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Linking Heavy Metal Levels in Aquatic Environments to Bioaccumulation in Fish

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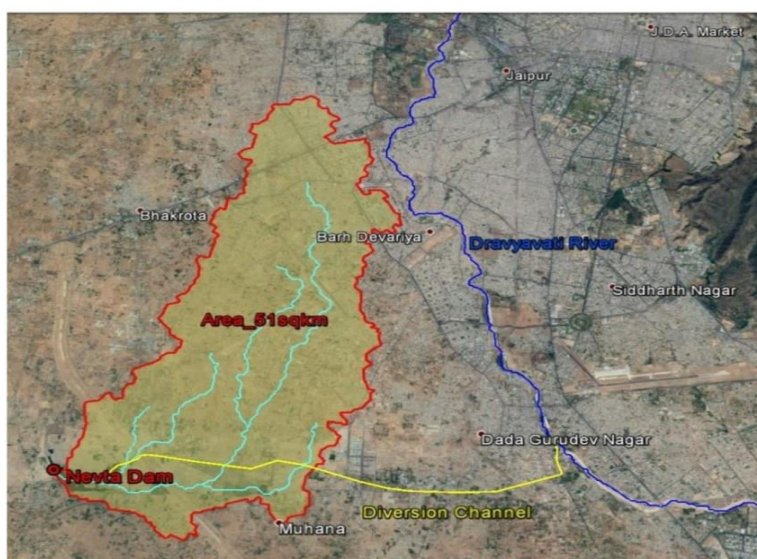
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ABSTRACT: Human health as well as aquatic species are seriously threatened by heavy metal pollution in aquatic environments. This study examines how heavy metals bioaccumulate in Labeo rohita (rohu), a popular freshwater fish, from two aquatic sites of Jaipur, Rajasthan those have been industrially contaminated. The quantities of heavy metals, such as lead (Pb), arsenic (As) and cadmium (Cd) were measured in water and fish samples. The concentration of heavy metals in Labeo rohita was influenced by factors such as the sampling location, the size of the fish, and the season. Bioaccumulation analysis revealed that metals were predominantly stored in the gills, liver and muscle tissues. Fish muscle tissue and water metal concentration showed seasonal changes, with higher amounts during the dry season.

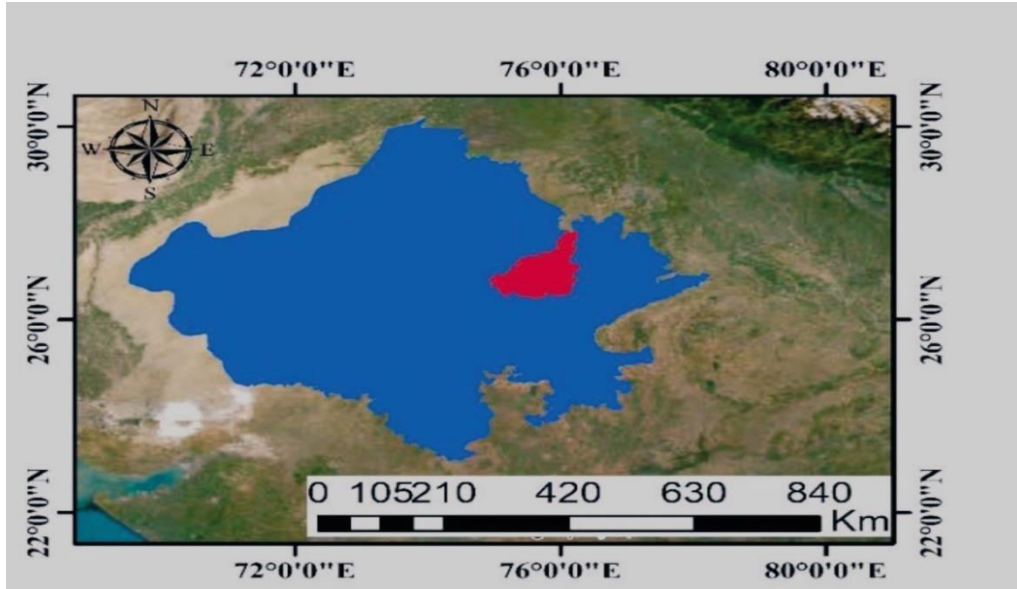
KEYWORDS: Bioaccumulation, Heavy metals, Jaipur, Water sites.

