https://dx.doi.org/10.4314/dujopas.v10i4c.20
ISSN (Print): 2476-8316
ISSN (Online): 2635-3490
Dutse Journal of Pure and Applied Sciences (DUJOPAS), *Vol. 10 No. 4c December 2024*

Bioaccumulation of Some Heavy Metals in Organs of *Heterotis niloticus* and *Tilapia zillii* in Maladumba Wetland, Misau LGA, Bauchi North-Eastern Nigeria

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Abstract

Fish is a highly valued source of protein, prized for its exceptional quality, polyunsaturated fatty acids, vitamin B, and other essential nutrients. This study, conducted in Maladumba Wetland, Misau Local Government Area of Bauchi State, northeastern Nigeria, aimed to assess the concentration of heavy metals (lead, chromium, cadmium, and copper) examine the spatio-temporal dynamics of physicochemical parameters in the wetland and evaluate the accumulation of these heavy metals in the kidney, liver, flesh, and gills of two commercially important fish species, Heterotis niloticus (African bony tongue) and Tilapia zillii (Mango Fish). Water quality parameters such as pH, dissolved oxygen (DO), temperature, etc. were measured. Data were analyzed using ANOVA, Tukey's test, and Pearson's correlation. The mean physicochemical parameters recorded in water were temperature (23.83 ± 0.94°C), pH (6.61 ± 0.17), DO (4.63 ± 0.11 mg/L), BOD (28.41 ± 0.11 mg/L), COD (183.91 ± 3.01 mg/L), and turbidity (28.17 ± 0.17 NTU). The mean concentrations (mg/kg) of heavy metals in Heterotis niloticus were cadmium (0.93 ± 0.01), chromium (5.01 ± 0.17), copper (7.31 ± 0.04), and lead (7.15 ± 0.04). In Tilapia zillii, the concentrations were cadmium (3.00 ± 0.20), chromium (5.00 ± 0.17), copper (9.95 ± 0.03), and lead (6.80 ± 0.17). Copper was the most abundant heavy metal in both fish species, while cadmium was the least. The study highlighted the risks associated with heavy metal contamination in the Maladumba Wetland and the potential dangers of consuming contaminated fish. Further research is recommended to explore the human health implications of heavy metal bioaccumulation in fish from this wetland.

Keywords: Bioaccumulation, Heavy Metals, Maladumba Wetland, Spatio temporal dynamics, Water Quality

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INTRODUCTION

Fish is one of the most important protein foods of great interest for consumers considering its high-quality protein, polyunsaturated fatty acids, vitamin B and other important nutrients (Sarojnalini and Hei, 2019). However, environmental pollution poses greater risks in certain coastal regions and wetlands due to rapid industrial development and diverse human activities. Aquatic organisms such as fishes can accumulate these contaminants in their organs (kidney, flesh, liver, and gills) and give rise to health risk (Agbugui and Abe, 2022). Heavy metals have been considered a serious global environmental threat, and aquatic organisms like fish can absorb toxic metals from the surrounding water as well as food (Sharma *et al.*, 2024). The presence of toxic heavy metals in fish can undermine their nutritional benefits. Several unfavourable effects of heavy metals to human's health have been known for long time, and this include serious threats like renal failure, liver damage, cardiovascular disease, and even death. (Bawuro *et al.*, 2018).

A significant amount of untreated industrial effluents is discharged into aquatic environments, posing threats to aquatic flora, fauna, and humans. Heavy metals such as Copper (Cu), Lead (Pb), Chromium (Cr), and Cadmium (Cd) are key components of these ecosystems, typically present in low concentrations. Heavy metals accumulate in the fish in two ways i.e. direct and indirect accumulation. Direct accumulation is by consumption of contaminated food and water through the digestive system and this is considered as direct exposure, indirect accumulation through the permeable membranes such as gills and skins. The level of heavy metals concentration in fish organs indicates their levels also in their surrounding environment. Contamination of heavy metals in water may lead to changes in the chemical components of the aquatic environment which may influence the behavioural, physiological, cell structure, gill's function, liver function, skin function, and kidney function of fishes (Shahjahan *et al.*, 2022).

