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BIOACCUMULATION OF HEAVY METALS IN FISHES (*CATLA CATLA* AND *TILAPIA MOZAMBIQUE)* OF LAKSHMINARAYANA LAKE, EDULABAD, HYDERABAD, TELANGANA

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ABSTRACT

Chronic exposure to heavy metals can lead to organ damage, impaired growth, reproductive issues, and compromised immune function. Monitoring Catla catla in Lakshminarayana Lake helps evaluate environmental pollution and potential human health hazards, emphasizing the delicate balance between aquatic ecosystems and our well-being. This study aims to understand heavy metal levels in the lake and their accumulation in fish tissues, crucial for evaluating ecological health and fish safety. By analyzing heavy metal concentrations in the muscle, liver, and gill tissues of Catla catla and Tilapia mozambique, this research provides a unique view of bioaccumulation patterns not previously explored in this context.In the study of Catla catla tissue samples, the muscle tissue exhibits varying heavy metal bioaccumulation patterns, with nickel (Ni) having the highest concentration, followed by cadmium (Cd), lead (Pb), zinc (Zn), and chromium (Cr). The liver tissue shows chromium (Cr) as the dominant metal, followed by nickel (Ni), lead (Pb), cadmium (Cd), and zinc (Zn). In the gills, chromium (Cr) has the highest concentration. For Tilapia mozambique tissue samples, the muscle tissue stands out with zinc (Zn) as the primary metal, followed by cadmium (Cd), nickel (Ni), lead (Pb), and chromium (Cr). In the liver, zinc (Zn) dominates, followed by cadmium (Cd). The gills of Tilapia mozambique also exhibit high zinc (Zn) concentration. This research contributes to evaluating ecological health, heavy metal pollution, and fish safety in Lakshminarayana Lake. Understanding bioaccumulation patterns aids in safeguarding aquatic ecosystems and human health

Keywords: *Catla catla, Tilapia mozambique,* Lakshminarayana, Hyderabad, Edulabad, Zn, Ni.

1. INTRODUCTION

Heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As) are persistent environmental pollutants. Unlike organic pollutants, heavy metals are non-biodegradable and can accumulate in aquatic ecosystems, leading to long-term ecological consequences (Shahjahan et al., 2022). These metals can enter water bodies through various pathways, including industrial effluents, agricultural runoff, and atmospheric deposition. Once in the aquatic environment, heavy metals can

be taken up by aquatic organisms, leading to bioaccumulation and biomagnification through the food chain (Hayati et al., 2017). Fish are particularly susceptible to heavy metal contamination due to their position in the aquatic food web. They can accumulate heavy metals in their tissues, including muscle, liver, and gills, which can have detrimental effects on their health and survival (Suhendrayatna et al., 2002). Catla catla and Tilapia mozambique are two fish species commonly found in Lakshminarayana Lake. These species are important not only for their ecological roles but also for their economic value as a source of food for local communities.

Catla catla is commonly known as the Indian carp or catla fish, is a freshwater species native to the Indian subcontinent. Its robust, elongated body features a slightly convex dorsal profile, and its coloration ranges from silver to light gray. Notably, the head lacks scales, and the mouth is large and upturned, adapted for surface feeding (Avigliano et al., 2019). Barbels near the mouth aid in sensory perception. The dorsal fin displays a distinct black margin. Ecologically, *Catla catla* plays a vital role as an herbivorous filter feeder, consuming phytoplankton, algae, and detritus. However, its significance extends beyond ecological dynamics. Tilapia is scientifically known as *Oreochromis mossambicus*, is a freshwater fish species native to southeastern Africa and Asia. Its robust, elongated body features a slightly compressed shape. The coloration of *Tilapia mozambique* varies, ranging from silvery-gray to olive-brown. Ecologically, *Tilapia mozambique* plays a vital role as an herbivorous filter feeder, consuming phytoplankton, algae, and detritus. However, its significance extends beyond ecological dynamics (Virk et al., 2003). Bioaccumulated heavy metals pose health risks to both the fish and humans who consume them. Chronic exposure may lead to organ damage, impaired growth, reproductive issues, and compromised immune function. Monitoring *Tilapia mozambique* helps evaluate environmental pollution and potential human health hazards, emphasizing the delicate balance between aquatic ecosystems and our well-being.