I. INTRODUCTION

Aquatic ecosystem receives most of the substances and heavy metals are one of them which are molecule of specific gravity >5.0 and non-biodegradable. There exist numerous sources of heavy metals like- Cadmium, Arsenic, Mercury, Lead etc. which are basically due to anthropogenic activities and as heavy metals are not degradable, because heavy metals are extremely persistent and have the ability to bioaccumulate and magnify in the food chain, their pollution is especially important in ecotoxicology consequently, it becomes detrimental to living organisms at higher trophic levels (Storelli et al.2005).



Newta dam stretch on Google Earth Image



Map of Kanota Dam

In aquatic ecosystem, metal toxicity is also influenced by many abiotic factors such as hardness, pH, alkalinity, oxygen content of water. Whereas, when we talk about the fish along with the environmental factors, size, age and weight of fish also matters regarding the metal toxicity. Kanota is an essential water reservoir that provides a lifeline for the surrounding villages and agricultural areas, it is important to the region's biodiversity, environmental balance, and water conservation. Primarily, it is polluted by a number of factors, chiefly human activity and urbanization. The uncontrolled release of partially or fully treated sewage from adjacent residential and industrial areas into the dam, runoff from agriculture like pesticide, fertilizer, Industrial waste. In contrast Newta dam get more urban pollution like plastics, untreated sewage and nowadays these dams are becoming convenient and refreshing escape for residents and tourist alike.

Labeo rohita is selected for this study as these species are very crucial both biologically and economically, these are taken as staple food by most of the people. Rohu, an endemic fresh water fish species, having high protein content and considered to be the tastiest fish of India. The population of this fish declined in these years due to overfishing, habitat loss, over pollution and by many other activities of humans, so due to these circumstances also it is considered as an objective for this study. And also fish are constantly in direct contact with contaminated water, they could be used as excellent biological marker of heavy metals in aquatic ecosystem. Fish absorbs heavy metals through their gills, skin, and gastrointestinal tract. Over time, these metals accumulate in various tissues, posing significant risks to fish health and the consumer who rely on them as a protein source. The goal of the current investigation was to assess the level of heavy metal contamination in water and Labeo rohita in Newta and Kanota dam of Jaipur district of Rajasthan.

II. MATERIAL AND METHODS

Sample collection, preparation and analysis

Water sample were taken in 3 seasons from both Kanota and Newta dam of Jaipur in polyethylene bottles, firstly water was collected from both the sites and physio-chemical parameters and heavy metal were analyzed. The fish samples were brought to the laboratory on the same day and each fish's total length (cm) and weight (gm) were measured at each sampling period. Six fish of species *L. rohita* were taken from both the dams and dissected in the laboratory using sterilised instruments. Tissues were washed with the help of double distilled water, and kept in petri dishes. The wet soft tissues of fish were subjected to digestion in a glass vessel containing diacid HNO₃ and HCLO₄ in a 2:1 ratio; utilizing a hot plate maintained at a temperature of 130°C until complete dissolution of the materials was achieved. Subsequently, the fine particulates dispersed in the water sample was isolated by filtration through Whatman GF/C

filters. Following that the prepared samples were diluted with double-distilled water to bring them within the acceptable standard range.

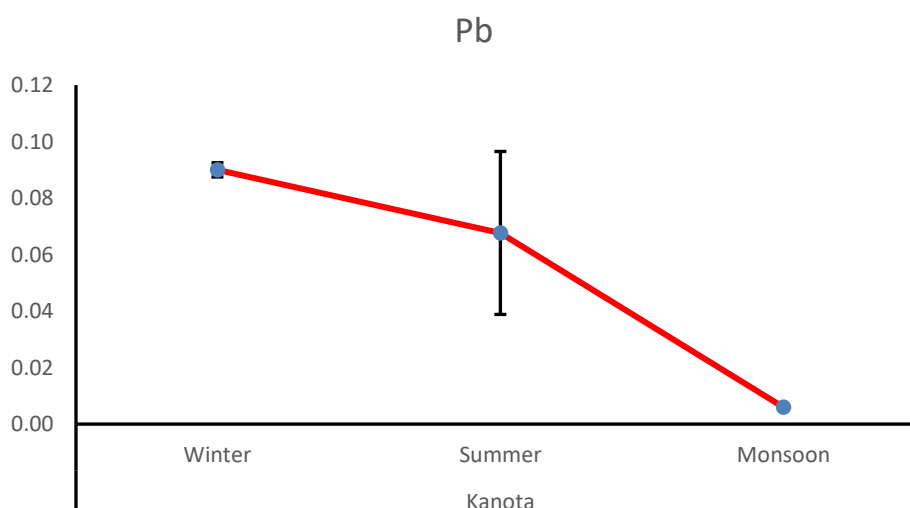
The metal load in dissected fish tissues samples was evaluated using ICP-OES, with each sample analyzed alongside a calibration blank, and a method blank, allowing for verification of contamination in sample preparation, reagents, and procedures. Analyze samples, alternating them with analyses of calibration blank. Between the sample and the blank, rinse with diluted acid for at least 60 s. To find the concentration outside of the linear calibration range, properly dilute and acidify the sample.