Due to anthropogenic and industrial activities carried out in Wetland, so many water pollutants are released into the Wetland. Among environmental pollutants, heavy metals are of major concern; due to their potential toxic effect and ability to accumulate in fishes (Garai *et a*l., 2021) thus, the pollution of the aquatic environment with heavy metals has become a serious problem worldwide in recent years. Heavy metals that are deposited in the aquatic environment such as Cadmium (Cd), chromium (Cr), copper (Cu) and Lead (Pb) accumulated in food chain and caused ecological damage and also caused threat to human health, (Sonone *et al.*, 2020). Studies have shown that fish accumulate these heavy metals from the surrounding water bodies through drinking contaminated water and ingestion of contaminated food (Idodo, 2012). Heavy metals such as Lead, Chromium, Copper and Cadmium are essential metals since they are useful in biological system. However, these essential metals can also produce toxic effects when they are taken into biological systems through ingestion and skin absorption. Hence this study was conducted in Maladumba Wetland, Misau Local Government Area, Bauchi State, Northeastern Nigeria, to evaluate the concentration of selected heavy metals (Lead, Chromium, Cadmium, and Copper) within the wetland. It also aimed to analyze the spatio-temporal variations in the wetland's physicochemical parameters and determine the levels of these heavy metals in various organs (kidney, liver, flesh, and gills) of two commercially significant fish species, *Heterotis niloticus* (African bony tongue) and *Tilapia zillii* (Mango Fish).

MATERIALS AND METHODS

Study Area

Maladumba wetland is one among the natural wetlands in Bauchi state, Nigeria. It is located in Maladumba town (11^0 13′56.28′′N, 10^0 21′ 42.12′E′) which is approximately 18km south-east of Misau town and 2km east of Shelong town, a fishing village in Misau Local Government Area of Bauchi State as presented in Figure. 1. The region experiences two distinct seasons: the dry season, lasting from November to April, and the wet season, from May to October. Daily temperatures fluctuate seasonally, and the area receives an average annual rainfall ranging from 150 to 1000 mm. The climate is characterized by high rates of evapotranspiration (Ajakaye *et al.,* 2022).

