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Seasonal Dynamics of Heavy Metals Bioaccumulation in Key Organ of *Catla Catla* collected from Jaipur Lake

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Abstract

Heavy metals are widespread in the environment. Some of them are essential for living organisms as they play key roles in vital physiological functions, while others are non-essential and can be toxic. Even essential metals can become harmful when their concentrations exceed permissible limits. Heavy metals are commonly found in aquatic bodies and organisms such as fish. Fish constitute an important part of the human diet, serving as a rich source of proteins, vitamins, and minerals. However, they may pose potential health risks due to contamination with heavy metals. Therefore, regular monitoring is crucial, as it provides valuable information for assessing the potential health risks associated with heavy metal exposure.

Keywords - Bioaccumulation , *Catla Catla* , Chandlai Lake, Heavy Metals

1. Introduction

In recent decades, environmental contamination by hazardous pollutants has intensified due to accelerated industrialisation, urbanisation, population growth, and anthropogenic pressures such as intensive agricultural practices. Among environmental pollutants, heavy metals constitute a significant class of contaminants owing to their persistence, non-biodegradability, and propensity for bioaccumulation and biomagnification in aquatic food webs. Aquatic ecosystems are particularly vulnerable to heavy metal contamination arising from agricultural runoff (**Han & Gu, 2023**), effluent discharge from wastewater treatment plants **(Soleimani et al., 2023**), mining and ore-processing activities **(Lakra et al., 2019),** acid mine drainage **(Lebepe et al., 2020**), and industrial emissions **(Adegbola et al., 2021**). Therefore, systematic assessment of the bioaccumulation of

these metals in aquatic biota such as fish is essential for evaluating their ecological and toxicological implications.

Fish represent an affordable source of high-quality protein, essential vitamins, omega-3 fatty acids, minerals, and other vital nutrients **(Esilaba et al., 2020**). However, fish inhabiting environments contaminated with heavy metals are at risk of bioaccumulating these toxic elements, which can subsequently be transferred to humans through consumption **(Kumar et al., 2022**). The degree of heavy metal accumulation in fish is influenced by several factors, including exposure duration, species type, organism age, and the presence of coexisting metals (**Bawuro et al., 2018**). Different organs exhibit varying capacities for metal accumulation; organs such as the liver, kidneys, and gills typically retain higher concentrations than muscle tissues **(Debipersadh et al., 2023; Njinga et al., 2023**). Owing to their ecological distribution and sensitivity to contaminants, fish are frequently employed as bioindicators for monitoring metal pollution in aquatic ecosystems. Therefore, assessing the concentration and distribution of heavy metals in fish and associated water bodies, particularly those influenced by anthropogenic disturbances, is of critical environmental significance.

This research aims to investigate the distribution patterns of three heavy metals—arsenic, lead, and mercury—in the liver tissues of *Catla* fish. The primary objective is to assess the seasonal variations in the concentrations of these metals in the liver of the fish, thereby providing insights into temporal fluctuations and potential environmental impacts.

2. Study Area

Chandlai Lake is a freshwater lake located approximately 30 kilometres from Jaipur, near the Tonk route and the village of Chandlai. Renowned for its tranquil natural surroundings, scenic beauty, and diverse migratory bird populations, it serves as an important ecological site. The lake's coordinates are about 26°41'45" North latitude and 75°52'36" East longitude (26.6954°N, 75.8775°E). Chandlai Lake's water is extensively used for agricultural irrigation and fish farming. Due to these uses and their ecological significance, regular monitoring of pollutants, particularly heavy metals in both the water and fish, is crucial to ensuring environmental and public health safety.

Map -Chandlai Lake

3. Methodology

3.1 Sample collection

. Fish were obtained from four different locations across the lake. Three fish samples were collected from different locations. Fish were captured using gill nets, with their weights recorded before being stored in an icebox and promptly transported to the laboratory. Upon arrival, a ventral incision was made to excise ,liver from the fish.

3.2 Sample Digestion & Heavy Metal Analysis

. Approximately 2 g of homogenized fish (liver) tissue was digested using a wet digestion method with concentrated nitric acid to oxidize organic matter. The mixture was heated at around 120°C for 2 to 3 hours to ensure complete decomposition and metal release. After cooling, the digested sample was diluted with distilled or deionized water to a known volume for accurate heavy metal analysis. The ICP(Inductively Coupled Plasma)technique is used for heavy metals analysis.

4. Results And Discussion

This study conclusively demonstrates that heavy metal accumulation *Catla* fish varies significantly across different seasons.

Liver	***Catla***			
mg/kg	**Winter**	**Summer**	**Monsoon**	**Post-monsoon**
Pb	0.367±0.003*	0.403±0.003***	0.327±0.003	0.383±0.003**
Hg	0.067±0.003	0.080±0.000*	0.063±0.003	0.077±0.003*
As	0.987±0.003**	0.109±0.003***	0.953±0.003	0.105±0.000***

Table 1- Seasonal trends in heavy metal concentrations were assessed in the liver tissues of *Catla,* sampled from Chandlai Lake. Data are presented as mean ± standard error of the mean (mg/kg tissue). Comparative statistical analysis was performed with monsoon season values as a reference. Levels of statistical significance for observed differences are denoted as follows: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

