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Heavy Metal Evaluation and Bioaccumulation Status of Selected Fish Species of River Gongola, Gombe State, Nigeria

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Abstract

Fish and other aquatic creatures are seriously threatened by chemical pollutants such as heavy metals that contaminate the aquatic environment. This could have long-term consequences for the human food chain. The aim of the study was to investigate the levels of heavy metals in water and bioaccumulation factor of heavy metals in selected fish species of River Gongola. Water and fish samples were collected monthly for 18 months (between December 2021 and May 2023) between the hours of 08:00am and 11:00am each sampling day. Heavy metals in the water and the fishes were analysed following standard procedure using Atomic Absorption Spectrophotometer. The results of the water analysis showed that Cadmium (Cd), Arsenic (As), Nickel (Ni) and Manganese (Mn) were above the recommended limit of WHO/NSDWQ. Significant differences were observed in metal concentration in the tissues (liver, muscle and gills) of the three fish species. The liver concentrated higher levels of the metals followed by the gills and the muscle. However, the levels of the metals reported in the tissues of the three fishes were below the recommended standards. The Bioaccumulation Factor (BAF) values calculated were mostly less than 1 showing no probability of bioaccumulation except for As in *Bagrus bayad macropterus* and *Oreochromis niloticus* and Iron (Fe) in *B. bayad macropterus* and *Clarias gariepinus*. Regular assessment and monitoring of the water and fish resources of this river is required to ensure safety of these products for consumer use.

Keywords: Aquatic Environment pollution, Heavy Metal, Bioaccumulation, Bioconcentration, Safety of aquatic foods

Introduction

Our environment function as a sizable tank that takes in all that is given and returns them back in forms that could be either beneficial or detrimental. These changes could be caused by physical, chemical, biological or a combination of these processes (Botkin and Keller 2005). Water is regarded as one of the most precious and important natural resource since it is ultimately necessary for all life forms on earth. In addition to ecosystem services, water is critical to the socio-economic development of any society (Uzochukwu *et al.*, 2019; Varol and Sekerci 2018; Hajar 2019). Growing urbanization, industrialization, and population have resulted in an increase in wastewaters that may contain heavy metals, which are of particular concern due to their persistent and toxic nature in the environment (Maliszewska-Kordybach 1999; Barrie and

Jeffery 2006). The toxicity of the aquatic environment poses a threat to human health because there is a lack of safe and suitable potable water supplies for drinking and other uses, particularly in Nigeria's rural settlements. As a result, these people rely on rivers, streams, lakes, natural ponds, shallow hand-dug wells, and rainfall collections to meet their water needs. They also rely on aquatic animals for food, as these animals are capable of bioaccumulating pollutants like heavy metals (Nacher-Mester *et al.,* 2010; Ekere *et al.,* 2014).

Lenntech (2004) defines heavy metals as "any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations". These Metals are naturally occurring substances but are often dispersed or transported within the ecosystem by both human activity and a range of natural processes. Pollutants, especially heavy metals, which bioaccumulate and find their way back into the food chains, end up in the aquatic environment (Edward *et al.,* 2013). Environmental contamination by these metals has become a growing global public health and ecological concern in recent years. Despite the fact that heavy metals are naturally occurring elements in the earth's crust, human activities like mining and smelting, industrial production and use, and the use metals and metal-containing compounds in agriculture and domestic settings account for the majority of environmental and human contamination (He *et al.,* 2005; Herawati *et al.,* 2000 and Shallari *et al.,* 1998).

Fish is a vital source of protein in the human body. It supplies vital fatty acids, which lower the risk of heart disease and stroke. It also supplies vital vitamins and minerals and helps lower blood cholesterol levels (Al-Busaidi *et al.,* 2011). Furthermore, fish hold a significant position in the aquatic food chain and have the ability to accumulate these metals in a variety of tissues, including the liver, muscles, gills, kidneys, and gonads from the organisms they eat (Saha and Zaman 2012; Liana 2019). The main route through which aquatic pollutants, like heavy metals in this case, enter the food chain and eventually the human body is through fish consumption (APHA 1981). As a result of how fish react to changes in their environment, they can be used as an indicator of environmental pollution. In a contaminated environment, fish's rate of heavy metal intake is influenced by a variety of factors, including the length of exposure, the elements' concentration, and other ecological factors like salinity, pH and temperature.