Chronic exposure may lead to organ damage, impaired growth, reproductive issues, and compromised immune function (El Shafei et al., 2016). Monitoring *Catla catla* helps evaluate environmental pollution and potential human health hazards, emphasizing the delicate balance between aquatic ecosystems and our well-being. Understanding the levels of heavy metals in Lakshminarayana Lake and their accumulation in fish tissues is crucial for evaluating the ecological health of the lake and the safety of fish consumption for local communities. This research will contribute to the development of effective management strategies to mitigate heavy metal pollution, protect aquatic life, and safeguard human health. While heavy metal contamination in fish is a well-documented phenomenon, this study is unique in its focus on the specific fish species prevalent in Lakshminarayana Lake—*Catla catla* and *Tilapia mozambique*. By analyzing heavy metal concentrations in the muscle, liver, and gill tissues of these species, the research offers a detailed view of bioaccumulation patterns that has not been previously explored in this context.

2. MATERIALS AND METHODS

2.1. Study Area

The study area for assessing the bioaccumulation of heavy metals is Lakshminarayana Lake, also known as Laxminarayna Cheruvu. This lake is situated in Edulabad village, Ghatkesar, Telangana. Its coordinates are Latitude 17°25’26"N and Longitude 78°41’47"E (Figure-1).

Constructed in the 16th century, the lake spans approximately 5 square kilometers and is a popular spot for bird-watching, camping, and enjoying sunrise and sunset views. It hosts a diverse range of bird species, with a recorded count of 152 (Hans India, 2015). However, pollution from industrial waste has become a significant concern. The lake covers an area of 317 acres, with a tank area of 596 acres and a Full Tank Level (FTL) set at 100 meters above sea level. Its perimeter stretches for 12,500 meters, and it has a bund length of 2,400 meters. Notably, Lakshminarayana Lake is located 27 km away from Secunderabad Railway Station and 50 km away from Rajiv Gandhi International Airport. Nearby villages include Marripalli Guda, Bokkoini Guda, Sanadu Patla Guda, and Ghanapur.

Figure-1. Laxminarayna Lake. Edulabad village, Ghatkesar, Telangana

2.2. Selected Fish Species

Selected fish species, *Catla catla* and *Tilapia mozambique* were caught using gill nets with the help of local fishermen from Lakshminarayana Lake in Edulabad, Hyderabad of Telangana State. Fish samples of uniform size were collected in order to avoid the possible error due to size differences. The fish were labelled with an identification number.

2.3. Analysis of Heavy Metals in Fishes Tissue:

2.3.1. Sample Collection

Fish samples were meticulously gathered from six distinct points around the lake with the assistance of local fishermen. This diverse sampling approach helps ensure a representative analysis of heavy metal contamination across different areas of the lake. The collected fish were immediately cleaned

and placed into labeled carry bags to prevent cross-contamination and ensure proper identification. These bags were then packed with ice packs to preserve the freshness of the samples during transport to the laboratory.

2.3.2. Sample Preparation

Cleaning and Dissection: Each fish was carefully cleaned to remove any external contaminants. The scales were removed, and the fish were dissected to collect various tissue samples. Typically, gills, muscle, and liver tissues are of primary interest due to their high potential for bioaccumulating heavy metals.

Tissue Handling: The dissected tissues were promptly placed into labeled petri dishes to ensure accurate identification and tracking. The dishes were then stored under appropriate conditions to prevent any degradation or contamination of the samples.

