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Research Article

Occurrence of Heavy Metals Accumulation in the Organs and Tissues of *Clarias gariepinus* from River Hadejia and Nguru Lake

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ABSTRACT

Contamination by heavy metals in fish is of significant interest. The occurrence of Heavy metals in fish is an important issue because fish are consumed as a source of protein and, when consumed, could cause serious harm to human health. The study aims to assess levels of heavy metals in different tissues of *Clarias gariepinus* obtained from the River Hadejia and Nguru Lake. The gills, liver, and muscle were dissected and analyzed for the presence of lead, cadmium, and chromium using the atomic absorption spectrophotometer. Also, oxidative enzymes were measured in the tissues of the fish using standard protocols, and histological examination was carried out to reveal alterations in tissues. Results revealed high heavy metal content in fish, for instance, fish from Hadejia River had a Pb concentration of 29.97mg/Kg, 17.53mg/Kg, and 20.93mg/Kg in the gills, liver, and muscles respectively, as Cd concentration of 2.41mg/Kg, 2.17mg/Kg and 5.43mg/Kg was observed in the gills, liver, and Muscle of fish from Nguru Lake. Antioxidant enzyme activities showed that superoxide dismutase (SOD), glutathione (GSH), and catalase (CAT) were all at elevated levels in the fish. Histology examination showed varying degrees of alterations with the gill filaments showing proliferation of cells, clubbing, lamella cell hyperplasia, and fusion in the fish at both water bodies, indicating high levels of toxicity in the fish. These results reveal contamination and a corresponding effect in antioxidant production as an adaptive response to oxidative damage, highlighting serious consequences in the consumption of fish obtained from both water bodies.

Keywords: Bioconcentration; *Clarias gariepinus*; Pollution; Safety; Toxicity

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INTRODUCTION

The aquatic ecosystem is noticeably an interaction between living organisms and their environment, when the environment is contaminated with heavy metals, it results to a threat to the wellbeing of fish and other aquatic lives and of significant health risks to consumers (Adaka, 2017) Monitoring the concentration of heavy metals in water, sediments and aquatic fauna is important as levels of heavy metals in these matrices gives vital information regarding the degree of pollution, sources of contamination and their distribution (Maurya *et al*., 2018). Pollution by heavy metals is considered a worldwide phenomenon and the bioaccumulation of these metals is detrimental to the wellbeing of fish. According to Ajala *et al*., 2022, fishing is one of the major sources of livelihood for many Nigerians and despite the introduction of modern aquaculture to increase fish production, the demand for fish consumption still outweighs the national production. For the non-essential metals e.g., aluminum (Al), cadmium (Cd), mercury (Hg), chromium (Cr), lead (Pb) their toxicity rises with increasing concentrations, the presence of heavy metals in water bodies is not only deadly to the fishes but also of significant risks to their consumers (Musa and Imam, 2021). When exposure level becomes high beyond the tolerance range, metals like cadmium, mercury, lead and chromium have been reported to be very toxic even at lower concentration. Various researchers have carried out works involving heavy metals in fish, Chukwudi *et al*. (2022), investigated heavy metals concentration in three fish species which included

Tilapia zilli, Clarias spp and *Chana obscura* in the wetlands of Niger delta. Okieke *et al.* (2021) reported the presence of heavy metals such as Cd and Pb in water, sediment and fish of Isoko region of Delta state Nigeria and they observed that Cd in concentration of 0.5mg/Kg and 67mg/Kg was recorded in the gills and muscles of the studied fish. Other works carried out with high heavy metal contents includes that of (Ighalo and Adeniyi, (2020); Abalaka *et al*., 2020 and El-Ishaq *et al*., 2016). Different sectors could be said to be responsible for the heavy metal concentrations seen in the freshwater systems of Nigeria ranging from industrial and pharmaceutical discharges (Anyakora *et al.,* 2011; James *et al.,* 2013; Ayeni; 2014). Agricultural and food Industry discharges (Okunade and Adekalu, 2013), Leachate from dumpsites (Afolayan, 2018) discharges from chemical plants, opencast mining (Okolo and Oyedotun, 2018), effluents from the refinery (Okonofua *et al*., 2021), cement production and excavations (Inyinbor *et al*., 2012; Sanusi *et al*., 2017) all these could be the projected source of pollution.

When fishes interact with pollutants from either heavy metals or pesticides, these pollutants become accumulate in the tissues of fish and they catalyze reactions that bring about reactive oxygen species (ROS) Farombi *et al*. (2007). This ROS is formed through two mechanisms which includes the formation of reactive oxygen species through redox cycling brought about as a result of the interactions of redox-active metals while metals without redox potential impair antioxidant defences, especially that of thiol- containing antioxidants and enzymes (Sevcikova *et al*., 2011; Akinwade *et al*., 2016) When the levels of ROS is raised it leads to oxidative damage including lipid peroxidation, protein and DNA oxidation and enzyme inactivation. Oxidative stress cannot be avoided in living organims, it results from imbalance between the production of ROS and antioxidant defensives in living organism (Nishida, 2011). Elevated production of ROS can be readily induced by pesticides, transitional metal ions and petroleum pollutants (Lushchak, 2009). Elevated production of ROS causes oxidation of proteins and lipids, change/alterations in gene expression and changes in cell redox redox status (Sevcikova, *et al.,* 2011). Superoxide dismutase (SOD), Catalase (CAT), Glutathione reductase (GSH) and Glutathione - s – transferase (GST) are the main antioxidant enzymes and important indicators of oxidative stress. When fish is stressed oxidative stress enzymes are readily released becoming inducible and indicating their readiness to adapt to stressful conditions (Nwani *et al*., 2015).