River Gongola at Yamaltu Deba is one of the many fresh water bodies that empty into the River Benue at Numan. Pollutants are discharged into the river by households, and water runoff from Ashaka. Kwadon, Zambuk, Gombe, and the nearby towns and villages also contribute to the pollution level. Other sources of pollution include farmlands, parking lots, corrosive roofs, and mechanic workshops that use lead-acid batteries. Petroleum products, fertilizers, pesticides, paints, colouring dyes, hazardous chemicals, detergents, cosmetics, automobile emissions, and industrial byproducts are a few examples of these pollutants. High concentrations of heavy metals and synthetic organic compounds, along with a host of other pollutants and waste products, end up in the river (Ezekiel *et al.*, 2019). Therefore the quality and safety of this water body and fish obtained from the river is consequential because aquatic life forms and crops irrigated by this water have the tendency to absorb and accumulate heavy metals thereby resulting in detrimental effects to the final consumer. Hence, the objective of the study is to evaluate the heavy metal content of water and bioaccumulation status of some commonly consumed fish species.

Materials and Methods

Study Area

River Gongola at the study location is located about 30km from Gombe town. The River lies within latitude 10°21′42.73″N and longitude 11°23′13.56″E of the equator. The River is a major tributary of the River Benue, and it originates from the Jos plateau area. The region experiences two distinct seasons: the wet season (May -September), which is characterized by heavy rainfall and potential flooding, and the dry season (October- April), which is characterized by dry weather. The region's climate is classified as a tropical continental type in Nigeria. The dry season is also characterized by cool, dusty, dry winds that are followed by intense heat (Santuraki *et al.*, 2022). The Sudan Savannah type of vegetation is found in this location and most of the forest cover has been reduced to semi-desert shrubs (Lazarus, 2020). In addition to fishing, livestock grazing, and poultry, the people in the area also engage in irrigation farming along the river valley, producing crops such as maize, sorghum, groundnut, millet, vegetables, and beans (Lazarus and Oruonye, 2019).

Collection, Preparation and Analysis of Water Sample

Twenty four (24) water samples were collected from two sampling points between the hours of 9:00 am and 12:00 noon between December 2021 and May 2023. Water sampling bottles were rinsed twice with the water before sampling was done. Sampling bottles were immersed about 10 cm below the water surface and required volume of water samples were taken at each sampling site then rinsed with 0.01N nitric acid and then kept in deep freezer prior to the time of analysis. Heavy metals (Cu, Pb, Cr, Cd, As, Ni, Fe, Mn and Zn) were then analyzed using Atomic Absorption Spectrophotometer (AAS) following standard laboratory procedure of AOAC (2000).

Fish Sample Collection and preparation

Fresh Fish samples (*B. bayad macropterus*, *O. niloticus* and *C. gariepinus*) of uniform sizes were collected using gill nets with the assistance of local fisher men. The Fish samples were collected once in a month for the period of eighteen (18) months from December 2021 to May 2023. The fish samples were labeled, put in an ice box and transported to the Biochemistry laboratory of Gombe State University on the same day for storage and processing. The fish samples were put on a dissection board and allowed to thaw at room temperature (if already frozen) before dissecting. Dissection of the fish samples was done using a clean stainless steel knife to separate liver, gill, and muscle tissues. Composite samples of liver, gill, and muscle tissues of each species were drawn. Each composite sample comprised of three (3) fishes of same species. The liver, gills and the muscles of the three different fish species were placed differently on a foil paper and put in an oven at a temperature of 105^0C for 24 hours to obtain a constant oven-dry weight (AOAC 2000). After oven drying, the samples were then homogenized differently for the three fish species using porcelain mortar and pestle and put in well labeled sample bottles prior to digestion.