2.3.3. Digestion of Tissue Samples

To analyze the heavy metal content in fish tissues, an acid digestion procedure similar to that used for water samples was employed (Fawad det al., 2017):

Tissue samples from the gills, muscle, and liver were finely minced to increase the surface area and facilitate complete digestion. A representative portion of each tissue type was then weighed and placed into digestion vessels. Each tissue sample was treated with a mixture of acids—commonly hydrochloric acid (HCl) and nitric acid (HNO_3). The typical volumes used are 6 ml of HCl and 3 ml of HNO_3, though these can be adjusted based on the tissue mass and specific requirements. The acids are chosen for their ability to dissolve complex matrices and release metal ions into solution. The acid-treated tissue samples were heated on a hot water bath or hot plate until the volume was reduced significantly. This process, similar to that used for water samples, helps break down the organic matrix of the tissues and convert the metals into a soluble form. The heating continued until the volume was concentrated to approximately 5 ml. After digestion, the samples were allowed to cool. Following cooling, 45 ml of milli-Q water was added to each sample to achieve a final volume of 50 ml. This step is crucial for standardizing the sample concentration for accurate measurement by Atomic Absorption Spectrophotometry (AAS).

2.3.4. Heavy Metal Analysis by Atomic Absorption Spectrophotometry (AAS)

Post-digestion, the metal concentrations in the fish tissue samples were determined using Atomic Absorption Spectrophotometry. Before analyzing the tissue samples, calibration curves for each heavy metal (Cd, Cr, Pb, Ni, Zn) were established using standard solutions. This calibration ensures accurate quantification of metal levels in the tissue samples. Standard solution of each sample Cd, Cr, Pb, Ni, and Zn were prepared for Atomic absorption spectroscopy to be used. A known 1000 mg/l concentration of the metal solution was prepared from their salts.

The digested samples were introduced into the AAS instrument, where the metal ions were detected based on their specific wavelengths. The instrument measures the amount of light absorbed by the metal ions, which is directly proportional to their concentration in the tissue samples. The results obtained from AAS were used to calculate the concentration of each heavy metal in the fish tissues. These concentrations were then compared to established safety standards to assess the level of contamination and potential health risks.

2.4. Statistical Analysis

Data collected were subjected to one-way analysis of variance (ANOVA), and were used to assess whether samples varied significantly between species, possibilities less than 0.05 ($p<0.05$) were be considered statistically significant.

3. RESULTS

3.1. Bio-accumulation of Heavy Metals in *Catla catla* tissue Samples

Metal Bioaccumulation in Muscle Tissue: In Catla catla, the muscle tissue exhibits varying heavy metal bioaccumulation patterns. Among the metals analyzed, nickel (Ni) stands out with the highest concentration, followed by cadmium (Cd), lead (Pb), zinc (Zn), and chromium (Cr), in that order (Ni > Cd > Pb > Zn > Cr). This pattern suggests that the muscle tissue effectively accumulates nickel. Although muscle generally contains lower levels of heavy metals compared to other tissues, the elevated Ni concentration underscores its importance for monitoring potential contamination effects on fish health.