III. RESULTS AND DISCUSSION

The results for the dam water samples from two sampling sites are presented in Table-

Heavy metal content in water of Kanota dam in different seasons (Table 1)

Metal		Summer	Rainy	Winter
Pb	Mean± SD	0.0677±0.0408	0.006±0.0062	0.090±0.0035
Cd	Mean± SD	0.0863±0.0038	0.00467±0.0017	0.071±0.0059
As	Mean± SD	0.0707±0.0054	0.005±0.00163	0.038±0.0061



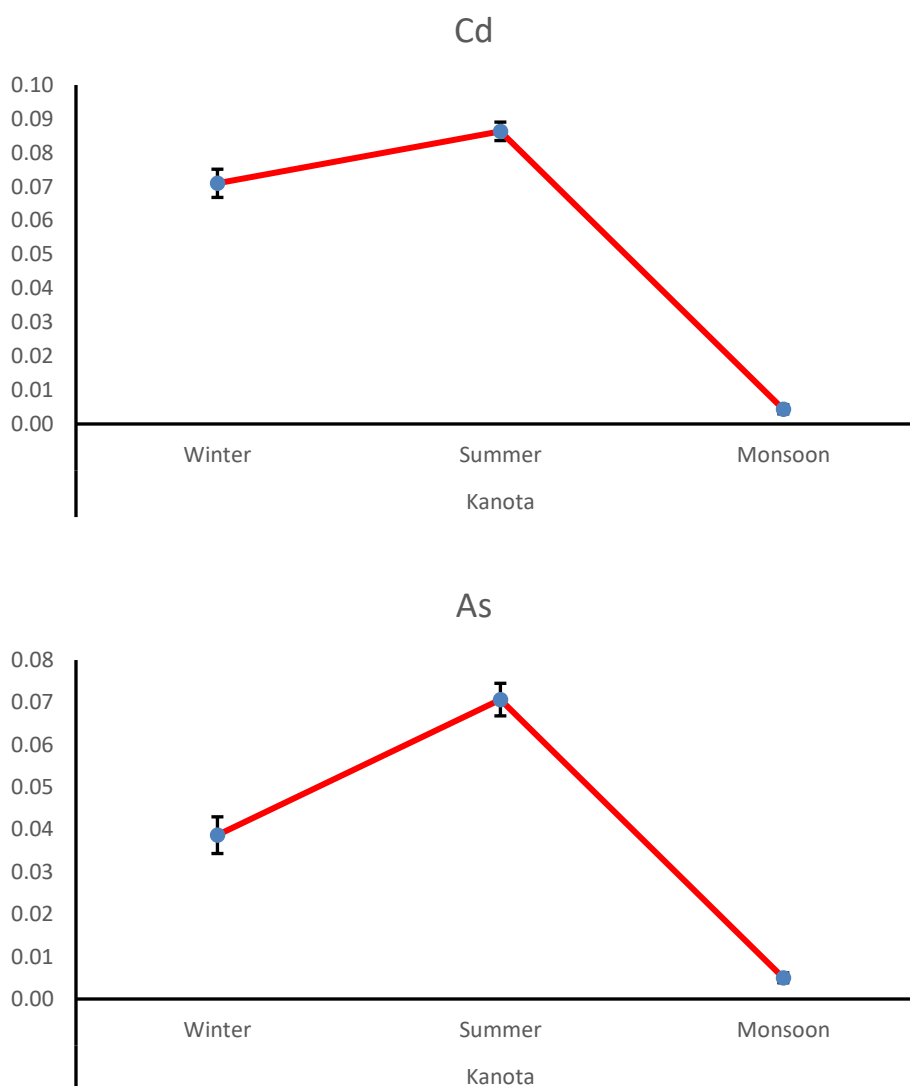


Figure- 1 Concentration of Pb, Cd, and As in Kanota dam during each season.