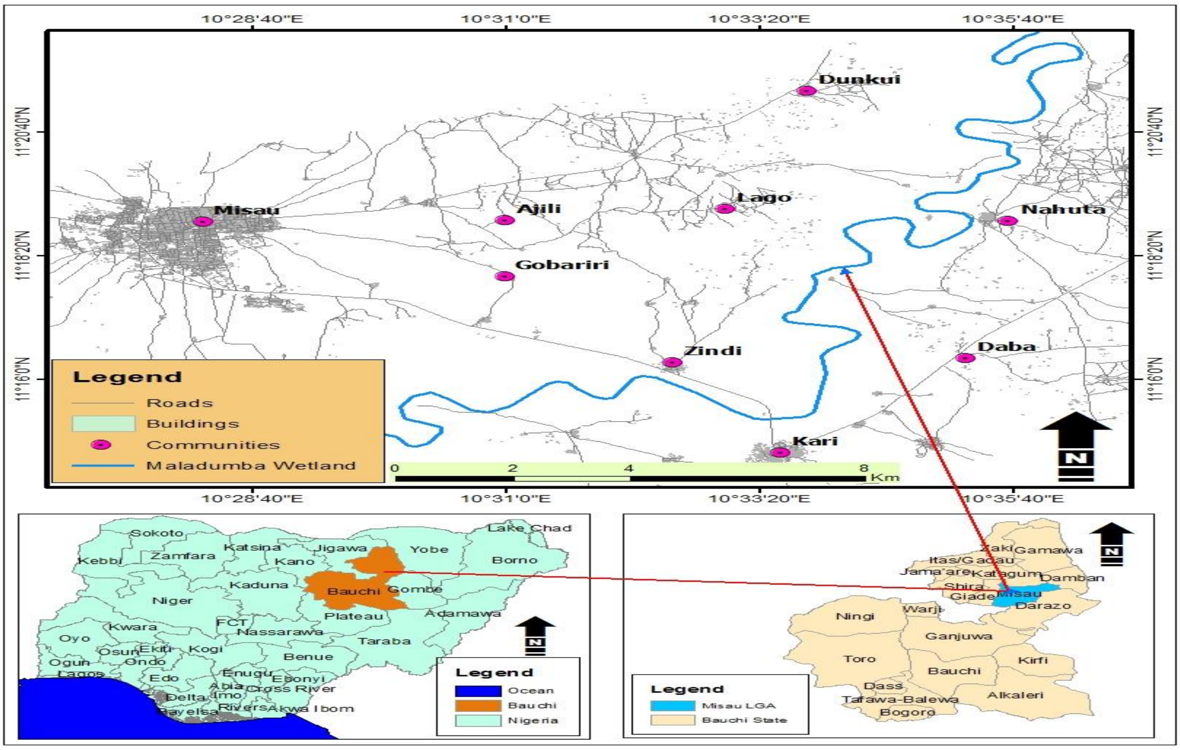

Figure: 1: Map of Study the Study Area Showing Maladumba Wetland Area

Collection of Water Sample

Eight (8) water samples were collected during both the dry and rainy seasons, with four (4) samples taken in each season. The samples were obtained from two (2) inflow and two (2) outflow sites of the Maladumba Wetland during the evening period using transparent containers. The bottles were rinsed with water from the wetland and were submerged below the level and filled completely to the top. The lid of the container was screwed so tight to prevent leakage. The water samples were securely collected and transported to the laboratory for analysis. The water samples were carefully collected and safely transported to the laboratory for analysis. In the laboratory, they were assessed for various physicochemical parameters, including temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), and turbidity.

Collection of Fish Samples

Fishes viz; *Heterotis niloticus* (African bony tongue) and *Tilapia zillii* (Mango fish) were caught directly from the Maladumba lake by using fish traps set overnight with the help of local fishermen at the wetland in two seasons i.e. dry and wet seasons, using standard fishing gear described by United Nations Environment Programme (UNEP, 2012); *Heterotis niloticus*

(African bony tongue) was caught with baited fishing hook, while *Tilapia zillii* (mango fish) was caught with fishnet mesh size three(3) inches by local fishermen. The difference in fishing gears was due to the variation in size of the two fish species. Four (4) fish of each species were collected during each sampling. The collected fish were preserved and transported to the laboratory, where they were identified, weighed, and their total length measured. The fish were then frozen and later analyzed, focusing on the targeted organs: liver, kidney, flesh, and gills. A specialist from Department of Fisheries and Aquaculture, Bayero University Kano state, Nigeria, analyzed the fish species.

Assessment of Physicochemical Parameters of Water

Temperature and pH of the water were measured in-situ; and other parameters analyses were carried out in the laboratory using APHA (2012) standard procedures. Collected water samples were assessed in laboratory for dissolved oxygen (DO) concentration, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and turbidity.

Determination of Heavy Metals Concentration

The fish samples were rinsed with distilled water and scales of *Heterotis niloticu*s and *Tilapia zillii* were removed. The fishes were dissected into separate organs flesh, gills, liver and kidney using stainless steel instrument and digested by the method described by Voegborlo and Adimado (2010).

In the first procedure, the fish sample was digested with hydrochloric acid ($HClO_4$) and nitric acid (HNO_3) with ratio (1:1), followed by sulphuric acid (H_2SO_4) and the mixture was heated at 200^0C for 30 minutes. Based on that, the complete digest was cooled down at room temperature made up to 50ml scale with distilled water and analysed for Lead (Pb), Copper (Cu),Chromium (Cr), and Cadmium (Cd) using atomic absorption spectrophotometer (AAS modern AA55).

After selecting the various wave lengths at which the heavy metals were determined. An analytical blank was prepared in a similar manner. The results were expressed as mg/kg wet weight.

Statistical Analysis

Data obtained from this study were presented in mean plus or minus standard error of their replicate, and presented in tables and charts. Significant differences in spatiotemporal dynamics of physicochemical parameters and that of heavy metals concentration in the organs examined were determined using the analysis of variance (ANOVA) coupled with the Tukey range test. Results of the test were considered significant if the calculated P values were < 0.05.T-test was used to show variation of data between the two seasons.

RESULTS AND DISCUSSION

Physicochemical Parameters of Maladumba Wetland

The overall physicochemical parameters of the Maladumba Wetland are presented in Table 1. A significant difference ($p<0.05$) was observed in water temperatures between the wet and dry seasons at the river stations of the wetland. The highest water temperature during the wet season was recorded at Station 2 (outflow/wet), measuring 23.83 ± 0.94°C. In contrast, the highest temperature during the dry season was observed at Station 1 (inflow/dry), with a value of 21.32 ± 0.09°C.