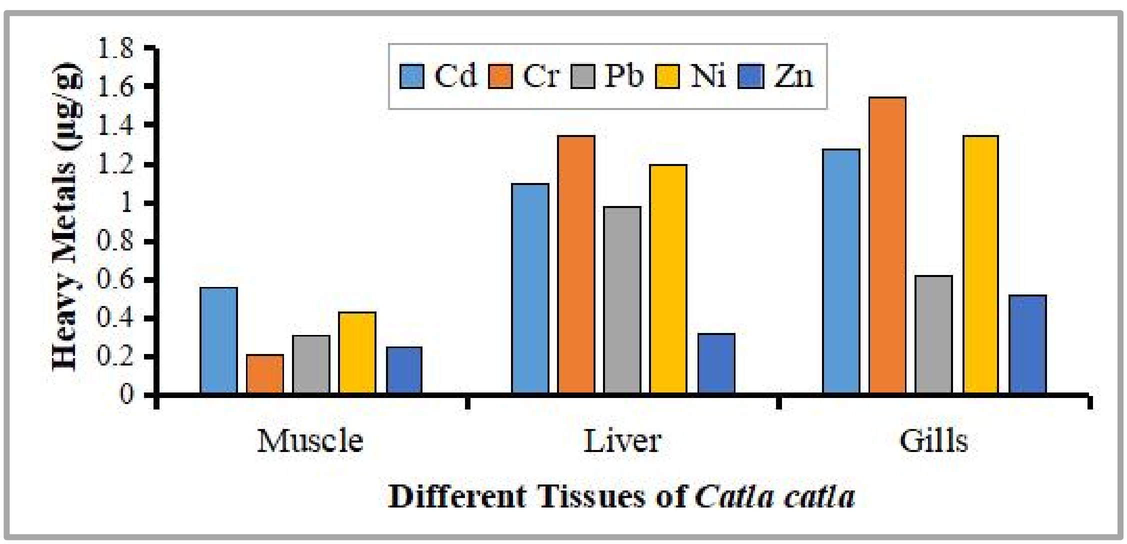

Figure-2. Bioaccumulation of heavy metals in the Muscle, Liver and Gills of *Catla catla* from Lakshminarayna Lake in Edulabad, Hyderabad

Metal Bioaccumulation in Liver Tissue: The liver tissue of Catla catla reveals a distinct heavy metal accumulation pattern. Chromium (Cr) accumulates at the highest concentration, followed by nickel (Ni), lead (Pb), cadmium (Cd), and zinc (Zn) (Cr > Ni > Pb > Cd > Zn). This indicates that the liver plays a significant role in accumulating and possibly detoxifying specific metals, with notable concentrations of Cr and Ni. Additionally, the higher levels of Pb in the liver compared to the muscle and gills emphasize the liver's function in handling and storing heavy metals

Metal Bioaccumulation in Gills Tissue: In *Catla catla*, heavy metal bioaccumulation in the gills is particularly pronounced. Chromium (Cr) exhibits the highest concentration, closely followed by nickel (Ni), cadmium (Cd), and zinc (Zn), in that order (Cr > Ni > Cd > Zn > Pb). Given their direct exposure to contaminated water, the gills play a crucial role in accumulating these metals, with Cr and Ni being especially significant (Figure-2 and Table-1). This pattern underscores the gills' critical function in environmental monitoring and highlights potential risks associated with aquatic pollution

3.2. Bio-accumulation of Heavy Metals in *Tilapia mozambique* tissue Samples

Metal Bioaccumulation in Muscle Tissue: In Tilapia mozambique, the muscle tissue reveals distinct patterns of heavy metal accumulation. Among the metals analyzed, zinc (Zn) stands out with the highest concentration, averaging 1.88 µg/g. This level significantly surpasses the concentrations of other metals: cadmium (Cd) at 0.38 µg/g, nickel (Ni) at 0.41 µg/g, lead (Pb) at 0.48 µg/g, and chromium (Cr) at 0.49 µg/g. The order of metal accumulation in the muscle tissue follows Zn > Pb > Ni > Cr > Cd. The elevated Zn levels underscore its importance and potential impact on fish health, emphasizing that the muscle tissue serves as a primary site for zinc accumulation.