Fishes are usually very sensitive in their environment, the effect of pollutants such as heavy metals and pesticide residues can be revealed when fish are studied as biomarkers of environmental bio-monitoring (Bakr *et al*., 2016) thus, some genetic, biochemical and morphological responses can be utilized as tools for bio monitoring. Chronic pollution in fish include increased incidence of disease, low fecundity, abnormalities in developmental stages and changes in genetic make-up. Genotoxic potential of aquatic pollution in fish has been investigated by different methodologies like random amplified polymorphic polymerase chain reaction (Bakr *et al*., 2016). When organisms in contaminated environments show loss of DNA structural and functional integrity, histopathological investigations have proved to be a sensitive tool to detect direct effects of chemical compounds within target organs of fish, it reveals useful data in relation to change in tissue arrangement and morphological changes prior to an external manifestation (Deore and Wagh, 2012). Alterations and abnormalities are easily observed in affected organs of fish in order to study the effect of toxic pollutants affecting the well-being of fish. Histopathological investigations have proved to be a sensitive tool to detect direct effects of chemical contaminants within the target organs of fish (Bakr, 2016).

The aim of this study was to assess the levels of heavy metals (Pb, Cd and Cr) in different tissues of *Clarias gariepinus* as bioindicator of sediment and water quality problems of River Hadejia and Lake Nguru.

MATERIALS AND METHODS

The study was carried out at the Hadejia – Nguru Wetlands (HNW). This area lies between latitudes 12^0 10N and 13^0 N and longitudes 10^0 15E and 11^0 30E. The HNW lie within the semi-arid region of Nigeria. The topography of the area is mostly low-lying flat surfaces on the north eastern side and limited local relief in the southern and western parts. Rainfall pattern in the Hadejia and Nguru areas has not been stable over the years, but in most cases starts from June and falls through September. Vegetation is mainly Sudan Savanna, with transitional northern Guinea Savanna and Sahel Savanna in the Southern and Northern limits respectively, Abubakar *et al.* (2015). The area is largely an agricultural practicing area at both seasons and depends on the use of fertilizers and pesticides which might contain heavy metals that might be carried into the water bodies as runoff from the rain. Fishing activities are also carried out with some fisherfolks using toxic chemicals to capture fish.

Fish Sampling and Analysis: *Clarias gariepinus* were caught from the two sampling sites through the services of hired fishermen. Samples were collected bi-monthly during the entire period of study (March 2020-February 2021). A total of 280 fish specimens was utilized for the study, the fish specimens were gotten very early in the morning by 6a.m. and transported in ice cold containers to the Laboratory of the Department of Fisheries and Aquaculture Federal University Dutse for dissection and analysis. Dissection of the fish commenced immediately to remove the organs to be used for analysis, the target organs were the gills muscles and liver, these were refrigerated for further analysis.

Heavy Metals Analysis

Analysis was carried by the method described by APHA, (2005). Dissected muscles, gills and liver were removed and oven dried at a temperature of 105ºC until a constant weight was achieved, the dried samples were turned in to powdery form using a porcelain mortar prior to digestion. To digest the samples the powdered muscles, gills and liver were homogenized and subjected to concentrated nitric acid and hydrogen peroxide (1:1) v/v of the powdered sample was placed into a 250ml round bottom flask and 10ml each of HNO_3 (65%) and H_2O_2 (30%) was added and the content of the flask was allowed to undergo reactions. The content of the flask was heated on a heating mantle to a temperature of 130ºC dissolution inside a fume hood to reduce the volume to 3ml-4ml, the digested sample was allowed to cool and filtered into a conical flask, the filtered sample was transferred to a 50ml volumetric flask. The concentration of Cd, Al, Cr, Pb and Hg was determined using the Atomic Absorption spectrophotometer (Buck scientific model 230) at the soil science Department of Ahmadu Bello University, Zaria.

Measurement of Markers of Oxidative Stress

Gills, liver and muscles samples were analyzed for markers of oxidative stress: superoxide dismutase (SOD), catalase (CAT), and glutathione (GSH). These were determined according to the analytical method described by Achuba *et al*. (2014). The gills liver and muscle were separated and homogenized with 10ml of ice-cold 0.05M phosphate buffer pH 7.0 containing 1% (w/v) Triton X-100, excess butylated hydroxyl toluene (BHT) was added with a few crystals of protease inhibitor, phenylmethylsulfonyl fluoride. Triton X-100 solubilizes membrane-enclosed organelles while BHT prevents in vitro oxidation of lipid during homogenization. The extract was centrifuged at7000gfor20minutesat40˚C.

Catalase Extraction and Assay

(CAT) Catalase activity was determined according to Beers and Sizer (1952) by measuring the decrease in H_2O_2 concentration at 240 nm absorbance. An extinction coefficient of 40 M-1 cm-1 for H_2O_2 (Abel, 1974) was used for calculations.

Extraction and Assay of Superoxide Dismutase (SOD)

The resulting supernatant was used to assay superoxide dismutase (SOD) activity based on its ability to inhibit the oxidation of epinephrine by superoxide anions (Aksnes and Njaa, 1981) Enzyme activity was analyzed with an SP 1800 UV/VIS spectrophotometer.

Assay of Glutathione (GSH)

Glutathione (GSH) was determined by adopting the method described by Sedlak and Lindsay, 1968. Where the tissue sample was prepared by washing with PBS twice, 0.1g of the sample was added into homogenizer, 1mL reagent was added (the proportion of tissue and reagents are kept constant) and this was fully grinded on ice (using liquid nitrogen gave a better grinding effect) centrifuge was done at 8000x g for 10minutes at 4ºC. Spectrophotometer was then preheated for 30minutes and adjustment was made to a wave length of 412nm with distilled water before the values for GSH was measured.

