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Assessment of Heavy Metals in *Clariasgariepinus*Organs (Gills, Liver and Muscles) at Kiri Reservoir, Adamawa State, Nigeria

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Abstract: A study on assessment of heavy metals was carried out fortnight using standard methods for the period of six months**.** *Bioaccumulations of heavy metals including Cadmium, Zinc, Iron, Copper, Manganese and Lead (Cd, Zn, Fe, Cu, Mn and Pb) in catfish (Clariasgariepinus) organs (gills, liver and muscle) were investigated. Zinc, Iron, Copper and Manganese (Zn, Fe, Cu, and Mn) at station A, B and C recorded concentrations (0.531mg/kg, 7.07mg/kg, 0.489mg/kg, & 0.177mg/kg) within the international permissible limits in fish organs. Cadmium (Cd) and Lead (Pb) recorded concentrations (0.099mg/kg &0.917mg/kg) above the international permissible limit in fish organs. Gills and liver of Clariasgariepinus contained the highest concentration of most of the detected heavy metals, while muscles appeared to be the last preferred site for the bioaccumulation of heavy metals. The edible part (Muscle) of Clariasgariepinus showed higher levels of Cadmium (Cd) and Lead (Pb) at the study area. This may be due to bioaccumulation over a period of time in the muscles of Clariasgariepinus.*

Keywords: *AAS,Clariasgariepinus, Heavy Metals, Kiri,Pollution.*

I. Introduction

Water is the major constituents of living matter. From 50% to 90% of the weight of living organisms is water. Water covers 71% of the Earth's surface [1]. It is vital for all known forms of life. The aquatic environment with its water quality is considered the main factor controlling the state of health and disease in both cultured and wild fishes. Pollution of the aquatic environment by inorganic and organic chemicals is a major factor posing serious threat to the survival of aquatic organisms including fish, [2].

Water pollution is a major global problem which requires on-going evaluation and revision of water resource policy at all levels (international down to individual aquifers and wells). Unfortunately, the availability and quality of water have been impacted upon by both natural and anthropogenic sources leading to poor quality and productivity of aquatic Environment [3]. It has been suggested that it is the leading worldwide cause of deaths and diseases, and that it accounts for the deaths of more than 14,000 people daily[4].Water pollution occurs when a body of water is adversely affected due to addition of large amounts of materials to the water, making it unfit for intended use. Such water is considered polluted. Two forms of water pollution exist; point source and nonpoint source. Point sources of pollution occur when harmful substances are emitted directly into a body of water. This includes effluent sewage treatment works, or of waste from factories [5]. While nonpoint source delivers pollutants indirectly through environmental changes, for example fertilizer or herbicide application is carried into streams by rain in form of run-off which in turn affects aquatic life [5]. Technology exists for point sources of pollution to be monitored and regulated although political factors may complicate matters. Nonpoint sources are much more difficult to control. Pollution arising from nonpoint sources account for majority of contaminants in streams and lakes. Pollution of the aquatic environment by inorganic chemicals has been considered a major threat to the aquatic organisms including fishes. The agricultural drainage water containing pesticides and fertilizers and effluents of industrial activities and runoffs in addition to sewage effluents supply the water bodies and fishes with huge quantities of inorganic anions and heavy metals [6]. The most anthropogenic sources of metals are industrial, petroleum contamination and sewage disposal [7].

Heavy metals are ubiquitous in the environment [8], readily dissolved in and transported by water and can be taken up by aquatic organism due to bioaccumulation and bio-magnifications in the chain either as such or their metabolites thus causing concern on the animal at the top of the food chain [9].Some heavy metals such as Pb, Cd, Hg, which are non-essential for biological system are the most toxic while continuous exposure of aquatic organism to their low concentration may result in bioaccumulation and subsequent transfer to man through food web [10,11]. Heavy metal can be incorporated into food chains and concentrated in aquatic organisms to a level that affects their physiological state. Of the effective pollutants are the heavy metals which have drastic environmental impact on all organisms. Trace metals such as Zn, Cu and Fe play a biochemical role in the life processes of all aquatic plants and animals; therefore, they are essential in the aquatic environment in trace amounts [12]. Anthropogenic heavy metals following their introduction to water bodies through atmospheric fallout or through the use of domestic antiseptic soaps and pesticides in our farms are washed into water and concentrated by aquatic organisms [13].