In the water samples of Kanota dam, the average concentration of heavy metals, namely Lead, Cadmium and Arsenic in winter was 0.090, 0.071 and 0.03867 mg L⁻¹, respectively. Among these three heavy metals Cadmium was highest and that of Lead was lowest during the summer season. During winter season the order of accumulation of heavy metals was Pb>Cd>As and during Rainy season it was Pb>As>Cd. The accumulated concentration of heavy metals in most of them was highest in summer and lowest in wet season due to the 'dilution effect' as had been reported in Malik *et al.* (2010) and Jain and Sharma (2001).

Heavy metal content in water of Newta dam in different seasons (Table 1.1)

Metal		Summer	Rainy	Winter
Pb	Mean± SD	0.0623±0.0377	0.0026±0.0012	0.063±0.0082
Cd	Mean± SD	0.081±0.0049	0.0015±0.0005	0.064±0.0014
As	Mean± SD	0.0436±0.0033	0.0023±0.0009	0.020±0.0077

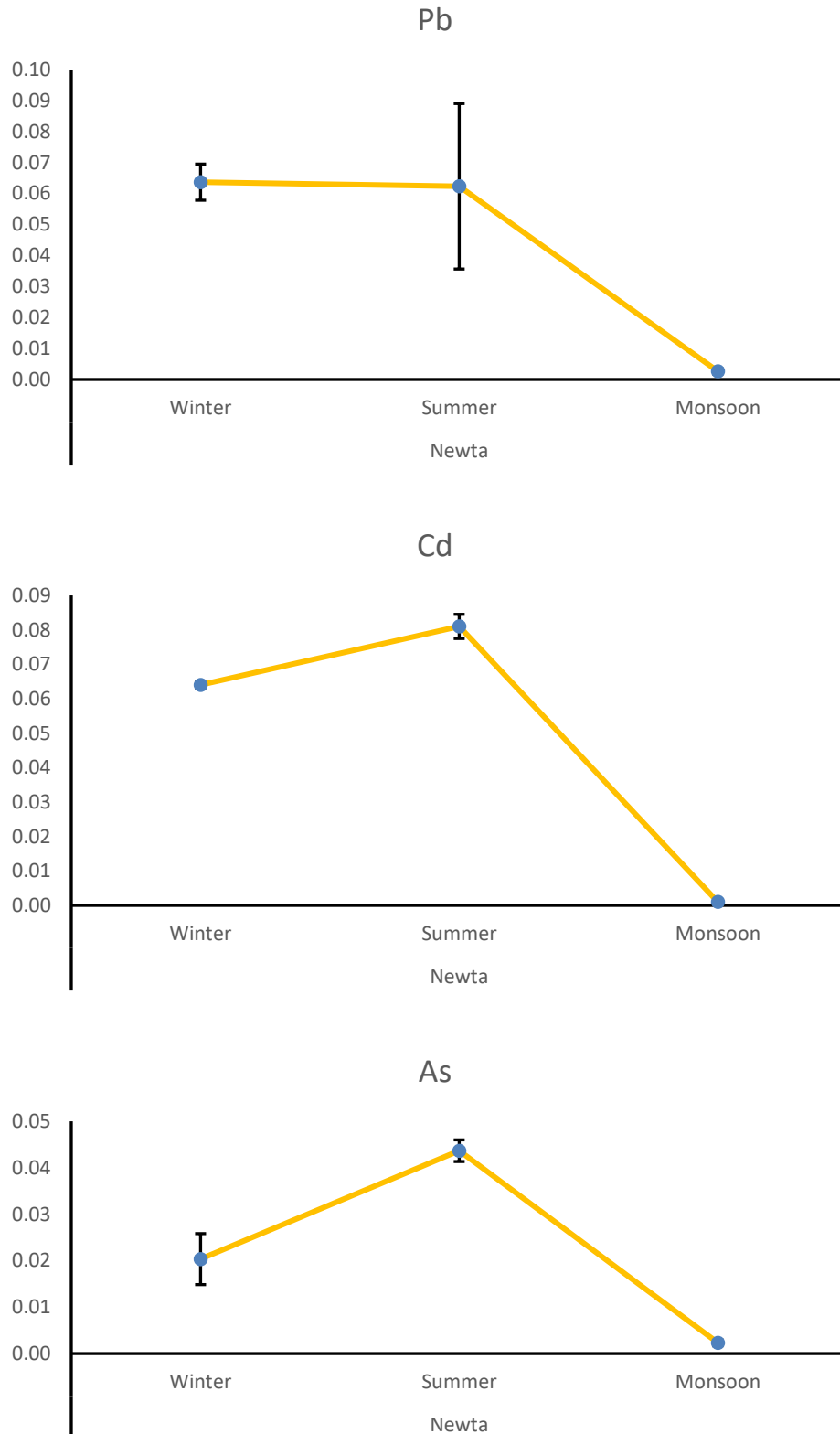


Figure-1.1 Concentration of Pb, Cd, and As in Newta dam during each season.

The average concentration of Heavy metal in water samples of Newta dam varies between 0.0026 to 0.063 for Pb during different seasons. The average concentration of Cd ranges between 0.0015 to 0.081 in all the three seasons and for As it varies between 0.0023 to 0.0436 during different seasons. As we compare between the average concentrations of heavy metals in both the sites we found that in Kanota dam the concentration was higher than the Newta dam.