Fish Samples Digestion and Analysis

Samples were digested in the Biochemistry department laboratory of Gombe State University. Prior to the digestion process, all glass wares and sample bottles were carefully cleaned with deionized water and oven dried. The powdered samples (1 g of each of the fish samples) were precisely weighed using weighing balance (Ohaus Model- AR 2130) and placed into a round bottom flask. Each sample was mixed with concentrated acids(10 ml nitric acid (HNO_3) and 5 ml perchloric acid ($HClO_4$) prepared in a measuring cylinder), shaken and placed on a hot plate (Kjabahl litter) to digest until a transparent or clear solution was reached. After letting the mixture cool, it was filtered through whatman No.1 filter paper, and the filtrate was then filled with deionized water to the mark of 100ml. The mixture was then put into a labeled sample bottle for analysis. A sample blank was also made using the same digestion process but without the fish samples and it was put into the sample bottles for analysis (AOAC 2000).

The samples were analyzed using an atomic absorption spectrophotometer (Bulk scientific, model 205). Calibration of the instrument was performed by first analysing two standard solutions for each metal, followed by the blank analysis before the sample analysis. The metals analyzed for were, Copper, Chromium, Cadmium, Arsenic, Nickel, Iron, Manganese and Zinc.

Bioaccumulation Factor (BAF)

According to USEPA (2014) guidelines and adopted by Ahmad *et al.,* (2018), the BAF is defined as the ratio of chemical concentration of metals in the organism to that in the surrounding water. The bioaccumulation Factor (BAF) for heavy metals in fish was calculated as described by Oboh and Okpara (2019).

$$\mathbf{BAF} = \frac{\text{Heavy metal concentration in fish } (mg/kg)}{\text{Heavy metal concentration in water } (mg/l)} \text{ -------------------------------------- } (1)$$

Results

Heavy Metals in Water

The result of the heavy metals analysis of water for the two sampled stations is shown in Table 1. The values of Cu, Pb, Cr, Fe and Zn were below the WHO and NSDWQ recommended limit for water. Cd and As were above the recommended limit of both WHO and NSDWQ but Mn at station 2 was above the recommended limit of both WHO and NSDWQ. Ni in both stations was also above the WHO limit of 0.07mg/l. The values recorded for Cd, As and Ni at both stations were 0.01±0.01, 0.03±0.04, 0.10±0.07 and 0.01±0.01, 0.03±0.03, 0.10±0.07 respectively for stations 1 and 2. Cu, Pb, Cr and Zn were highest at station 1 while Cd, As, Ni, Fe, and Mn were highest at station 2. The pattern of metal concentration for station 1 was Zn > Mn > Ni > Cu > Cr >As > Fe > Cd > Pb while for station 2, Zn > Mn > Ni > As > Cu > Cr > Fe > Cd > Pb.

Table 1: Summary of Heavy Metals Concentration in water of river Gongola

Heavy Metals	Station 1	Station 2	P-value	WHO	NSDWQ
	Mean±SD	Mean±SD			
Cu	0.04±0.03	0.03±0.02	P>0.05	2	1
Pb	0.01±0.01	0.00±0.00	P>0.05	0.01	0.01
Cr	0.03±0.03	0.03±0.03	P>0.05	0.05	0.05
Cd	0.01±0.01	0.01±0.01	P>0.05	0.003	0.003
As	0.03±0.04	0.03±0.03	P>0.05	0.01	0.01
Ni	0.10±0.07	0.10±0.07	P>0.05	0.07	0.02
Fe	0.03±0.02	0.03±0.02	P>0.05	0.3	0.3
Mn	0.37±0.48	0.47±0.70	P>0.05	0.4	0.2

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Zn	0.96±0.89	0.54±0.33	P<0.05	5	3