Fish have been the most popular choice as test organisms because they are presumably best-understood organisms in the aquatic environment [14] and also due to their importance to man as a protein source (15). Therefore, this research on a fish species that are of commercial importance in Adamawa state and generally worldwide, is to determine the levels of contamination and the bioaccumulation of some heavy metals such as; Iron, Zinc, Copper, Manganese, Cadmium and Lead (Fe, Zn, Cu, Mn, Cd and Pb) in fish organs (gills, liver and muscles) of commercially important fish species (Clariasgariepinus) in Kiri reservoir, Adamawa State, Nigeria.

II. Material And Methods

1.1 Study Area

Kiri Reservoir is on coordinates 9°40′47″N 12°00′51″E and on the southern part of Adamawa State, Nigeria [16]. It is situated within Shelleng Local Government Area and about 20km from Numan Local Government. It is a 1.2 km long, 20 m high zoned embankment with an internal clay blanket. Three sampling station were identified during the studies, these are; **Station A** (Along BabanDaba), **Station B** (Kiri) and **Station C** (Tallum). The stations were randomly selected after preliminary studies of the Reservoir.

2.2Duration of Sampling

The sample collection lasted for a period of six months (July-December, 2014). Concentrationof Heavy metals in Clariasgariepinus organs (gills, liver and muscles) were assessedin laboratory for the period of this studyby taking the sample fortnight.

2.3Sampling Methods

Fishing was done during late night with the help of professional local fishermen. Fish samples were collected from **STATION A** “Along BabanDaba”, **STATION B** “Kiri, Behind the Dam” and **STATION C** “Tallum” during the period of this study for measuring heavy metals concentration. The fish samples were kept refrigerated and transferred cold to the laboratory for analysis.

2.4 Digestion and Determination of Heavy Metals in Fish Samples

Fish species (Clariasgariepinus) were collected fortnight from each station for heavy metals analysis. The collected fish were washed with deionized water, put in clean plastic bags and store to freeze until analysis were carryout.Two grams of the tissue sample (wet weight) were subjected to digestionby adding 10ml of freshly prepared 1:1 concentrated HNO3-HCLO3 in beaker, cover with a watch glass till initial reaction subsided in about 1 hour. The digests were kept inplastic bottles and heavy metal (Iron (Fe), Zinc (Zn), Manganese (Mn), Cupper (Cu), Cadmium (Cd) and Lead (Pb) concentrations were determined using anAtomic Absorption Spectrophotometer (AAS)-VGP210. The concentrations of heavy metals were expressed in mg/kg wet weight for fish organs [17].

III. Results And Discussion

3.1 Cadmium (Cd)

The concentration of Cadmium (Cd) in gills ranged between 0.072mg/kg and 0.099mg/kg (Table 1). The highest concentration of 0.099mg/kg was detected in the month of July at both Stations A, B and C. The lowest concentration 0.072mg/kg was detected at station C in the month of September. There was no significant different in the Cadmium (Cd) concentration in the gills at ($P>0.05$). The concentration of Cadmium (Cd) in liver ranged between 0.062mg/kg and 0.095mg/kg (Table 1). The lowest concentration of 0.062mg/kg were detected in the month of September at Station C and the highest concentrationof 0.095mg/kg were detected at Station A, B and C in the month of July. The concentration of Cadmium (Cd) in the liver indicates that there was no statistical different between Station A, B and C at ($P>0.05$). While the concentration of Cadmium (Cd) in the muscles ranged between 0.070mg/kg and 0.099mg/kg (Table 1). The highest concentration of 0.099mg/kg was observed at station A in the month July. Lowest concentration of 0.070mg/kg was detected at station B in the month of September. In July, there were statistical difference in the Cadmium (Cd) concentration at ($P<0.05$), but there was no statistical different in Cadmium (Cd) concentration at station A, B and C in the month of August, September, October November and December at ($P>0.05$).