Histopathological Examination of Sensitive Organs for Tissue Damage

At the point of fish dissection, the gills, liver and muscle of the exposed and control fish were removed and stored in Bouin's fluid prior to examination. They were later dehydrated in ascending alcohols, and treated with toluene and infiltrated with molten paraffin wax. Microtone sections were stained with the hematoxylin and eosin staining technique, examined with a Leica DM 750 microscope and photographed with a Leica ICC 50HD camera (Roberts, 2001; Auwioro, 2010)

Data Analysis

Generated data were analyzed using the social science statistical package (SPSS) version 25. All results are expressed as mean± standard deviation and data were analyzed using one-way analysis of variance (ANOVA). Significant difference between contaminated sites and control were determined at 5% confidence level ($P < 0.05$) using Duncan multiple test range.

RESULTS

Concentration of heavy metals (Table 1) in *Clarias gariepinus* from Hadejia River showed that the gills had a concentration of 29.17mg/Kg, Cd was 2.41mg/Kg and Cr was 79.13mg/Kg, while, the fish from Nguru Lake gave values of Pb in the gills to be 13.06mg/Kg, Cd was 2.18mg/Kg and Cr was

97.24mg/Kg. there was a significant difference (P>0.05) in the concentration of Pb in fish gills from Hadejia River and Nguru Lake but no significant difference(P<0.05) was observed between the concentration of Cd and Cr in the gills of fish in both water bodies. All the values for heavy metals in the gills from both water bodies were higher than the recommended values as outlined by FAO and FEPA in Table 2.

Lead (Pb) concentration in the liver of fish from Hadejia River showed values of 17.53mg/Kg, Cd gave values of 1.72mg/Kg and Cr was 80.15mg/Kg, while, the fish obtained from Nguru Lake gave Pb concentration of 16.59mg/Kg, Cd was 2.17mg/Kg and Cr was 43.09mg/Kg respectively. There was a significant difference (P>0.05) between Cr concentration in the liver of fish found in both water bodies. Values for heavy metals were higher than the recommended permissible level for heavy metals in fish. The concentration of Pb in the muscles of the fish from Hadejia River gave values of 20.93mg/Kg, Cd recorded a value of 1.34mg/Kg and Cr had a concentration of 115.94mg/Kg, while the muscle of the fish from Nguru recorded 17.92mg/Kg of Pb, 5.43mg/Kg of Cd and 45.18mg/Kg of Cr. The values obtained for all the heavy metals studied in the muscles of fish at the two sites showed a significant difference (P>0.05) and were far above the permissible limit for heavy metals in fish as outlined in Table 2.

The result for oxidative stress enzyme activities in *Clarias gariepinus* from Hadejia River and Nguru Lake is presented in Table 3. The result showed that the oxidative stress enzyme, superoxide dismutase (SOD) was highest in the fish from Hadejia River with a value of 32.43U/ml as recorded in the liver and that of the fish from Nguru Lake gave values of 30.83U/ml, there was no significant difference (P<0.05) in the liver concentration of *C. gariepinus* in both water bodies. The result for Reduced glutathione (GSH) is presented in Table 3: The highest GSH levels were found in the gills with a value of 1016 µg/ml from Hadejia River, highest GSH levels in Nguru Lake were recorded in the muscles of the fish with a value of 454.62 µg/ml. Catalase level in *C. gariepinus* was highest in Nguru Lake having similar values of 67.80 U/ml in the liver and muscle respectively as seen in Table 3.

Histopathological Examination of Tissues of *Clarias gariepinus* from Hadejia River and Nguru Lake

Microscopic histopathological examination of various organs of catfish showed some damage/changes in the gill, liver and muscle affected by the presence of heavy metals in the Hadejia River and Nguru Lake. Plate I showed the changes seen in the tissue organization of *C. gariepinus* from the Hadejia River. Gill filaments showed more detrimental effects such as cell proliferation, clubbing, hyperplasia and fusion of lamellar cells, loss of secondary lamellae and inflammatory cells. Plate II showed the histology of the tissues of the fish from Nguru Lake. There was hepatocyte degeneration and erythrocyte distortion, and hepatocyte vacuolization was also noted clogging and degeneration were observed in the hepatocytes. Before the examination, there was no evidence of tissue damage, color change, odor, or texture changes and all tissues were consistent.

Table1: Heavy metal concentration (mg/Kg) in organs of *Clarias gariepinus* from Hadejia River and Nguru Lake

Sites	Organs	Lead (Pb)	Cadmium (Cd)	Chromium (Cr)
Hadejia River	Gills	29.97±2.95[a]	2.41±1.54[a]	79.13±50.46[a]
	Liver	17.53±8.08[b]	1.72±0.86[a]	80.15±72.74[a]
	Muscle	20.93±9.42[a]	1.34±0.93[a]	115.94±70.78[b]
Nguru Lake	Gills	13.06±13.59[b]	2.18±1.09[a]	87.24±12.43[a]
	Liver	16.59±14.92[b]	2.17±0.79[a]	43.09±19.67[c]
	Muscle	17.92±15.17[b]	5.43±0.04[b]	45.18±19.15[c]

Table 2: Maximum Permissible Limit (MPL) of Heavy Metals According to Some International standards (mg/Kg)

Organization	Chromium	Lead	Cadmium	References
WHO/FAO	0.05	0.5	0.05	FAO (2004)
EU	0.05	0.5	0.1	EU (2002)
EC		0.025	0.007	EC (2006)
FEPA	0.15-1.0	0.2	0.2	FEPA (2003)

EU – European Union EC- European Communities FEPA- Federal Environmental Protection Agency.