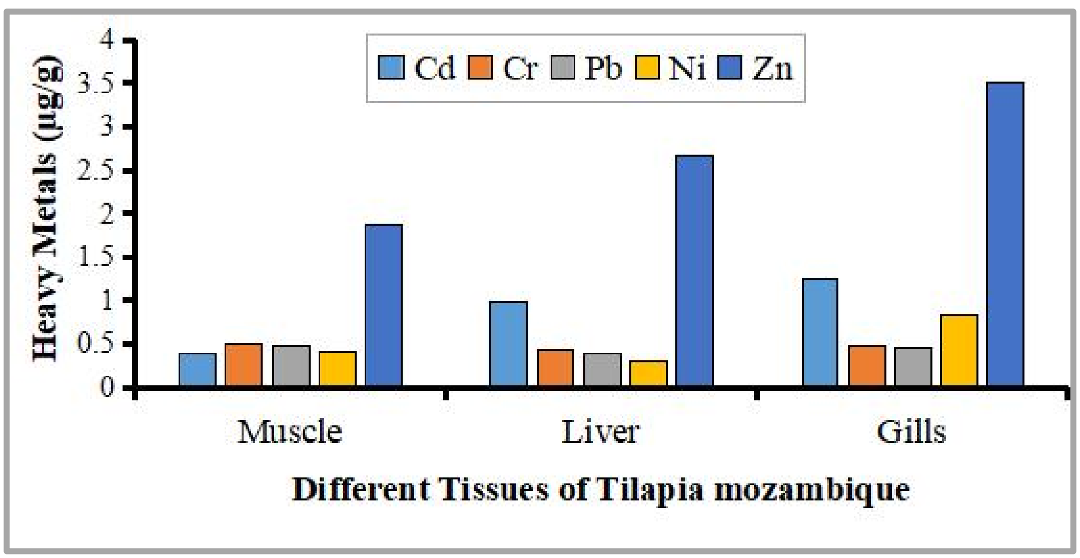

Figure-3. Bioaccumulation of heavy metals in the Muscle, Liver and Gills of *Tilapia mozambique* from Lakshminarayna Lake in Edulabad, Hyderabad

Metal Bioaccumulation in Liver Tissue: In Tilapia mozambique's liver tissue, zinc (Zn) remains the dominant metal, averaging 2.66 µg/g. Cadmium (Cd) follows at 0.98 µg/g. Comparatively lower concentrations are observed for nickel (Ni), lead (Pb), and chromium (Cr). The order of metal accumulation in the liver tissue is Zn > Cd > Cr > Pb > Ni. Given the prominence of Zn in the liver, it likely plays a significant role in processing and storing this essential trace element. Understanding these bioaccumulation patterns contributes to assessing environmental pollution impacts and informs targeted conservation strategies.

Metal Bioaccumulation in Gills Tissue: In the gills of Tilapia mozambique, the concentration of zinc (Zn) is highest at 3.50 µg/g, followed by cadmium (Cd) at 1.25 µg/g, and nickel (Ni) at 0.83 µg/g. Lead (Pb) and chromium (Cr) have lower concentrations at 0.45 µg/g and 0.48 µg/g, respectively (Figure-3 and Table-1). The order of metal accumulation in the gills is Zn > Cd > Ni > Cr > Pb. The elevated levels of Zn and Cd in the gills, compared to other tissues, highlight the gills' crucial role in accumulating metals from the aquatic environment

3.3. Comparison of Heavy Metals among Species of Fish

To Compare the Bioaccumulation of Heavy Metals, a comparative analysis of heavy metal bioaccumulation between *Catla catla* and *Tilapia mozambique* was conducted and presented in Table-1.

Table-1. Comparative analysis of Heavy Metals among Musle, Liver and Gills tissues of two different fish species

Sl. No	Samples Metals	Heavy Metal Concentration in *Catla catla* (µg/g)			Heavy Metal Concentration in *Tilapia mozambique* (µg/g)		
		Muscle	Liver	Gills	Muscle	Liver	Gills
1	Cd	0.56	1.1	1.27	0.38	0.98	1.25
2	Cr	0.21	1.34	1.54	0.49	0.43	0.48
3	Pb	0.31	0.98	0.62	0.48	0.38	0.45
4	Ni	0.43	1.2	1.34	0.41	0.31	0.83
5	Zn	0.25	0.32	0.52	1.88	2.66	3.5

These two fish species exhibit distinct patterns in their metal uptake and storage, which can provide valuable insights for environmental assessment and conservation strategies. *Tilapia mozambique* consistently shows significantly higher concentrations of zinc across all tissues. Zinc is an essential trace element involved in various physiological processes, but excessive accumulation can be detrimental to fish health. This species also accumulates more cadmium (Cd) in both muscle and liver. Cadmium is a toxic heavy metal that can adversely affect fish metabolism, growth, and reproduction.