The present results revealed that the concentration of Cadmium (Cd) in fish organs has bio-accumulated more with the highest concentration in gills and muscles than that of liver. This is at variance with the work of [18] who reported high accumulation of heavy metals in liver and gills tissues to the metalothionein 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. Concentration of Cadmium (Cd) in the gills, liver and muscles has reach the maximum permissible limit of 0.05mg/kg set by [19],[20],[21].This source of water supply is susceptible to pollutiondue to heavy human dependency on Kiri reservoir and it may be as a result of runoff from waste dump around the reservoir. Notably there is indiscriminate dumpingof waste and agricultural practices taking place around the reservoir. Waste disposal around the reservoir is through open dump for solid waste, pit latrines, septic tank for human wastes. Liquid wastes are admitted through the major drainage networks and emptied into Kirireservoir.Acute Cadmium (Cd) intoxication is a potential fatal, but very rare event [22]. Chronic exposure to Cadmium (Cd) presents a larger threat to human health [23]. It can results in the accumulation of Cadmium complexes in the kidney (potential bone mineralization) and decreased lung function; it's also a known human carcinogen [24]. It has no known beneficial role in human metabolism. Cadmium (Cd) is found in soil and Ocean water and up to 10% of the Cadmium (Cd) ingested from dietary source such as food and water is observed by the body. The implication of Cadmium (Cd) in this work is that, Cadmium (Cd) may pose health hazard to fishesand consumers, and may results to Cadmium (Cd) related disorder such as complexes in the kidney.

3.2 Zinc (Zn)

The concentration of Zinc (Zn) in gills ranged between 0.251mg/kg and 0.462mg/kg (Table 2). Station A has the highest concentration of 0.462mg/kg in the month of July and the lowest concentration 0.251mg/kg was detected at station B in the month of September. In the month of July and December, there were statistical difference in the concentration of Zinc (Zn) in the gills at the stations at ($P<0.05$), but there was no statistical different in Zinc (Zn) concentration in gills at station A, B and C in the month of August, September, October, and November at ($P>0.05$).The concentration of Zinc (Zn) in the liver ranged between0.118mg/kg and 0.531mg/kg (Table 2). The highest concentration 0.531mg/kg was observed at station A in the month of July and lowest 0.118mg/kg was detected in the month of September at station B (Table 2). The concentrations of Zinc (Zn) in the Liver at station A, B and C were statistically different from each other throughout the period of the study at ($P<0.05$). While the concentration of Zinc (Zn) in the muscles ranged between 0.109mg/kg and 0.243mg/kg (Table 2). The highest concentrations of 0.243mg/kg were detected at station A in the month of July, while station B has the lowest concentration of 0.109mg/kg in the month of September. In the month of September the concentration in station A, B and C were not statistical different at ($P>0.05$), but there were statistical different in the month of July, August, October, November and December at ($P<0.05$).

The concentration of Zinc (Zn) obtained from this study in gills, liver and muscles were within the permissible limits of 100mg/kg for food fish set by [19], [20], [21]. This agreed with [18] who reported the highest accumulation of heavy metals in liver and gills tissues to the metalothionein proteins which synthesized in the liver and gills tissues when fish are exposed to heavy metals and detoxify them.Zinc (Zn) is an essential element in animal's diet, but it is regarded as potential hazard for both animals and human health [25]. Highest concentration of Zinc (Zn) may cause some toxic effects. [26]reported that 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.