Table 3: Levels of SOD, GSH and Catalase in organs of *Clarias gariepinus* from the Hadejia River and Nguru Lake

Organ/Tissue	Control	Hadejia River	Nguru Lake
Level of SOD (U/ml)			
Gills	ND	9.40±4.50^{b}	2.33±1.03^{a}
Liver	1.83±0.01^{a}	32.43±2.05^{d}	30.83±2.82^{d}
Muscle	0.41±0.10^{a}	1.55±0.50^{a}	ND
Level of GSH **(**µg/ml)			
Gills	0.54±0.39^{a}	1016.64±0.54^{f}	95.36±5.11^{b}
Liver	0.34±0.04^{a}	102.51±2.06^{c}	21.88±2.81^{b}
Muscle	4.97±0.07^{a}	57.65±7.10^{b}	454.62±4.47^{d}
Level of Catalase (U/ml)			
Gills	ND	6.10±0.12^{b}	9.49±0.00^{b}
Liver	ND	0.68±0.00^{a}	67.80±2.60^{c}
Muscle	ND	0.68±0.00^{a}	67.80±2.60^{c}

Values are means ± SD of determination for a single fish spp from two water bodies- means with different superscript letters in the same row are significantly different at P< 0.005.
ND = not detected

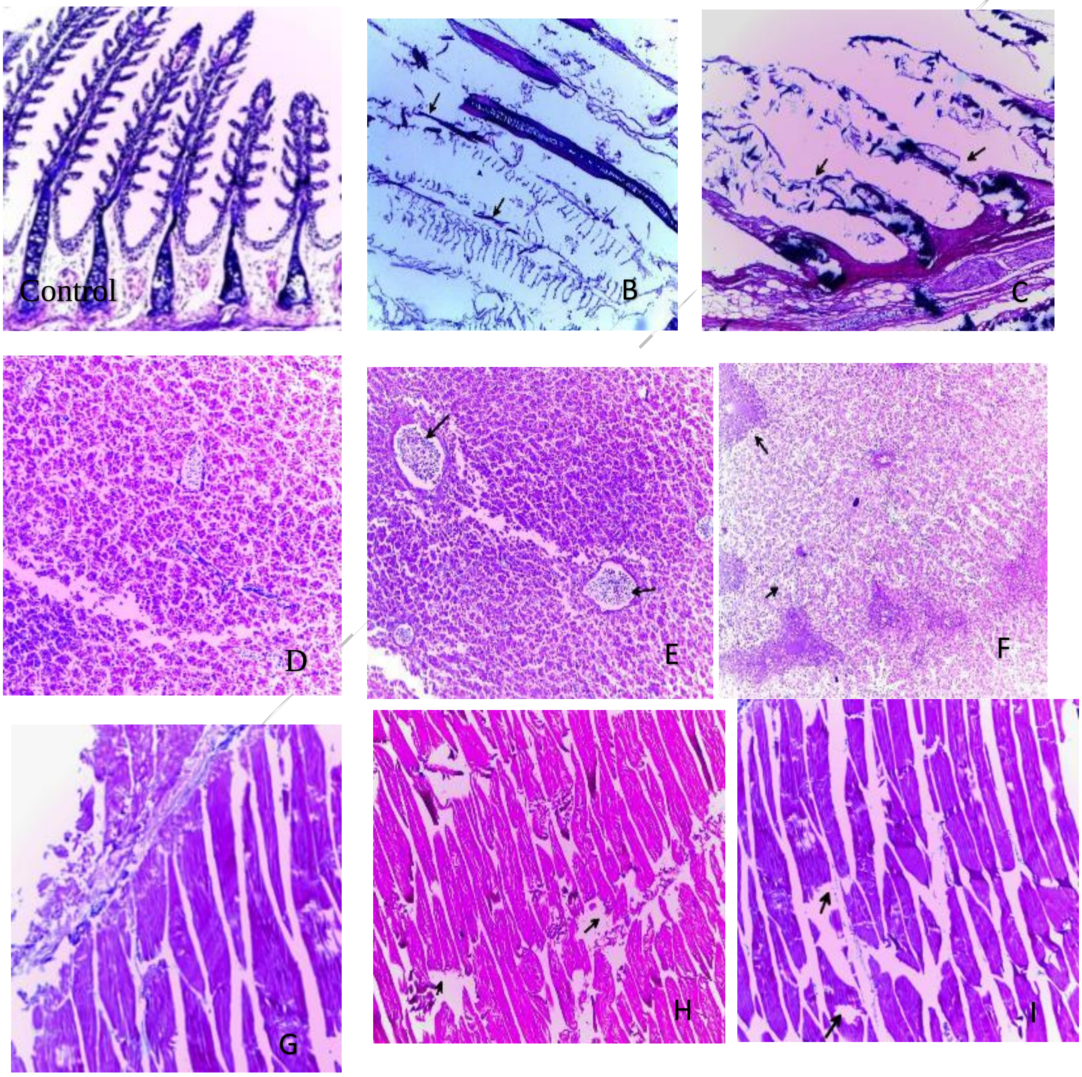

Plate I(A-I): Histology of gill, liver and muscle cells of *C. gariepinus* from Hadejia River showing Normal gill architecture without any observable difference in control (A), desquamation of secondary lamella and edema(B), filament degeneration(C), normal hepatocytes with blood vessel with no abnormal alteration in the control(D), swollen hepatocytes with vacuolated cytoplasm(E), distortion of bile duct, redblood cells (F), marked thickening and separation of muscle bundles in (G), lesions and compact muscles (H) and haemolysis in (I),

