	0.02 ^a ±0.02	0.09 ^b ±0.03	0.04 ^a ±0.03
May	0.06 ^b ±0.02	0.02 ^a ±0.03	0.01 ^a ±0.03	0.01 ^b ±0.00	0.02 ^a ±0.01	0.02 ^a ±0.01	0.05 ^a ±0.03	0.08 ^a ±0.04	0.04 ^a ±0.04
June	0.02 ^b ±0.01	0.02 ^a ±0.01	0.01 ^a ±0.01	0.09 ^b ±0.02	0.02 ^a ±0.03	0.05 ^a ±0.03	0.02 ^a ±0.02	0.05 ^a ±0.03	0.03 ^a ±0.03

Table 2. Mean ± SD error of Copper (Cu) concentration in the Muscles, Gills and liver of *Clarias gariepinus* in Lake Njobiliyo

Months	Sites A Muscle	B	C	Sites A Gills	B	C	Sites A Liver	B	C
March	0.09 ^a ±0.04	0.20 ^a ±0.06	0.15 ^a ±0.06	0.35 ^{ab} ±0.09	0.25 ^a ±0.12	0.25 ^a ±0.12	0.21 ^{ab} ±0.01	0.26 ^b ±0.02	0.22 ^a ±0.02
April	0.27 ^b ±0.04	0.26 ^a ±0.06	0.21 ^a ±0.06	0.22 ^b ±0.05	0.24 ^a ±0.07	0.15 ^a ±0.07	0.18 ^{ab} ±0.03	0.20 ^b ±0.05	0.26 ^a ±0.05
May	0.23 ^b ±0.03	0.22 ^a ±0.04	0.22 ^a ±0.04	0.18 ^b ±0.05	0.26 ^a ±0.07	0.21 ^a ±0.07	0.77 ^b ±0.83	0.77 ^a ±1.18	1.14 ^a ±1.18
June	0.23 ^b ±0.05	0.20 ^a ±0.07	0.20 ^a ±0.07	0.21 ^b ±0.05	0.25 ^a ±0.07	0.26 ^a ±0.07	0.19 ^b ±0.05	0.21 ^a ±0.07	0.26 ^a ±0.07

NB: Values with the same superscript are not significantly different from each other and values with different superscript are significantly different from each other (P<0.05)

Table 3. Mean ± SD error of Iron (Fe) concentration in the Muscles, Gills and liver of *Clarias gariepinus* in Lake Njobiliyo

Months	Sites A Muscle	B	C	Sites A Gills	B	C	Sites A Liver	B	C
March	2.20 ^b ±0.50	3.22 ^a ±0.71	2.82 ^a ±0.71	2.44 ^b ±0.60	2.18 ^a ±0.85	3.05 ^a ±0.85	2.05 ^b ±0.13	1.68 ^a ±0.18	1.90 ^a ±0.18
April	3.26 ^a ±0.48	2.71 ^a ±0.68	3.11 ^a ±0.68	2.70 ^b ±0.62	2.93 ^a ±0.88	2.32 ^a ±0.88	2.49 ^b ±0.30	3.02 ^a ±0.43	2.59 ^a ±0.43
May	4.02 ^{ab} ±0.35	2.21 ^a ±0.49	2.75 ^b ±0.49	3.06 ^b ±0.59	3.84 ^a ±0.84	2.30 ^a ±0.84	2.51 ^b ±0.44	2.70 ^a ±0.62	2.39 ^a ±0.62
June	2.69 ^b ±0.37	2.61 ^a ±0.53	2.71 ^a ±0.53	2.90 ^b ±0.36	2.55 ^a ±0.51	3.03 ^a ±0.51	3.19 ^b ±0.71	2.40 ^a ±1.01	2.70 ^a ±1.01

Table 4. Mean ± SD error of Zinc (Zn) concentration in the Muscles, Gills and liver of *Clarias gariepinus* in Lake Njobiliyo

Months	Sites A Muscle	B	C	Sites A Gills	B	C	Sites A Liver	B	C
March	0.20 ^a ±0.03	0.20 ^a ±0.04	0.17 ^a ±0.04	0.14 ^b ±0.01	0.15 ^a ±0.02	0.13 ^a ±0.02	0.17 ^a ±0.02	0.19 ^a ±0.03	0.17 ^a ±0.03
April	0.16 ^b ±0.03	0.20 ^a ±0.04	0.19 ^a ±0.04	0.13 ^b ±0.03	0.18 ^a ±0.04	0.18 ^a ±0.04	0.16 ^b ±0.02	0.20 ^a ±0.03	0.19 ^a ±0.03
May	0.12 ^{ab} ±0.02	0.20 ^a ±0.03	0.18 ^a ±0.04	0.18 ^a ±0.02	0.16 ^a ±0.02	0.23 ^a ±0.02	0.18 ^b ±0.02	0.18 ^a ±0.03	0.17 ^a ±0.03
June	0.20 ^b ±0.03	0.16 ^a ±0.04	0.18 ^a ±0.04	0.20 ^b ±0.03	0.18 ^a ±0.04	0.16 ^a ±0.04	0.15 ^b ±0.02	0.18 ^a ±0.03	0.12 ^a ±0.03