3.3 Iron (Fe)

The concentration of Iron (Fe) in gills ranged between3.267mg/kg and 4.548mg/kg (Table 3). Station A has the highest concentration of 4.548mg/kg in the month of July, while the lowest concentration of 3.267mg/kg was detected at station C in the month of September. The concentration of Iron (Fe) in the gills were statistically different in Station A, B and C at ($P<0.05$). The concentration of Iron (Fe) in the Liver of Clariasgariepinus ranged between 7.073mg/kg and 13.856mg/kg (Table 3). Station A has the highest concentration of 13.856mg/kg in the month of July, and station C recorded lowest concentration of 7.073mg/kg in the month of September. In the month of August and September, the concentrations of Iron (Fe) were not statistical different from each other at station A, B and C at ($P>0.05$), but Iron (Fe) concentration were statistically different in the month of July, October, November and December at the same stations at ($P<0.05$).Whilethe concentration of Iron (Fe) in the Muscles of Clariasgariepinus ranged between 2.101mg/kg and 3.33mg/kg (Table 3). The highest concentration of 3.338mg/kg was detected at station A in the month of July, and the lowest concentration 2.101mg/kg was detected in the month of September at station B. The concentration of Iron (Fe) were statistically different in the muscles throughout the period of this study at station A, B and C at ($P<0.05$).

The results of the concentration of Iron (Fe) in the gills, liver and muscles agreed with the work of [27], who reported that liver and gills accumulate highest concentration of Iron (Fe), with liver serving as the primary source of iron storage, which is particularly susceptible to overload and related damage. This shows that the concentration of Iron (Fe) during the study period was in several fold below the recommended maximum permissible limit 0f 100mg/kg set by [19],[20],[21].Iron (Fe) was the highest in bioaccumulation among the heavy metals investigated in this study; this may be due to the unique nature of Iron metabolism.Iron (Fe) toxicity is the most common metal toxicity worldwide [28]. The classic symptom of Iron overloaded, especially in the context of disease hemochromatosis is skin hyperpigmentation (to a bronze or grey colour) due to deposits of Iron and melanin complexes in the skin. Iron toxicities is also associated with joint disease, Arrthythmia, heart failure, increase risk in the liver related disorder, cancer and breast [29].

3.4 Copper (Cu)

The concentrationof copper (Cu) in the Liver of Clariasgariepinus, ranged between 0.351mg/kg and 0.489mg/kg (Table 4). Copper were detected at station A only throughout the period of the study. The month of July has the highest concentration of 0.489mg/kg, and lowest concentration of 0.351mg/kg in the month of September. The concentration of copper (Cu) in the Liver were statistical different from each other at station A, B and C throughout the period of this study at ($P<0.05$). The concentration of Copper (Cu) in the gills and muscles where not detected throughout the period of this studies.

The results also revealed that copper (Cu) has bio-accumulated only in the liver.This agreed with [18] who reported the highest accumulation of heavy metals in liver and gills tissues to the metalothionein proteins which synthesized in the liver and gills tissues when fish are exposed to heavy metals and detoxify them. The present study revealed that the bio-accumulation of copper (Cd) in the liver is within the maximum permissible limits of 3.0mg/kg set by [19],[20],[21] and other relevant agencies.Although copper (Cu) 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 Wilsons disease) can be neurotoxic [30], and acute unintentional copper toxicities are more frequently reported than those of Arsenic [22].

3.5 Manganese (Mn)

The Concentrations of 0.001mg/kg were detected in gills of Clariasgariepinus in the month of July, November and December at station A only (Table 5). The manganese (Mn) concentration remains undetected in the month of August, September and October. The concentration of manganese (Mn)in the gills were not statistical different from each other at ($P>0.05$). While the concentration of Manganese (Mn) in the Muscles of Clariasgariepinus ranged between0.102mg/kg and 0.177mg/kg (Table 5). Station B has the highest concentration of 0.177mg/kg in the month of July, while the lowest concentration of 0.102mg/kg is experienced at station B in the month of October. In the month of August, September, October and November, the concentration of Manganese (Mn) in muscles at station A, B and C were not detected, but there was a statistical different in the month of July and December at same stations at ($P<0.05$). The concentration of Manganese r (Mn) in the liver where not detected throughout the period of this studies.