Heavy Metals in the Fishes

For the liver, the variations observed for the concentration of heavy metals in the three fish species are shown in figure 1. The concentration of Cu, Cd and Ni were highest in *C. gariepinus*, Cr and As were higher in *O. niloticus* and Fe and Zn were highest in *B. bayad macropterus*. Mn values were higher in both *B. bayad macropterus* and *C. gariepinus.* In terms of heavy metal bioaccumulated, Zn recorded the highest values in all the three fish species as seen in figure 1. For the muscle, figure 2 shows the variation in the metal concentrations. The values of Zn were highest for all the three fish species with *C. gariepinus* having the highest value followed by *O. niloticus* and *B. bayad macropterus*. The highest concentration of Cu was found in *C. gariepinus* and the lowest in *O. niloticus*. *B. bayad macropterus* had the highest concentrations of Cr and Fe; even as *O. niloticus* had the highest concentration of As, Ni and Mn. All the concentrations were below the WHO standard for metals in fishes.

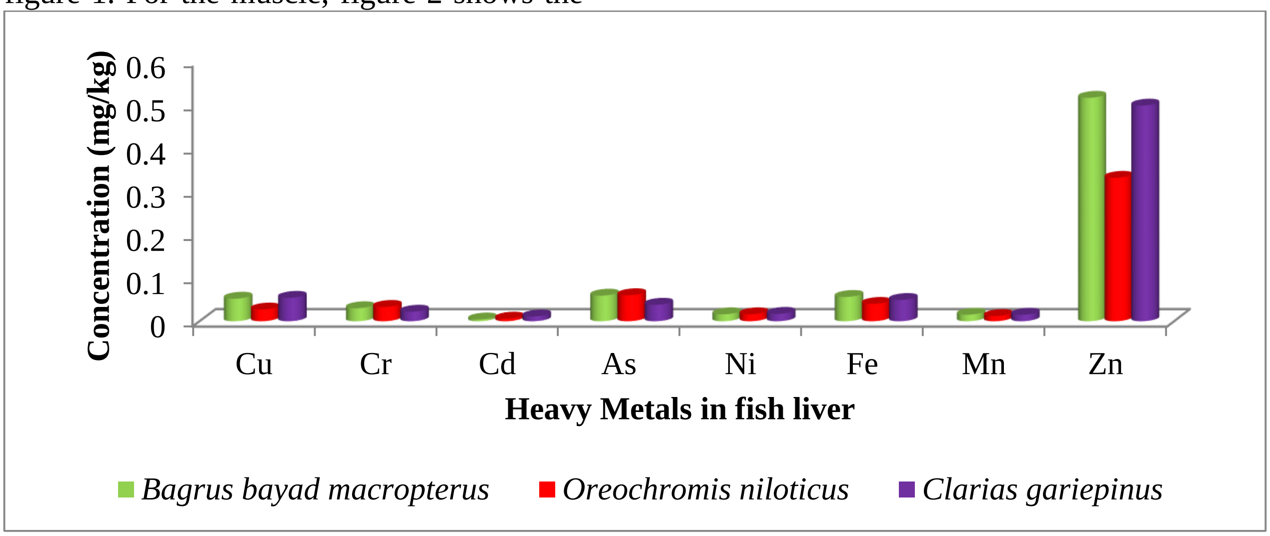

Figure 1: Heavy Metals concentrations (mg/kg) in liver of the three fish species

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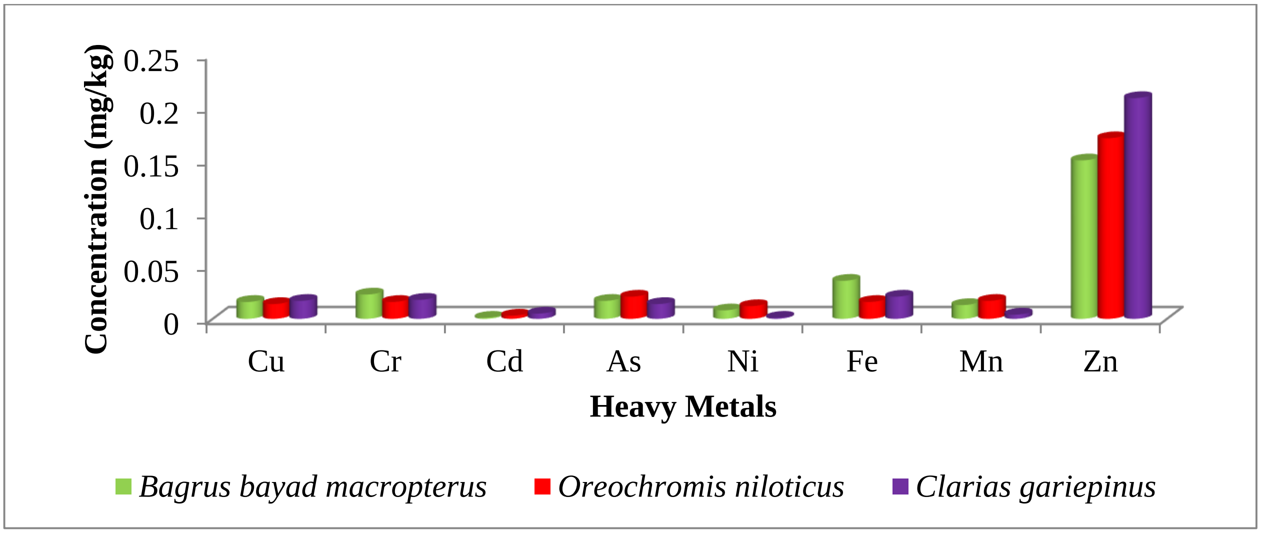

Figure 2: Heavy Metals concentrations (mg/kg) in Muscle of the three fish species

Like the liver and muscle, the values of Zn in the gills of the three fish species were also higher than the other heavy metals studied. The highest value was observed in *B. bayad macropterus* followed by *C. gariepinus* as shown in figure 3. *O. niloticus* had the lowest values for all the heavy metals as seen in figure 3. Cr, As, Mn and Zn had the highest concentration in *B. bayad macropterus*. Ni and Cu had the highest concentration in *C. gariepinus* while both Cd and Fe were higher in *B. bayad macropterus* and *C. gariepinus*. However, all the values observed were below the WHO standard for heavy metals in fish. Analysis of variance showed that the levels of the heavy metals were higher in the livers than the gills and the muscles as shown in figure 4.