Heavy metal concentration is more in dry season as compared to wet season due to reduced dilution which means higher concentrations, decreased water flow causing them to accumulate in localized areas, evaporation effects and higher anthropogenic activities.

Kanota dam receives pollutants from upstream agricultural runoff and urban waste, including industrial effluents, which degrade its water quality significantly during seasonal variations. In contrast, Newta dam primarily faces challenges related to siltation and general urban impacts rather than direct industrial contamination.

Traces of heavy metals in liver tissues of *Labeo rohita* collected from Kanota and Newta dams during investigated seasons. Values are in mg/kg tissue which is represented in Mean \pm SEM. Variations in the numerical values are compared against variables of monsoon season. * $p<0.05$, ** $p<0.01$, and *** $p<0.001$ (Table-1.2)

Liver	Kanota			Newta		
	Winter	Summer	Monsoon	Winter	Summer	Monsoon
Pb	0.031 \pm 0.004	0.02 \pm 0.002**	0.04 \pm 0.01	0.024 \pm 0.002***	0.013 \pm 0.001**	0.005 \pm 0.001
Cd	0.01 \pm 0.01	0.08 \pm 0.004***	0.005 \pm 0.001	0.01 \pm 0.001	0.071 \pm 0.003***	0.003 \pm 0.001
As	0.01 \pm 0.001**	0.15 \pm 0.01***	0.003 \pm 0.001	0.01 \pm 0.003	0.135 \pm 0.01***	0.002 \pm 0.001

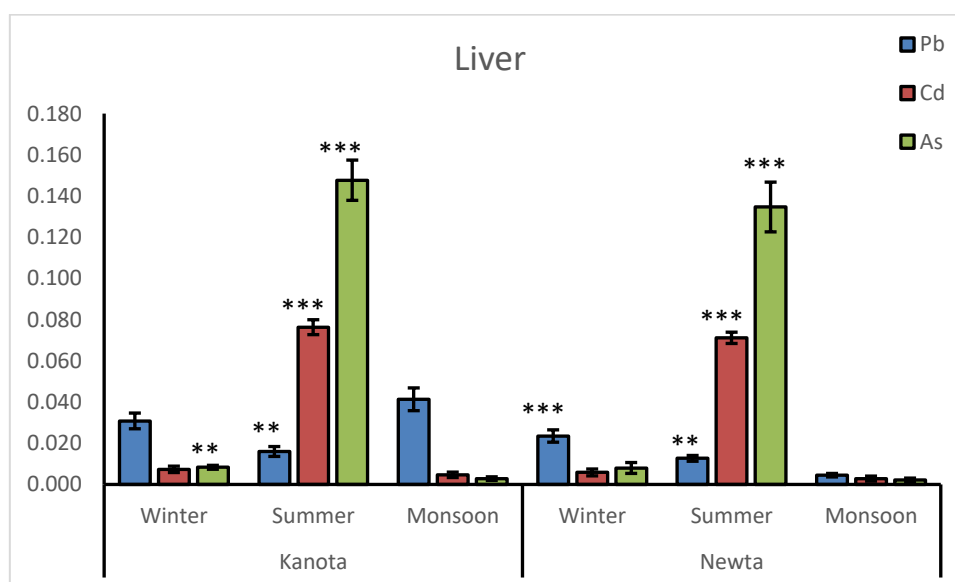


Figure- 1.2Traces of heavy metals in liver tissues of *Labeo rohita* collected from Kanota and Newta dams during investigated seasons. Variations in the numerical values are compared against variables of monsoon season. * $p<0.05$, ** $p<0.01$, and *** $p<0.001$.