Manganese (Mn) is an essential micro nutrient, as it functions as a co-factor for many enzymes activities [31]. High concentration interferes with Central Nervous System of vertebrates by inhibiting dopamine formation as well as interfere ring with other metabolic pathways, such as Sodium (Na) regulation which ultimately can cause death. High manganese levels are a matter of concern as the consumption of manganese contaminated fish could result in the Manganese related disorders in the consumers. In the present study, the concentration of manganese in the gills and muscles is below the maximum permissible limits of 1.0mg/kg for food fish set by [19], 20], [21]. Manganese was not detected in the liver throughout the period of the study**.**

3.6 Lead (Pb)

The concentration of Lead (Pb) in the gills of Clariasgariepinus ranged between 0.610mg/kg and 0.917mg/kg (Table 6). The lowest and highest concentration of 0.610mg/kg and 0.917mg/kg were detected at station B in the month of September and July respectively. There were no statistical different in the concentration of Lead (Pb) in the month of July and September at ($P>0.05$), station A, B and C were statistically different in the month of August, October, November and December at ($P<0.05$).The concentration of Lead (Pb) in the liver of Clariasgariepinus Ranged between0.007mg/kg and 0.463mg/kg (Table 6). The highest concentration of 0.463mg/kg was detected at station B in the month of July. The lowest concentration of 0.007mg/kg is experienced at station A in the month of December. The concentration of Lead were statistically different throughout the period of thisstudy at station A, B and C at ($P<0.05$). While the concentration of Lead (Pb) in the muscle of Clariasgariepinus ranged between 0.001mg/kg and 0.455mg/kg (Table 6). The highest concentration of 0.455mg/kg was observed at station B in the month of July. The lowest concentration of 0.001mg/kg is experienced at station C in the month of December. In the month of September, the concentration of Lead (Pb) were not statistical different at Station A, B and C at ($P>0.05$), but the concentration were statistically different in the month of July, August, October, November and December at same stations at ($P<0.05$).

In the present study, Lead (Pb) concentration in the gills, liver and muscles, agreed with [18]who reported the highest accumulation of heavy metals in liver and gills tissues to the metalothionein proteins which synthesized in the liver and gills tissues when fish are exposed to heavy metals and detoxify them. According to [19], [20], [21], the maximum accepted limits is 0.2mg/kg for food fish.The present results indicated that the concentration levels of Lead (Pb) was higher than the permissible limits set for human consumption by various regulatory agencies and therefore indicated possible health risks associated with consumption of these fish.This source of water supply is susceptible to pollutiondue to heavy human dependency on this Kiri reservoir and it may be as a result of runoff from waste dump around the reservoir. Notably, there is indiscriminate dumpingof waste and agricultural practices taking place around the reservoir. Waste disposal around the area is through open dump for solid waste, pit latrines, septic tank for human wastes. Liquid wastes are admitted through the major drainage networks and emptied into Kirireservoir.Lead (Pb) may enter the aquatic environment through soil erosion and leaching gasoline combustion, municipal and industrial wastes and runoff [32].Lead (Pb) is considered as toxic but non-essential metal implying that it has no known function in the biochemical processes [33]. According to [34] pregnant women exposed to lead were found to have high rates of still births and miscarriage. [35]Also reported that Lead (Pb) has caused mental retardation among children. Hypertension caused by Lead exposure has also been reported.