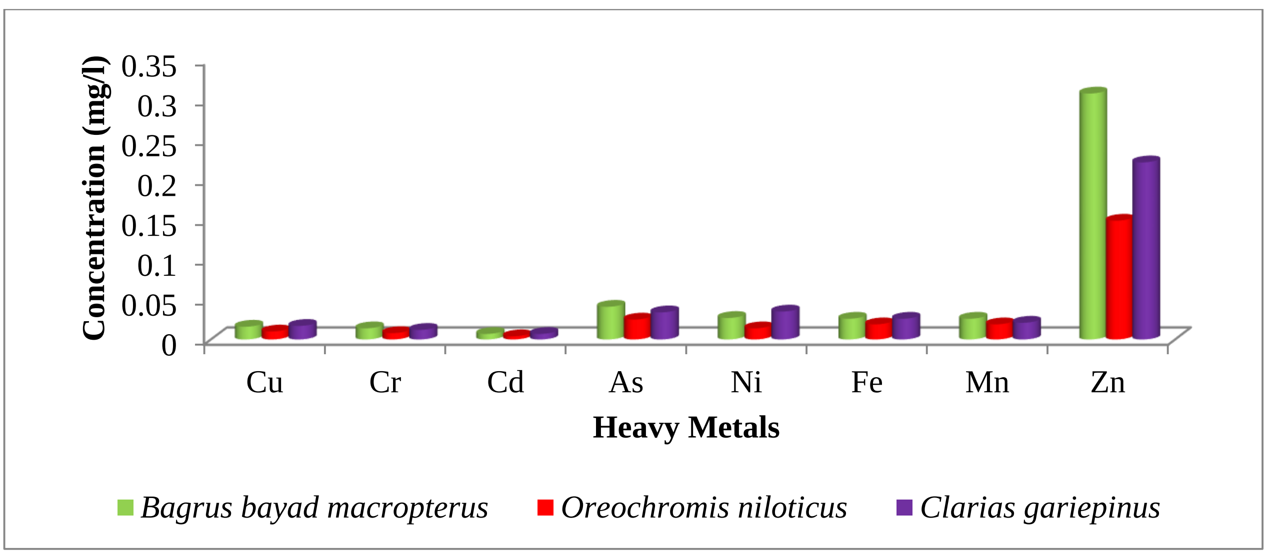

Figure 3: Heavy Metals concentrations (mg/kg) in gills of the three fish species

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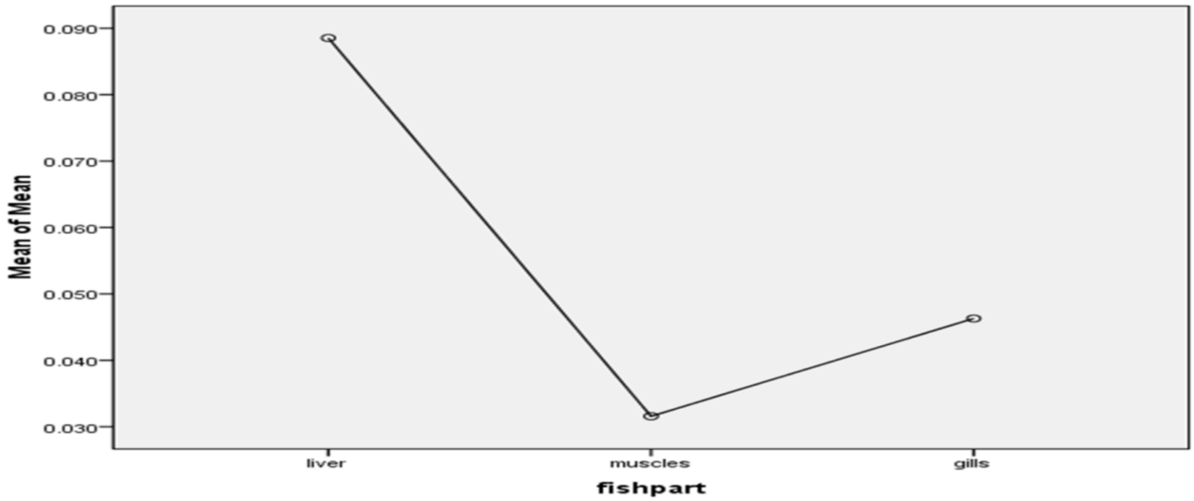

Figure 4: ANOVA Graph showing variation in heavy metals concentrations between fish parts

Bioaccumulation Factor (BAF) of Heavy Metals in Fishes

The BAF calculated for the three fish species are shown in Table 2. BAFs values of As (1.22±0.02 and 1.10±0.02) for *B. bayad macropterus* and *O. niloticus* and Fe (1.46±0.02 and 1.19±0.01) for *B. bayad macropterus* and *C. gariepinus* were greater than 1 and higher than the BAFs of the other heavy metals studied. All the other heavy metals had BAF values less than 1.

Table 2: Bioaccumulation factors of Metals in *B. macropterus, O. niloticus* and *C. gariepinus*

Heavy Metals	*B. bayad macropterus*	*O. niloticus*	*C. gariepinus*
Cu	0.82±0.02	0.50±0.01	0.86±0.03
Cr	0.70±0.01	0.59±0.01	0.54±0.01
Cd	0.33±0.00	0.36±0.00	0.64±0.00
As	1.22±0.02	1.10±0.02	0.90±0.01
Ni	0.18±0.01	0.14±0.00	0.18±0.02
Fe	1.46±0.02	0.93±0.01	1.19±0.01
Mn	0.04±0.01	0.04±0.00	0.03±0.01
Zn	0.43±0.18	0.29±0.10	0.41±0.16