Table 1: Spatial and Temporal Dynamics of Physicochemical Parameters of Maladumba Wetland

Season	Physicochemical Parameters					
(NUT)	T (°c)	pH	DO (mg/l)	BOD (mgl)	COD (mg/l)	TU
Infl-July/Sep	20.90±0.20[a]	6.05±0.06[a]	4.06±0.02[a]	20.03±4.77[a]	185.10±4.35[a]	28.17±0.17[a]
Infl-Feb/April	21.32±0.09[a]	5.61±0.30[b]	2.31±0.11[b]	25.05±0.02[a]	152.06±1.72[b]	19.16±0.03[b]
Outfl-July/Sep	23.83±0.94[b]	6.61±0.17[a]	4.63±0.11[a]	28.41±0.11[a]	183.91±3.01[a]	28.10±0.10[a]
Outfl-Feb/April	21.04±0.04[a]	5.40±0.36[b]	2.20±0.20[b]	25.05±0.02[a]	152.17±0.90[b]	19.16±0.04[b]
p-Value	0.000	0.002	0.000	0.601	0.000	0.000

Key; **Infl:** inflow, **Outfl:** outflow, **DO:** dissolved oxygen, **T:** temperature, **COD:** chemical oxygen demand, **BOD:** biological oxygen demand, **TU:** turbidity.

The analytical results were statistically significant at p≤0.05. Means in columns followed by the same letter(s) are not significantly different.

Heavy Metals Concentration (ppm) in Water of Maladumba Wetland

Summary of Lead, Cadmium, Chromium and Copper in water collected from Maladumba wetland during the wet and dry seasons, along with associated p-values are provided in table 2. The concentration of lead (Pb) in the water was measured at 2.17±0.03 ppm, indicating a relatively high level. In contrast, during the dry season, the lead concentration dropped significantly to 1.10±0.04 ppm. 0.00 p-value gave a highly significant difference in lead levels between the wet and dry seasons, indicating that seasonality has a profound impact on lead concentrations in the Maladumba wetland. However, Cadmium (Cd) concentration during the wet season was found to be 0.40±0.30 ppm, and it decreased slightly to 0.10±0.10 ppm during dry season.

The p-value of 0.158 suggests that the difference in cadmium levels between the two seasons is not statistically significant at the conventional significance level of p<0.05. The concentration of Chromium (Cr) was 0.90±0.26 ppm during the wet season and 0.30±0.26 ppm in the dry season. The p-value of 0.05 suggests that the reduction in chromium levels from wet to dry season is statistically significant, albeit only marginally. Copper (Cu) concentration was 0.70±0.26 ppm during wet season and 0.40±0.20 ppm during dry season. The p-value of 0.192 indicates that the difference in copper levels between the two seasons is not statistically significant, similar to cadmium.

From the result however, the heavy metals analysis for Maladumba wetland water indicate significant variations in lead and chromium concentrations between the wet and dry seasons. Lead level substantially decreased during the dry season; chromium level also decreased but to a lesser extent. Cadmium and copper levels on the other hand, show no significant differences between the two seasons. These findings may have important implications for understanding the environmental dynamics and potential risks associated with heavy metals contamination in Maladumba wetland.

Table 2: The Heavy Metals Concentration (ppm) in The Water of Maladumba Wetland.

Heavy Metals	Wet Season	Dry Season	p-value	WHO (2012) Standard
Lead	2.17±0.03	1.10±0.04	00	0.16
Cadmium	0.40±0.30	0.10±0.10	0.15	0.21
Chromium	0.90±0.26	0.30±0.26	0.05	0.27
Copper	0.70±0.26	0.40±0.20	0.192	1.35

Seasonal Variation in Concentration Of Heavy Metals (Mg/Kg) Within the Various Parts of *Heterotis Niloticus* and *Tilapia Zillii*

The study presented the concentration of heavy metals in order of liver, kidney gills and flesh. Essential metal Copper (Cu) and nonessential metal Lead (Pb) indicated higher bioaccumulation of metals in the liver organ (Table 3).