IV. Conclusion

In conclusion, essential metals such as Iron, Zinc, Copper and Manganese (Fe, Zn, Cu&Mn) investigated were found to have accumulated in varying degree but within the maximum permissible limits set by [19], [20], [21]. Non-essential metals Lead (Pb) and Cadmium (Cd) was found to have bio-accumulated beyond the permissible limit.The present results shows that the Fish at Kiri Reservoir is polluted with Lead (Pb) and Cadmium (Cd) and it can risk getting polluted with other heavy metals and may pose a health challenges to human and fish species.The present results also shows that, heavy metals concentration in Fish organs (gills, Liver & Muscles) follows this order Fe>Pb>Zn>Cu>Mn>Cd, with Iron (Fe) significantly more concentrated than other metals investigated.

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Appendix:

Table 1: Heavy Metals Concentration in the Gills, Liver and Muscles of Clariasgariepinus in mg/kg

Cadmium
Station AStation BStation C

	Gills	Liver	Muscles	Gills	Liver	Muscles	Gills	Liver	Muscles
July	0.099^{a}	0.095^{a}	0.099^{a}	0.099^{a}	0.095^{a}	0.095^{a}	0.099^{a}	0.095^{a}	0.095^{a}
August	0.088^{a}	0.080^{a}	0.086^{a}	0.088^{a}	0.081^{a}	0.085^{a}	0.088^{a}	0.080^{a}	0.086^{a}
September	0.074^{a}	0.068^{a}	0.071^{a}	0.075^{a}	0.068^{a}	0.070^{a}	0.072^{a}	0.062^{a}	0.072^{a}
October	0.085^{a}	0.078^{a}	0.081^{a}	0.085^{a}	0.078^{a}	0.080^{a}	0.086^{a}	0.071^{a}	0.082^{a}
November	0.091^{a}	0.089^{a}	0.090^{a}	0.091^{a}	0.089^{a}	0.090^{a}	0.091^{a}	0.088^{a}	0.090^{a}
December	0.095^{a}	0.092^{a}	0.095^{a}	0.095^{a}	0.094^{a}	0.095^{a}	0.095 ^{a}	0.094^{a}	0.093^{a}

Source: Field survey, 2014.

Table 2: Heavy Metals Concentration in the Gills, Liver and Muscles of Clariasgariepinus in mg/kg

Zinc

	Station A			**Station B**			**Station C**		
	Gills	Liver	Muscles	Gills	Liver	Muscles	Gills	Liver	Muscles
July	0.462^{a}	0.531^{a}	0.243^{a}	0.347^{b}	0.163^{bc}	0.15^{bc}	0.358^{b}	0.283^{ac}	0.219^{ac}
August	0.392^{a}	0.451^{a}	0.206^{a}	0.294^{a}	0.138^{bc}	0.127^{bc}	0.304^{a}	0.240^{ac}	0.186^{ac}
September	0.337^{a}	0.387^{a}	0.177^{a}	0.252^{a}	0.118^{bc}	0.109^{a}	0.261^{a}	0.206^{ac}	0.159^{a}
October	0.385^{a}	0.445^{a}	0.203^{a}	0.289^{a}	0.125^{bc}	0.110^{bc}	0.300^{a}	0.226^{ac}	0.182^{ac}
November	0.421^{a}	0.495^{a}	0.210^{a}	0.313^{a}	0.135^{bc}	0.125^{bc}	0.321^{a}	0.253^{ac}	0.207^{ac}
December	0.433^{a}	0.510^{a}	0.221^{a}	0.324^{b}	0.142^{bc}	0.139^{bc}	0.334^{b}	0.278^{ac}	0.210^{ac}

Source: Field Survey, 2014

Table 3: Heavy Metals Concentration in the Gills, Liver and Muscles of Clariasgariepinus in mg/kg