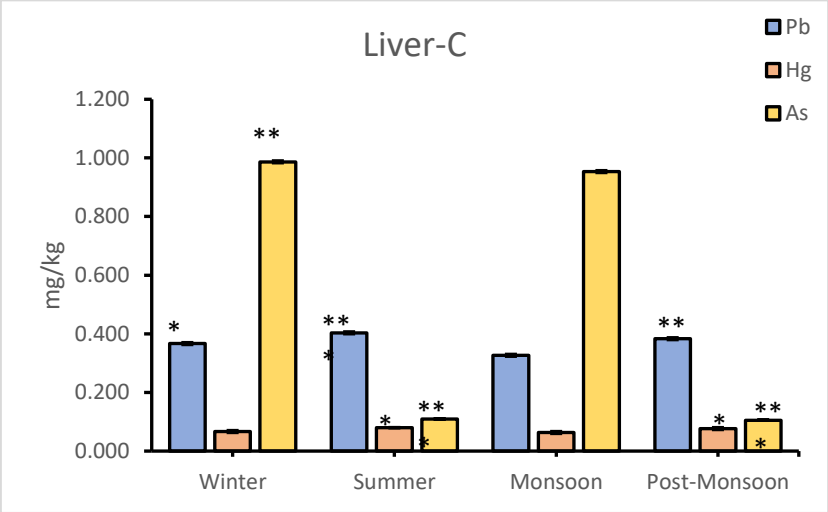

Figure- 1 Traces of heavy metals in liver tissues of *Catla* collected from Chandlai Lake during the investigated seasons. Variations in the numerical values are compared against the variables of the monsoon season. *p<0.05, **p<0.01, and ***p<0.001.

The estimation of heavy metal levels in the liver of *Catla* fish collected from the studied lake indicated seasonal variations in accumulation. The accumulation patterns observed in this research emphasize the liver's pivotal role as a primary site for detoxifying and storing heavy metals.

Lead -.Lead (Pb) is a highly toxic metal for aquatic animals, particularly fish. Exposure to Pb results in significant accumulation in specific fish tissues. This exposure leads to oxidative stress, neurotoxicity, and alterations in immune function..(**Lee, J.-W et al., 2019**)

The results of our study revealed a significant rise in lead (Pb) concentration during the post-monsoon, winter, and summer seasons compared to the monsoon period. The Pb concentrations in the liver were recorded as 0.383±0.003, 0.367±0.003, and 0.403±0.003 mg/kg for the respective seasons, while the concentration during the monsoon was 0.327±0.003 mg/kg. Statistically, the concentrations observed in all these seasons were significantly higher than those measured during the monsoon (p<0.05).

Mercury – In our research, the concentration of mercury (Hg) in the liver of Catla fish during the monsoon season was 0.063±0.003 mg/kg. Notably, all three subsequent seasons exhibited a slight increase in Hg levels; however, this increase was statistically significant only during the post-monsoon and summer seasons (p<0.05). The Hg concentrations recorded in the liver during post-monsoon, winter, and summer were 0.077±0.003, 0.067±0.003, and 0.080±0.000 mg/kg, respectively.In a study by Barone et al. on fish products in Italy, the average mercury concentration across 11 common marine fish species purchased from shops was reported to be 0.40 mg/kg. This value is significantly higher than the average mercury level of 0.10 mg/kg found in the marine fish samples analysed.**(Barone, G.,et al., 2015**)

Arsenic – In our Investigation, results found the concentration of arsenic (As) in the hepatic tissues of *Catla* fish demonstrated pronounced seasonal variability. Elevated concentrations, exceeding 0.9 mg/kg, were recorded during the monsoon and winter seasons, while a substantial decline was observed during the post-monsoon and summer periods. The As concentration during the monsoon was quantified at 0.953±0.003 mg/kg, whereas concentrations in post-monsoon, winter, and summer seasons were determined as 0.105±0.000 ($p<0.001$), 0.987±0.003 ($p<0.01$), and 0.109±0.003 mg/kg ($p<0.001$), respectively. A study conducted by Ayesha Malik in 2023 shows that the liver is the primary organ affected by arsenic poisoning. In fish, arsenic is efficiently metabolized, especially in the liver and gut, with a tendency to accumulate. This accumulation and the detoxification process cause various changes in the liver, including the presence of eosinophilic granules in the hepatocyte cytoplasm, nuclear vacuolation, nuclear hypertrophy, and irregularly shaped nuclei. The liver's vital role in metabolism and detoxification is reflected in these alterations. Additionally, brownish-yellow granules indicative of bile stagnation were observed in the cytoplasm, highlighting possible disruptions in bile flow.(**Malika a et ., 2015**)

5. Conclusion

The present study highlights the variable accumulation of heavy metals, in the liver *of Catla* fish across different seasons, with significantly higher levels observed during post-monsoon, winter, and summer compared to the monsoon period. Findings highlight the crucial role of aquatic ecosystems as sinks for heavy metals and the consequential impact on fish species that inhabit these waters. Seasonal fluctuations in metal concentration call for comprehensive longitudinal studies to better understand accumulation patterns and develop predictive models for environmental risk assessments. Future research should aim to elucidate the mechanistic pathways driving metal uptake and detoxification to inform effective remediation efforts.

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7. Author’s contribution

Nivedita Kumari contributed to data collection, data analysis, and drafted the initial manuscript. Poonam Yadav assisted with manuscript writing. Gareema was responsible for study design and manuscript editing. Dr. Bharti Chouhan contributed to the research conceptualisation and provided the final review and editing of the manuscript.

8. Conflicts of interest

The authors declare that there are no conflicts of interest related to this manuscript.

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