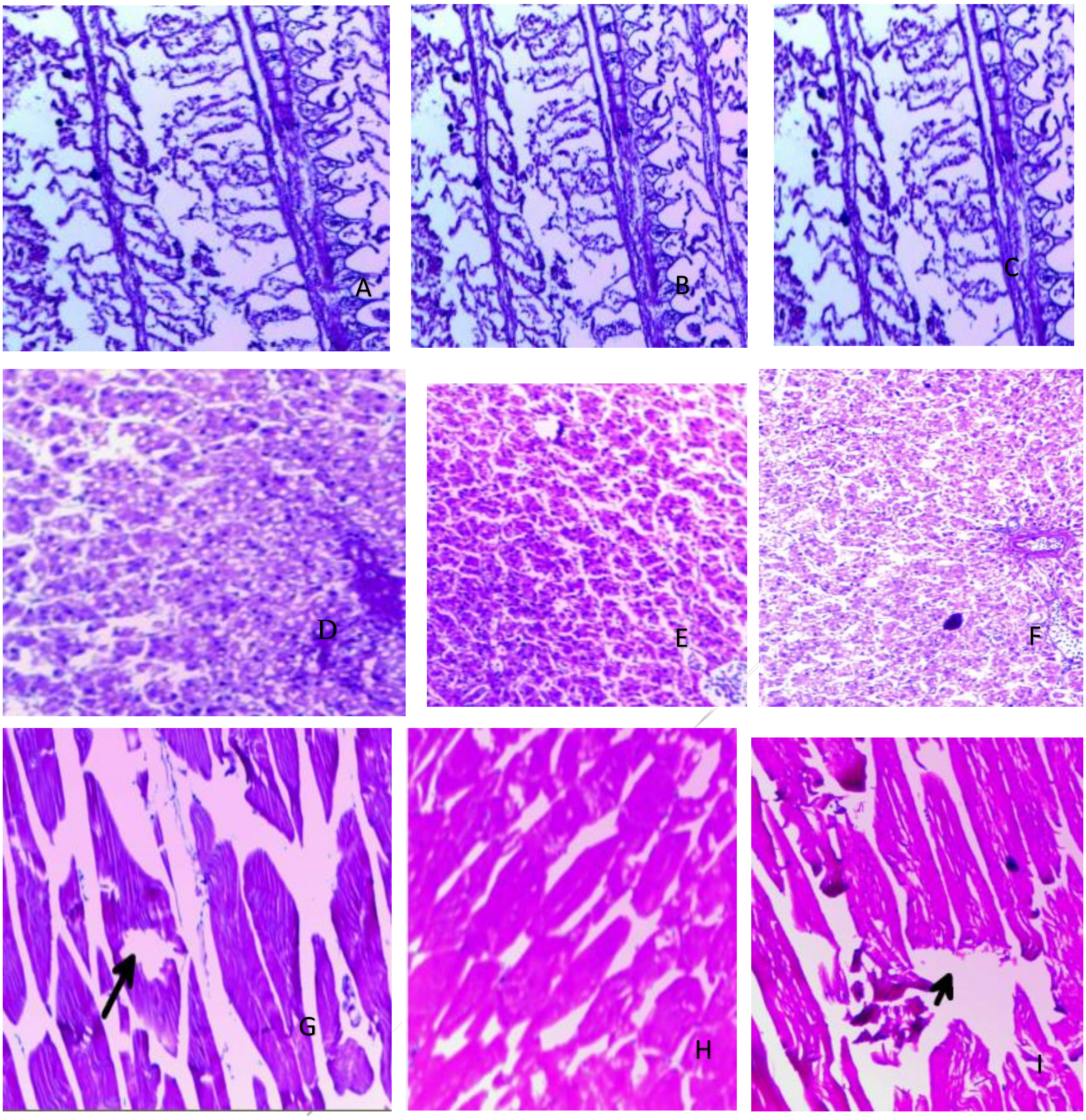

Plate II (A-I): Histology of gill, liver and muscle cells of *C. gariepinus* from Nguru Lake showing clubbing of cell lamellar(A), edema, clubbing and desquamation(B), filament degeneration(C) ; vacuolation of hepatocytes (D), dilated sinusoids(E),congested and dilated central vein(E), vacuolation of hepatocytes (F); marked thickening and separation of muscle bundle (G), minor dystrophic change (H) , vacuolated and swollen cells in C,

DISCUSSION

Heavy metal contamination levels observed in this study exceeded the recommended acceptable levels for heavy metals in aquatic foods and fish as recommended by FEPA and FAO. Levels of Pb in fish samples from both water bodies showed that the gills of the fish were contaminated the most. Pb has been classified as one of the toxic metals and indicates high toxicity when present in the body of fish, Arojojoye *et al*. (2018). The levels of Pb observed in the study is similar to the level obtained by Dutta *et al.* (2022) from their studies in East Kolkata wetlands, India when they studied three fish species namely, Rohu, Catla and Nile tilapia. The presence of Pb in water may be attributed to the presence of industrial and melting activities and also leaded gasoline (Galadima and Garba, 2012). Also, high value of Pb was recorded in studies conducted in Igbokada River in Ondo state (Arojojoye *et al*., 2018).

Concentration of Cd obtained in this study was above the permissible levels obtained in fish. Cd is a naturally occurring non-essential trace elements and it has a tendency to bioaccumulate in living organism up to hazardous levels thus, becoming a source of concern in the environment (Authman *et al*., 2015). The result obtained for Cd in the gills, liver and muscles of the studied fish from the two water bodies is similar to the one obtained by Hashim *et al*. (2014) from the study carried out at the lower Keratan River in Malaysia to which the concentration of Cd was above the critical limit level as outlined by FAO and FEPA.

Levels of Cr in fish was extremely high above the recommended acceptable limit in food, this was also reported by Enitan *et al.* (2018) in a study carried out at Ndawuse River, Abuja. Eminike *et al.* (2020) also reported high concentration of Cr from studies carried out at River Atuwura, south west Nigeria. The presence of Cr in the aquatic ecosystem has been reported to be through discharges from tanneries, textiles, mining and dyeing (Arunkumar *et al*., 2000; Abbas and Ali, 2007). Toxic effects of Cr in fish includes hematological, histological and morphological alterations, inhibition/reduction of growth, production of reactive oxygen species (ROS) and dysfunctional immune system.