Iron
Station AStation BStation C

	Gills	Liver	Muscles	Gills	Liver	Muscles	Gills	Liver	Muscles
July	4.548^{a}	13.856^{a}	3.338^{a}	4.92^{ab}	13.670^{a}	2.686^{bc}	4.176^{ac}	9.388^{b}	3.152^{ac}
August	3.923^{a}	11.191^{a}	2.870^{a}	4.231^{ab}	11.758^{a}	2.309^{a}	3.591^{ac}	8.346^{b}	2.710^{a}
September	3.559^{a}	10.183^{a}	2.611^{a}	3.858^{ab}	10.697^{a}	2.101^{a}	3.267^{ac}	7.073^{b}	2.466^{a}
October	4.094^{a}	11.710^{a}	3.002^{a}	4.427^{ab}	13.101^{ab}	2.389^{bc}	3.757^{ac}	8.447^{ac}	2.835^{ac}
November	4.337^{a}	12.798^{a}	3.101^{a}	4.512^{a}	13.312^{ab}	2.416^{bc}	3.957^{a}	8.952^{ac}	3.001^{ac}
December	4.438^{a}	12.998^{a}	3.220^{a}	4.678^{ab}	13.412^{ab}	2.589^{bc}	4.023^{ac}	9.000^{ac}	3.082^{ac}

Source: Field survey, 2014.

Table 4: Heavy Metals Concentration in the Gills, Liver and Muscles of Clariasgariepinus in mg/kg

Copper
Station AStation BStation C

	Gills	Liver	Muscles	Gills	Liver	Muscles	Gills	Liver	Muscles
July	ND	0.489^{a}	ND	ND	ND	ND	ND	ND	ND
August	ND	0.415^{a}	ND	ND	ND	ND	ND	ND	ND
September	ND	0.351^{a}	ND	ND	ND	ND	ND	ND	ND
October	ND	0.398^{a}	ND	ND	ND	ND	ND	ND	ND
November	ND	0.401^{a}	ND	ND	ND	ND	ND	ND	ND
December	ND	0.428^{a}	ND	ND	ND	ND	ND	ND	ND

Source: Field survey, 2014. ND: Not detected

Table 5: Heavy Metals Concentration in the Gills, Liver and Muscles of Clariasgariepinus in mg/kg

Manganese	**Station A**			**Station B**			**Station C**		
	Gills	Liver	Muscles	Gills	Liver	Muscles	Gills	Liver	Muscles
July	0.001[a]	ND	ND	ND	ND	0.177[ab]	ND	ND	ND
August	ND	ND	ND	ND	ND	ND	ND	ND	ND
September	ND	ND	ND	ND	ND	ND	ND	ND	ND
October	ND	ND	ND	ND	ND	0.102[a]	ND	ND	ND
November	0.001[a]	ND	ND	ND	ND	ND	ND	ND	ND
December	0.001[a]	ND	ND	ND	ND	0.166[ab]	ND	ND	ND

Source: Field survey, 2014. ND: Not detected

Table 6: Heavy Metals Concentration in the Gills, Liver and Muscles of Clariasgariepinus in mg/kg

Lead	**Station A**			**Station B**			**Station C**		
	Gills	Liver	Muscles	Gills	Liver	Muscles	Gills	Liver	Muscles
July	0.905[a]	0.246[a]	0.363[a]	0.917[a]	0.463[b]	0.455[b]	0.909[a]	0.387[b]	0.453[b]
August	0.721[a]	0.196[a]	0.292[a]	0.798[bc]	0.313[bc]	0.379[ab]	0.723[ac]	0.201[ac]	0.303[ab]
September	0.612[a]	0.135[a]	0.201[a]	0.61[a]	0.272[b]	0.201[a]	0.632[a]	0.213[b]	0.202[a]
October	0.755[a]	0.087[a]	0.113[a]	0.812[bc]	0.103[b]	0.132[a]	0.723[ac]	0.101[b]	0.101[a]
November	0.813[a]	0.082[a]	0.189[a]	0.872[bc]	0.123[b]	0.145[a]	0.852[ac]	0.113[b]	0.073[b]
December	0.741[a]	0.007[a]	0.052[a]	0.892[bc]	0.141[b]	0.153[ab]	0.732[ac]	0.113[b]	0.001[ac]

Source: Field survey, 2014.