Catla catla, on the other hand, exhibits greater accumulation of chromium, lead, and nickel. These metals are associated with industrial pollution and can pose risks to aquatic ecosystems, *Catla catla* tends to accumulate these heavy metals more prominently in the liver and gills. The liver plays a crucial role in detoxification processes, while gills are involved in metal uptake from water. These differences highlight species-specific adaptations and ecological roles.

4. DISCUSSION

The bioaccumulation of heavy metals in the muscle, liver, and gills of *Catla catla* and *Tilapia mozambique* from Lakshminarayna Lake offers insights into the environmental health of this aquatic system and highlights species-specific patterns in metal accumulation. The comparative analysis between these two species provides a clearer understanding of how different fish manage and store heavy metals in their tissues.

Catla catla demonstrates a notable pattern of metal accumulation across its tissues. In the muscle, nickel (Ni) accumulates the most, which aligns with findings from other studies showing that Ni can preferentially accumulate in muscle tissues due to its relatively high solubility and bioavailability in aquatic environments (Mamidala et al., 2013). Cadmium (Cd) also shows significant presence in the muscle, consistent with studies by Elango et al. (2003) which highlight Cd's tendency to accumulate in muscle tissues of fish, reflecting its potential impact on fish health and its mobility in aquatic systems. In the liver, chromium (Cr) accumulates most prominently, which contrasts with some other studies where lead (Pb) is found to be more concentrated in the liver (Brown et al., 1970). This could be attributed to species-specific differences in metal processing and detoxification. The gills of *Catla catla* show high levels of Cr and Ni, suggesting that these tissues are crucial for the initial uptake and processing of these metals from the surrounding water, as supported by the findings of Gujjeti et al. (2013), and Vijayagiri et al., (2012) which indicate that gills are primary sites for heavy metal absorption.

In *Tilapia mozambique*, zinc (Zn) consistently shows the highest concentrations across all tissues, with the gills showing the most significant accumulation. This finding aligns with the work of Dwivedi et al. (2007), which reports that Zn is commonly accumulated in gills due to its essential role in numerous biological processes and its high environmental presence. The liver also accumulates Zn prominently, reflecting its role in detoxification and storage, as supported by studies from Malik et al., (2014) Cadmium (Cd) and nickel (Ni) are notably present in the gills, indicating these tissues' effectiveness in metal accumulation from contaminated waters, a finding consistent with the observations of Olmedo et al., (2013) who report similar patterns in other aquatic species.

Comparing the two species, *Catla catla* and *Tilapia mozambique*, reveals that while both species accumulate heavy metals, the patterns differ notably. *Catla catla* shows higher accumulations of Cr and Ni in the gills and liver, whereas *Tilapia mozambique* exhibits higher overall concentrations of Zn, particularly in the gills. This discrepancy underscores the need for species-specific assessments when evaluating the impact of metal pollution in aquatic environments. Additionally, the observed differences in metal accumulation patterns between these species may be attributed to their different ecological roles, feeding habits, and physiological mechanisms.

Overall, these findings highlight the complexity of heavy metal bioaccumulation in fish and the importance of considering species-specific factors when assessing environmental contamination. Further research incorporating a broader range of species and environmental conditions would enhance our understanding of metal dynamics in aquatic ecosystems and inform better management practices for pollution control.

5. CONCLUSION

The mean concentrations of heavy metals in the muscle, liver, and gills of *Catla catla* and *Tilapia mozambique* from Lakshminarayna Lake reveal distinct patterns of bioaccumulation for each species. *Catla catla* demonstrates a pronounced accumulation of metals, particularly chromium (Cr), nickel (Ni), and cadmium (Cd), in the gills, indicating their role in processing environmental contaminants. In contrast, *Tilapia mozambique* shows a higher concentration of zinc (Zn) across all tissues, with the gills again being a major site of accumulation, followed by the liver and muscle. Both species exhibit significant accumulation of zinc and cadmium, reflecting the potential environmental impact of these metals. These findings highlight species-specific differences in metal bioaccumulation, emphasizing the need for targeted monitoring to assess and mitigate pollution effects in aquatic ecosystems.

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