Activities of superoxide dismutase (SOD), the redox sensitive thiol compound glutathione (GSH) and catalase (CAT) were all elevated in the organs studied, suggesting a reaction triggered as a result of the presence of heavy metal. When fishes interact with pollutants such as heavy metals, these toxic pollutants become accumulated in the tissues of fish catalyzing reactions that brings about reactive oxygen species (Sevcikova *et al*., 2011) the significant increase in oxidative stress enzymes observed in the organs can be attributed to the presence of heavy metals in high concentration and if metals are accumulated they might lead to the production of superoxide anions which leads to the induction of SOD to convert the superoxide radical to H_2O_2 (Farombi *et al*., 2007). According to Kadar and Santos, 2005, SOD catalytically scavenges superoxide radical which appears to be an important agent of oxygen toxicity. The resultant increase in GSH levels within the organs suggests an adaptative and protective role against oxidative stress induced by heavy metals. The results obtained in this study agrees with the report of Pandey *et al*. (2003), who reported an increase in GSH levels from the fish *Wallgo attu* from Panipat river, india. Increase in GSH in the gills suggests that they are more exposed to contaminants in water and fish body thus, allowing the heavy metal contaminated water to gain access to the fish body. Hadejia River can be attributed to the overshadowing effect of SOD. It has been shown that SOD inhibits CAT activity. Decrease in CAT was observed by Musa and Imam (2022) in *Oreochromis niloticus* from Hadejia Nguru wetlands, Nigeria.

The structural organization of tissues in the control fish was intact but distortion and abnormal features were recorded in the contaminated fish from both water bodies. The gill is one of the organs through which toxic substances can be brought in to the body and it happens to be an effective means of measuring the effect of aquatic pollutants in to water bodies (Pandey *et al*., 2008; Khan *et al*., 2011) gills from both rivers showed varying degree of alterations which agree with the findings of Odiegie *et al*. (2016) in their study on heavy metals impact on tissues of fish from Ikopa River, Benin. According to Singh *et al*. (2022), there are three mode of entry of heavy metals in to fish, the first is the gills, the second is the digestive tract and the last is the body of the fish. The present study revealed that the gills were highly contaminated with the studied heavy metals, Khan *et al.*, 2011, observed similar trend in the histology of the gills of African catfish *Claria0s batrachus* that was exposed to Pb and other metals. Varying degrees of liver degeneration was recorded like the degeneration of hepatocytes this high degree of alterations observed in the liver can be attributed to its function of detoxification and accumulation of toxic elements in its cells, this agrees with the findings of Ekeanyanwu *et al*. (2015, who reported high heavy metals content in the liver of fish from Oguta lake, Musa and Imam, 2022, also reported high alterations in the liver of African catfish *Clarias gariepinus* in the contaminated waters of Jigawa and Yobe States, Nigeria. The muscles of the fish from both water bodies showed pronounced alterations in the muscles even though the changes were much more pronounced in the gills and liver.

CONCLUSION

In conclusion this study has shed light on the status of heavy metals contamination in the two water bodies studied, the results showed high levels of heavy metals in fish and its potential health risks to consumers. The observed alterations in tissue histology further supports the potential toxic effects of the contaminants on fish health, additionally, observed high antioxidant activities in the fish may indicate a response to oxidative stress induced by the presence of contaminants in the aquatic environment. These findings have important implications for the management and conservation of fish populations in the area. Based on this finding, it is recommended that efforts be made to reduce the heavy metal content in fish species through appropriate interventions such as the management of water quality and the control of chemical inputs in to aquatic environments.

REFERENCES

Abalaka, S. E., Enem, S. I., Idoko, I. S., Sani, N. A., Tenuche, O. Z., Ejeh, S. A. and Sambo, W. K. (2020). Heavy metals bioaccumulation and health risks with associated histopathological changes in *Clarias gariepinus* from the Kado fish market, Abuja, Nigeria. *Journal of Health and Pollution*, 10(26).

Abbas, H. H. and Ali, F. K. (2007). Study the effect of hexavalent chromium on some biochemical, citotoxicological, and histopathological aspects of the *Orechromis spp*. fish. *Pakistan Journal of Biological Sciences*: PJBS, 10(22), 3973-3982.

Abel, H. (1974). *Catalase in method of enzymatic analysis* Brygmeyer, H.U(ED) Academic press, New York Pp. 673-684.

Abubakar, M.M., Kutama, A.S. and Sulaiman, I.M. (2015). Preliminary Survey of Fish Diversity in the Hadejia Wetlands. *International Journal of Biological Sciences (*IJBS):2(1) 23-29.

Achuba, F.I., Ebokaiwe, P. and Peretiemo-Clarke. B.O. (2014). Effect of environmental pollution on oxidative stress in African Catfish (*Clarias hetrobranchus) International Journal of Environmental Monitoring and Analysis.* **2**(6):297-301.

Adaka, G., Ajima, M., Ezeafulugwe, C., Osuigwe, D. and Nlewedim, A. (2017). Assessment of Heavy Metals in Fish Tissues of Some Fish Species in Oguta Lake, South-Eastern Nigeria. *Futo Journal Series* (FUTOJNLS) 3(1) pp. 249-257.

Afolayan, A.O. (2018) Accumulation of Heavy Metals from Battery Waste in Topsoil, Surface Water and Garden Grown Maize at Omilende area, Olodo, Nigeria. *Global Chall* 2(3): 1700090.