Discussion

The mean concentration of heavy metals in water of the two stations were mostly below the standard limit of WHO and NSDWQ except for Cd, As, Ni and Mn. Cadmium (Cd) in all stations was higher than the 0.003mg/l limit stipulated by WHO (2011) and NSDWQ (2015). According to Uba *et al.,* (2019), Cd is a very toxic metal that can replace Zn in the body and appears to be a cumulative toxicant that can harm fish and humans alike. Long-term exposure to Cd can cause disorders in the body. The high As levels recorded in this study might be due to agricultural impacts on the river at all the stations. All these stations are closed to agricultural lands that engage in both dry and rainy season farming. Municipal wastes discharges into river bodies have been reported to be one of the sources of nickel (Giuseppe *et al.*,, 2020). Manganese naturally occurs with iron, oxygen, sulfur, and chlorine and it is one of the most common metals in the earth crust (Williams *et al.,* 2012). Exposure to high Mn concentrations may cause neurotoxicity (Philip and Bernnard 2020; Saah *et al.,* 2021).

However, the mean concentration of all the heavy metals in the tissues of all the three fish species was below the recommended standard. This agrees with the reports of Rajeshkumar and Li (2018) and Ezekiel *et al.,* (2019) but disagrees with Davies and Ekperusi (2021). The pattern of metal uptake in this study was liver > gills > muscle. The higher concentration of the metals in the liver than other tissues agrees with the findings of Green *et al.,* (2023) and Akaninyene *et al.,* (2016). The reasons for this could be that the liver is an active organ involved in many physiological processes including detoxification of foreign substances in the body and it also plays a physiological role in the metabolism and storage of essential metals like Zn and Cu (Green *et al* . 2023). The liver also has a higher capacity for metal binding than other parts of the fish (Nazish *et al.*, 2020 and Bawuro *et al.,* 2018). After the liver, the gills is the next in uptake of metals in this study and gills are the primary pathway for metal ion exchange from water because of their large surface area which facilitates diffusion, which may be the reason why they accumulate more than the muscles (Qadir and Malik 2011; Dhaneesh *et al.,* 2012). It is therefore commonly believed that the majority of the metals that build up in the gills do come from the water. In all the tissues studied (liver, muscle and gills), the concentration levels of Zn was the highest among all the heavy metals studied. Zn may induce toxicity, marked by symptoms of agitation, muscular stiffness and soreness, lack of appetite and nausea (Sharma *et al.*, 2014). Reduced fertility is caused by hypogonadism, taste loss, and delayed growth, all of which require zinc, an essential trace metal (Sivapermal *et al.*, 2007).

One ecological method for determining the amount of pollutants in living things is the bioaccumulation factor, which is used in environmental assessment. The concentration of heavy metals in water divided by the concentrations in a fish was used to compute BAF in this investigation. An effective absorption of pollutants is indicated by a BAF value greater than 1 (Davies and Ekperusi 2021). In this study, most of the BAF values for all the heavy metals were less than 1 except for As in *B. bayad macropterus* and *O. niloticus* and Fe in *B. bayad macropterus* and *C. gariepinus* which were greater than 1, an indication of high uptake of these metals. The reason for this is that most of the heavy metals concentration were observed to be mostly higher in water than in the fishes except for As and Fe. *B. bayad macropterus* had the highest bioaccumulation factor because it has both As and Fe BAF values to be greater than 1. Despite the fact that the concentration of both As and Fe in the water and the fishes were below the standards, the reason for the BAF values being greater than 1 was as a result of higher concentration of these metals in the respective fishes than in the water.

Conclusion

The findings of the study showed that the water of River Gongola at this location is contaminated due to higher values of Cd, As, Ni and Mn. The liver concentrated higher levels of the metals followed by the gills and the muscle. However, the levels of the metals reported in the tissues of the three fishes were below the recommended standards. The BAF values show no probability of bioaccumulation in most of the fishes. The study concluded that the status of the fish is safe. Future research with other fish species is recommended.

Conflict of interest

The Authors declare no conflict of interest

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