NB: Values with the same superscript are not significantly different from each other and values with different superscript are significantly different from each other (P<0.05)

Discussion

The monthly mean concentration of Cadmium (Cd) in the fish ranged from $(0.01 \pm 0.00$ to 0.44 ± 0.3 mg/kg) in muscles, $(0.01 \pm 0.00$ to 0.09 ± 0.04 mg/kg) in the gills and $(0.02 \pm 0.09$ to 0.09 ± 0.03 mg/kg) in the liver recorded in March to June. The Concentration of cadmium in muscle, gills and liver were all above the permissible limits of 0.05 mg/kg set by WHO (2003), FAO (1985), APHA (1990). The level of Cd in the organs showed that highest levels were recorded in the muscles while lower levels of the heavy metal were found in the gills and liver respectively. This is not in agreement with the work of (Gorar *et al.*, 2012) who reported high accumulation of heavy metals in liver and gills tissues to the metallothionein proteins which synthesized in the liver and gills tissues when fish are exposed to heavy metals and detoxify them. The high concentration of Cadmium in the muscles may be as a result of bioaccumulation over a period of time. This agreed with the work of Evans *et al.* (1993) and (Begum *et al.*, 2005) who reported that fish accumulated heavy metals from feed ingredient, sediments and surrounding environment and can be considered as one of the significant indicator of freshwater system for the impact of metal pollution. Acute cadmium intoxication is a potentially fatal but very rare event as reported by (Bronstein *et al.*, 2011). Chronic exposure to cadmium (Cd) presents a larger threat to human health the (Gorar *et al.*, 2012). It can result in the accumulation of cadmium complexes in the kidney (potential bone mineralization) and decreased lung function, it is also a known human carcinogen (Sigel *et al.*, 2013) it has no known beneficial role in human metabolism.

The monthly mean concentration of Copper (Cu) in fish ranged from $(0.09 \pm 0.04$ to 0.27 ± 0.04 mg/kg) in muscle, $(0.15 \pm 0.07$ to 0.35 ± 0.09 mg/kg) in gills and 0.18 ± 0.03 to 1.14 ± 1.18 mg/kg) in fish liver recorded in the months of June to November. The levels of copper recorded in the fish parts were lower than the permissible limit 3.0 mg/kg set by WHO (2003) FAO (1985), APHA (1990). The result revealed that the concentration of copper (Cu) has bio-accumulated high in liver, followed by gills and the least was in muscle. The results showed similarities with the work reported by Wright and Baccareli, (2007) who reported that liver and gills have high accumulation of copper with liver serving as the primary storage, which is particularly susceptible to overload and related damage. Although copper plays an important role in human nutrition, toxicity at elevated exposure has been reported. Excessive copper (cu) (through overexposure or from copper metabolism disease like Wilson disease) can be neurotoxin (Wright and Baccareli, 2007).

The concentration of zinc (Zn) obtained from this study in muscles, gills and liver were within the permissible limits of 100 mg/kg for food fish set by WHO (2003) and FAO (1985). The results further showed that gills of recorded the highest concentration of Zn than Muscles and Liver. This finding agreed with the work of Zira *et al.*, (2015) that target organs such as gills and intestines are metabolically active parts that can accumulate heavy metals in higher levels and are considered to be the dominant site for contaminant uptake because of their anatomical and/or physiological properties that maximize absorption efficiency from water. Zinc is an essential element in animals diet, but it is regarded as potential hazard for both animals and human health (Datar and Vashishtha, 1990). ATSDR.(2005) reported ingesting high level of zinc for several months may cause Anaemia, damage the pancreases and decrease the level of high density lipoprotein (HDL) cholesterol. These fears are allayed in this study because of its low concentration.

The study revealed that the concentration of iron in muscles, gills and liver were below the recommended maximum permissible limit of 100 mg/kg set by WHO, (2003) and FOA, (1985). During the period of the study Iron (Fe) was the highest in bio-accumulation among the heavy metals investigated. This may be due to unique nature of Iron metabolism. Iron (Fe) toxicity is the most common metal toxicity worldwide (Kontohorghes *et al.* 2004). The symptom of Iron overload especially in the context of disease hemochromatosis is skin hyper pigmentation (to a bronze or grey colour) due to deposits of Iron toxicities is also associated with joint disease, Arrhythmia, heart failure, increase risk in the liver related disorder, breast cancer Nelson *et al.* (1995).

Conclusion

In conclusion, essential metal such as copper, Iron and zinc investigated were found to have accumulated in varying degree but within the maximum permissible limit set by WHO (2003), FAO (1985), APHA (1990). Non essential metal cadmium (Cd) was found to have bio-accumulated above the permissible limit set by WHO (2003), FAO (1985), APHA (1990). The present results shows that the Fish at Lake Njoboliyo is polluted with Cadmium (Cd) and it can risk getting polluted with other heavy metals and may pose a health challenges to human and fish species.

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