Ajala, O.A., Oke, M.R., Ajibade, T.F., Ajibade, F.O., Adelodun, B., Ighalo, J.O.,Ajala, M.O., Kumar, P., Demissie, H., Ugya, A.Y., Sulaymon, I.S. and Silva, L.F.O. (2022). Concentrations, Bioaccumulation, and Health risks Assessments of Heavy Metals in Fishes from Nigeria's Fresh water: A General Overview. *Environmental Science and Pollution Research* https://doi.org/10.1007/s11356-022-23390-1.

Alksnes, A., and Njaa, R.L. (1981). Catalase, Glutathione Peroxidase and Superoxide Dismutase in Different Fish Species. *Comp*. *Biochem, Physiol*. 69B: 893-896.

Anyakora, C., Nwaeze, K., Awodele, O., Nwadike, C., Arbabi, M., & Coker, H. (2011). Concentrations of Heavy Metals in Some Pharmaceutical Effluents in Lagos, Nigeria. J. *Environ. Chem. Ecotoxicol*, 3(2), 25-31.

American Public Health Association (APHA) (2005). Standard methods for the examination of water and waste water analysis. America water works association. (Water Environment Federation, Washington Dc, 289.

Arojojoye, O.A., Oyagbemi, A.A. and Afolabi, J.M. (2018). Toxicological Assessment of Heavy Metal Bioaccumulation and Oxidative Biomarkers in *Clarias gariepinus* from Igbokoda River of Southwestern Nigeria. *Bull Environ Contam Toxicol* 100(6):765-771.

Arunkumar, R. I., Rajasekaran, P. and Michael, R. D. (2000). Differential Effect of Chromium Compounds on the Immune Response of the African Mouth Breeder *Oreochromis mossambicu*s (Peters). *Fish & Shellfish Immunology*, 10(8), 667-676.

Authman, M., Mona, Z., Elsayed, K. and Hossam, A. (2015). Use of Fish as Bioindicator of the Effects of Heavy Metals Pollution. *J. Aquatic Res. Development* 6(4):328.

Auwioro, O.G. (2010). Histochemistry and Tissue Pathology, Principle and Techniques 2nd edition, claverianum press, Ibadan, Nigeria Pp 12.

Ayeni, O. (2014). Assessment of heavy metals in wastewater obtained from an industrial area in Ibadan, Nigeria. *RMZ–M&G [Internet]*, 61, 19-24.

Beers, R.F. and Sizer, I.W. (1995). A Spectrophotometric Method for Measuring the Breakdown of Hydrogen Peroxide by Catalas. *J biol. Chem.* 195; 133-104

Bakr, M.N., Aboel Hassan, M.D. (2016). Genotoxic and Histopathological Effects of Water Pollutants in Three Population Fish (*Oreochromis niloticus*) in Egypt. *International Journal of Mharmacy Sci. Rev. Res*. 38(1), 206-215.

Chukwudi, O., Mabel, I., Sabastina, O. and Fidelia, A. (2022). Speciation of Heavy Metals in Fish Specie in the Wettlands of Oil Bearing Communities of the Niger Delta. International Journal of Biosciences, 21(2):169-178.

Deore, S. and Wagh, S. (2012). Heavy Metal Induced Histopathological Alterations in Liver of *Channa gachua* (Ham). *Journal of Experimental Sciences,* 3(3):35-38

Dutta, J., Zaman, S., Thakur, K and Datta, R.. (2022). Assessment of the Bioaccumulation Pattern of Pb, Cd, Cr and Hg in Edible Fishes of East Kolkata Wetlands, India. *Saudi Journal of Biological Sciences* 29(1):758-786.

Ekeanyanwu, R.C., Nwokedi, C.L. and Noah, U.T. (2015). Monitoring of Metals in *Tilapia niloticus* Tissues, Bottom Sediments and Water from Nworie River and Oguta Lake in Imo State, Nigeria. *African Journal of Environmental Science and Technology,* **9**(8): 682-690. https://doi.org/10.5897/AJEST2015.1894.

El-Ishaq, A., Omotayo, A. R., & Hussaini, I. (2016). Determination of Some Trace Elements Cu, Fe, Pb, and Zn in the Gills, Muscles, and Tissues of Clarias gariepinus and Oreochromis niloticus found along River Yobe. *Journal of Medical and Biological Science Research*, 2(1), 27-32.

Emenike, P.C., Neris, J.B., Tenebe, I.T., Nnaji, C.C. and Jarvis, P. (2020). Estimation of Some Trace Metal Pollutants in River Atuwara Southwestern

Nigeria and Spatio-Temporal Human Health Risks Assessment. *Chemosphere* 239:124770.

Enitan, I.T., Enitan, A.M., Odiyo, J.O. and Alhassan, H.M. (2018). Human Health Risk Assessment of Trace Metals in Water due to Leachate from the Municipal Dumpsite by Pollution Index: A case Study from Ndawuse River, Abuja, Nigeria. *Open Chem* 16(1):214-227.

Farombi, E.O., Adelowo, O.A. and Ajimoko, Y.R. (2007). Biomarkers of Oxidative Stress and Heavy Metal Levels as Indicators of Environmental Pollution in African Catfish C*larias gariepinus* from Nigeria, Ogun river. Int.J.Envirnm. *Res. Public Health*, 4(2):158-165.

Galadima, A. and Garba, Z. N. (2012). Heavy Metals Pollution in Nigeria: Causes and Consequences. *Elixir J. Poll*. 45: 7917-7922.

Hashim, R., Song, T.A., Muslim, N.Z.M. and Yen, T.P. (2014). Determination of Heavy metal levels in Fishes from the lower Kelantan River, Kelatan Malaysia.

Ighalo, J. O., Adeniyi, A. G. and Marques, G. (2021). Artificial intelligence for surface water quality monitoring and assessment: A systematic literature analysis. Modeling Earth Systems and Environment, 7(2), 669-681.