Table 3: Seasonal Variation in Concentration of Heavy Metals in (mg/kg) within the Flesh, Kidney, Liver and Gills of *Heterotis niloticus* and *Tilapia zillii* in Maladumba Wetland

		Heterotis niloticus				*Tilapia zillii*			
Heavy metals	Season	Flesh	Gill	Kidney	Liver	Flesh	Gill	Kidney	Liver
Cadmium	Dry	0.83±0.03	0.73±0.04	0.93±0.01	0.50±0.05	0.87±0.02	0.36±0.03	0.81±0.03	2.91±0.02
	Wet	0.50±0.17	0.80±0.10	0.05±0.17	0.55±.03	0.07±0.26	0.75±0.04	3.00±0.20	1.40±0.17
Lead	Dry	7.15±0.14	4.16±0.03	0.00±0.00	6.81±0.32	6.09±0.03	3.38±0.03	0.00±0.00	1.50±0.17
	Wet	4.50±0.16	4.25±0.05	4.25±0.02	4.10±0.20	5. 05±0.03	6.80±0.17	0.00±0.00	4.16±0.03
Chromium	Dry	ND	2.13±0.05	5.01±0.17	3.11±0.03	0.40±0.02	3.30±0.05	4.61±0.02	4.16±0.03
	Wet	0.05±0.04	1.35±0.10	3.25±0.11	2.05±0.03	1.10±0.04	3.75±0.13	5.00±0.17	3.15±0.02
Copper	Dry	4. 61±0.04	5.63±0.03	4.91±0.01	7.31±0.04	5.11±0.45	6.73±0.03	4.20±0.04	6.04±0.09
	Wet	3.40±0.01	4.30±0.26	3.70±2.60	6.70±0.26	3.10±0.10	3.73±0.01	3.81±0.01	9.95±0.03

Key: ND; Not Detected

DISCUSSION

In the Maladumba wetland (river stations), there was a significant difference in the wet and dry season on water temperatures ($p<0.05$). Based on that, the highest wet and dry season water temperature was recorded in station 2 wet season (S2W) i.e. out flow/ wet (23.83 ± 0.94^{o}c) site and station 1 dry (S1D) i.e. inflow/dry (21.32 ± 0.09). The presence of high temperature in these sites may be related to the high total or too much accumulation of sediments that makes the water warmed. This is agreement with the result of Lopes *et al.,* 2021 that reported that Sediments can influence water temperature through various mechanisms, including heat exchange processes and the physical properties of the sediment itself. The wet and dry season's water temperature in S1W, S1D and S2D sites were significantly different from S2W. The wet season pH of the water in the station 2 wet (S2W-July/September) and station 1 wet (S1W-July/September) was significantly different from the other sites. The presence of high pH in the S2W site and S1W sites (6.61±0.17 and 6.06±0.06) might be related to the regular embarking on the anthropogenic activities such as washing clothes and bathing by using detergents and soaps around the sites. In general, chemicals, minerals, pollutants and any contaminant that interact with a water supply create an imbalance in the water's natural pH (EPA, 2014) The finding is consistent with Idodo (2012), who reported the increase of water pH due to soap and detergents' presence in the water. Based that, the dry and wet season pH of the water in all sites within the permissible limit of World Health Organization (WHO, 2012) (6.5-8.5). Similar finding have been reported by Toledo *et al.* (2021), who reported the increase of water pH due to soap and detergents' presence in the water. Based on the results, the pH levels of the water in all sites during both the dry and wet seasons fall within the permissible limits set by the World Health Organization (WHO, 2012) (6.5-8.5).

The dry and wet season's water turbidity was significantly different between the sites, the high-water turbidity was recorded in the S1W and S2W sites (28.17. ±0.17 and 28.10±0.10 NTU), and the presence of high turbidity might be related to the availability of nutrients, soil erosion from the road construction site and near-by block industry and also farmland by the water site, especially at the inflow site discharged into the wetland. There is also discharge of organic sewage from the residential area close to the wetland. This is in agreement with the statement of Peterse *et al*. (2024) that the presence of high sediments and discharge of sewage organic effluents increases river turbidity. The content of biological oxygen demand of water in both the wet and the dry season was significantly different between the sites. And the highest biological oxygen demand was recorded in S2W (28.41 ± 0.11). The presence of high BOD content in the S2W during wet season may be associated with the organic materials load and released from farm lands (Agriculture) and urban land use. The high Biological Oxygen Demand (BOD) values in S1D (25.05±0.02) and S2D (25.05±0.02) are attributed to the discharge of organic waste effluents from households into the water, a finding consistent with Nugraha *et al.* (2020). A significant difference in dissolved oxygen levels was observed between the wet and dry seasons across the stations. The highest dissolved oxygen (DO) was recorded in S2W (4.62±0.11), and S1W (4.06 ± 0.02) both in wet season. In dry season both inflow and outflow sites, recorded S1D (2.31 ± 0.11) and S2D (2.20 ± 0.20). The highest dissolved oxygen (DO) levels observed during the wet season may be influenced by temperature, as both temperature and DO exhibit seasonal and daily fluctuations. Cold water typically holds more dissolved oxygen than warm water. When temperature is low, the dissolved oxygen concentration is high, and when the temperature is high, the dissolved oxygen concentration is often lower (Boyd and Boyd, 2020). Low level of dissolved oxygen (DO) is affected by ionic strength and dissolved solids, oxygen solubility decreases as these parameters increase, reducing the amount of dissolved oxygen in water (Adesuyi *et al.,* 2021). The chemical oxygen demand (COD) content of water during the wet and dry seasons differs significantly ($P<0.05$) between the sites. The elevated COD levels in S1W (185.10±4.33) and S2W (183.91±3.01) during the wet season are attributed to the discharge of decaying plant matter, such as fallen leaves, human waste, and industrial effluents into the wetland. Additionally, sewage and agricultural runoff contribute to the high COD concentrations. COD levels increase with the presence of organic materials, including plant material. This finding is consistent with Xiao *et al.* (2020), which noted that COD rises when organic compounds, particularly those susceptible to oxidation by oxidizing agents like dichromates, are present in the water.