Iyinbor, A.A., Adekola, F.A. and AbdulRaheem, A.M. (2012). Estimation of some Trace Metal Pollutants in River Atuwara South western Nigeria and Spatio-Temporal Human Health Risks Assessment. *Chemosphere* 239:124770.

James, O. O., Nwaeze, K., Mesagan, E., Agbojo, M., Saka, K. L. and Olabanji, D. J. (2013). The concentration of heavy metals in five pharmaceutical effluents in Ogun State, Nigeria. *Bull Environ Pharmacol Life Sci*, 2(8), 84-90.

Khan, H.A. Sikdar-Bar, M Kamlesh, B. Wani, A.A. and Pervaiz, P.A (2011). Lead Nitrate Induced Histopathological Changes in the Gills of the African *Clarias Batrachus. J. Applied Sciences Research,* 7 (7): 1081-1086.

Lushchak, V., Kubrak, O. I., Lozinsky, O. V., Storey, J. M., Storey, K. B. and Lushchak, V. I. (2009). Chromium (III) induces oxidative stress in goldfish liver and kidney. *Aquatic Toxicology*, 93(1), 45-52.

Maurya, A., Negi, T. and Negi, R.K. (2018). Seasonal Assessment of Heavy metal Pollution in Water and Sediment of Fish Pond at Bhangwanpur, Roorkee(U.K) India. *Asian Journal of Animal Sciences* 12:16-22.

Musa, I.M. and Imam, T.S. (2021). Bio concentration of some Heavy Metals and Oxidative Stress Enzymes in *Oreochromis niloticus* (Tilapia Fish) from the Hadejia-Nguru Wetlands, Jigawa State. *DUJOPAS* 7 (4b): 168-180, 2021. https://doi.org/10.4314/dujopas.v7i4b.18.

Musa, M.I. and Imam, T.S. (2022). Histopathological and Oxidative Stress Responses of the African Catfish *Clarias gariepinus* in Heavy metal Contaminated Water from the Hadejia-Nguru Wetlands of North-Eastern Nigeria. *UMYU scientifica* 1 (2):77-87.

Nishida, Y. (2011). The chemical process of oxidative stress by copper (II) and iron (III) ions in several neurodegenerative disorders. *Moatshefte for chemie* 142, 375-383.

Nwani, C.D., Ekwueme, H.I., Ejere, V.C., Onyeke, C.C., Chukwuka, C.O., Peace, O.N. and Nwadinigwe, A.O. (2015). Physiological effects of paraquat in Juvenile African catfish Clarias griepinus (Burchell, 1822). *Journal of Coastal Life Medicine,* 3(1):35-43.

Odiegie, J.O., Erameh, T.O. and Odiegie, B.E. (2016). Heavy Metal Toxicity and Histopathology of Selected Organs of Tilapia Fish (*Tilapia zilli*) from Ikpoba River, Benin city, Nigeria. FUNAI, *Journal of Science and Technology* 2(1):10-22.

Okieke, U.J., Akpokodge, O.I. and Oshievire, B (2021). Bacteriological and Physiochemical Asessment of Water, Sediment and Fish qualities along Wetland in Isoko Region of Delta State, *Nigeria. Journal of Engineering Technology*, 6(12): 445-450.

Okolo, C.C. and Oyedotun, T.D.T. (2018). Open Cast Mining: Threat to Water Quality in Rural Community of Enyigba in South-Eastern Nigeria. Appl Water Sci 8(7):1-11.

Okonofua, E.S., Atikpo, E., Lasisi, K.H., Ajibade, F.O., Idowu, T.E. (2021). Effect of Crude Oil Exploration and Exploitation Activities on Soil, Water and Air in a Nigerian Community. *Environ Technol. https://* doi.org/10.1080/09593330.2021.1992508.

Okunade, D. A., and Adekalu, K. O. (2013). Physico-Chemical Analysis of Contaminated Water Resources due to Cassava Wastewater Effluent Disposal. *European International Journal of Science and Technology*, 2(6), 75-84.

Pandey, S; Parvez, S; sayeed, I; Haque, R; Bin-hafeez, B; Raisuddin, S. (2003). Biomakers of Oxidative stress: A comparative study of river Yamuna Fish Wallago attu (BI & schnn), *Sci Total Environ.* 2003, 309 105-15.

Pandey, S., Parvez, S. Ansari, R.A. Ali, M. Kaur, M., Hayat, F., Ahmad, F. & Raisuddin, S. (2008). Effects of exposure to multiple trace metals on biochemical, histological and ultrastructural features of gills of a freshwater fish, Channa punctatus Bloch. J. Chemico- Biological Interactions 174: 183–192.

Sanusi, K.A., Hassan, M.S., abbas, M.A. and Kura, A.M. (2017). Assessment of Heavy Metals Contamination of Soil and Water around Abandoned Pb-Zn Mines in Yelu, Alkaleri Local

Government of Bauchi State, Nigeria. *Int Res J. Public Environ Health* 4(5):72-77.
Sedlak J, Lindsay R.H. (1968). Estimation of Total Protein Bound and Non-Protein Sulfhydryl Groups in Tissues with Ellman'sreagent. *Anal Biochem*. October [cited10th Oct., 2022]; 25 1: 192– 205. DOI: 10.1016/00032697(68)90092-4.
Sevcikova, M., Modra, H., Slaninova, A. and Svobodova, Z. (2011). Metals as a cause of oxidative stress in fish: a review. *Veterinarni medicina,* 56, 2011(11):537-546
Singh, A., Sharma, A. K. Verma, R. L. Chopade, R. P., Pandit, P., Nagar, V., … S. Sankhla, M. (2022). Heavy Metal Contamination of Water and Their Toxic Effect on Living Organisms. IntechOpen. doi: 10.5772/intechopen.105075