There was a significant difference in water turbidity between the dry and wet seasons across the sites. The highest turbidity levels were recorded at the S1W and S2W sites (28.17±0.17 NTU and 28.10±0.10 NTU, respectively). The elevated turbidity can be attributed to factors such as the availability of nutrients, soil erosion from nearby road construction, the presence of a nearby block industry, and agricultural activities near the water site, particularly at the inflow area that drains into the wetland. Additionally, the discharge of organic sewage from residential areas close to the wetland contributes to the high turbidity. This study is in agreement with Salim *et al.* (2021) who found that the presence of high sediment levels and the discharge of sewage effluents increase river turbidity. The biological oxygen demand (BOD) content of water during both the wet and dry seasons showed a significant difference between the sites. And the highest biological oxygen demand was recorded in S2W (28.41 ± 0.11). The high BOD values in S1D (25.05±0.02) and S2D (25.05±0.02) are attributed to the discharge of organic waste effluents from households into the water, a finding consistent with Wulan *et al.* (2022). Additionally, a significant difference in dissolved oxygen levels between the stations was observed between the wet and dry seasons.

Copper (Cu) recorded highest concentration in liver and this bioaccumulation of liver may be linked to its function of metabolism, chemical process that occurs within living organism in order to maintain life. Higher concentration of lead and copper in the liver is also connected to natural protein binding such as metallothioneins. Liver serves as store for metals redistribution and detoxification. And this is the reason why liver organs are regarded as an indicator of water pollution than any organ in fishes. Similar results of Lead and Copper were recorded by Santos *et al.* (2022) Lead also recorded higher concentration in gills as well as in flesh. The lowest concentrations of metals recorded in the flesh, gills, and liver were for Cadmium, while the lowest metal concentration in the kidney was for Lead. The gills serve as pathways for the exchange of metal ions from the water, as their large surface area facilitates the rapid diffusion of metals. Hence, it is suggested that metals accumulated in gills are basically concentrated from water, and this is in agreement with the result of Garai *et al.* (2021) that reported that, the accumulation of metals in the gills of aquatic organisms is primarily influenced by their direct exposure to water, where metals are dissolved. Chromium (Cr) was not detected in the flesh of *Heterotis niloticus*, but was recorded at lower level in *Tilapia zillii* with (0.40±0.02) and this is may be due to the low activities of wood preservation and absence of hide tanning activities around the wetland as reported similarly by Butt *et al.* (2021).

CONCLUSION

The Maladumba Wetland is impacted by anthropogenic activities, including domestic sewage, industrial effluents, and agricultural processes, leading to heavy metal contamination and altered physicochemical parameters. This study revealed significant bioaccumulation of cadmium and copper in fish organs, particularly the liver, kidney, flesh, and gills of *Heterotis niloticus* and *Tilapia zillii*, posing potential long-term risks to aquatic life and human consumers. The wetland's physicochemical dynamics, such as elevated temperatures, turbidity, and nutrient levels during the wet season, indicate ongoing eutrophication driven by human activities.

Recommendations include strengthening monitoring programs to regularly assess heavy metal concentrations, implementing policies to regulate industrial and agricultural discharges, raising community awareness about the impacts of improper waste disposal, conducting further studies on potential health risks to fish consumers, and promoting conservation strategies to restore and protect the wetland ecosystem.

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