In liver tissues of *Labeo rohita* from both Kanota and Newta dams, Pb showed seasonal fluctuations, with higher levels in winter and lower in summer. Cd and As concentrations increased markedly, especially during summer, with Cd showing the steepest rise and As exhibiting many-fold elevation compared to monsoon. Overall, the liver proved to be the most responsive tissue for heavy metal accumulation, particularly for Cd and As.

(Table-1.3) Traces of heavy metals in gills of *Labeo rohita* collected from Kanota and Newta dams during investigated seasons. Values are in mg/kg tissue which is represented in Mean \pm SEM. Variations in the numerical values are compared against variables of monsoon season. * $p<0.05$, and *** $p<0.001$.

Gills	Kanota			Newta		
	Winter	Summer	Monsoon	Winter	Summer	Monsoon
Pb	0.027 \pm 0.002	0.03 \pm 0.002	0.033 \pm 0.01	0.02 \pm 0.002	0.02 \pm 0.005	0.03 \pm 0.01
Cd	0.01 \pm 0.002***	0.04 \pm 0.004	0.04 \pm 0.001	0.004 \pm 0.002** *	0.04 \pm 0.003	0.04 \pm 0.002
As	0.005 \pm 0.001** *	0.004 \pm 0.003** *	0.11 \pm 0.002	0.003 \pm 0.001* *	0.003 \pm 0.001 *	0.40 \pm 0.19

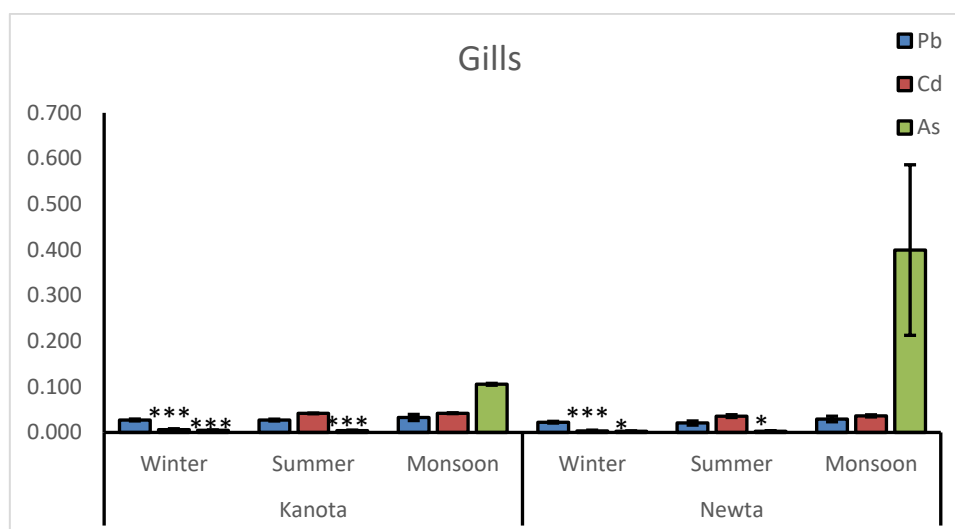


Figure- 1.3 Traces of heavy metals in gills of *Labeo rohita* collected from Kanota and Newta dams during investigated seasons. Variations in the numerical values are compared against variables of monsoon season. * $p<0.05$, and *** $p<0.001$.

In gills of *Labeo rohita* from both Kanota and Newta dams, Pb levels showed no significant seasonal variation. Cd concentrations declined sharply during winter, while As levels exhibited a drastic reduction during both winter and summer compared to monsoon. This indicates that Pb accumulation remains stable across seasons, whereas Cd and As are strongly influenced by seasonal changes, showing highest levels during monsoon.

Traces of heavy metals in muscle tissues of *Labeo rohita* collected from Kanota and Newta dams during investigated seasons. Values are in mg/kg tissue which is represented in Mean \pm SEM. Variations in the numerical values are compared against variables of monsoon season. * $p<0.05$, ** $p<0.01$, and *** $p<0.001$ (Table-1.4)

Muscles	Kanota			Newta		
MEAN	Winter	Summer	Monsoon	Winter	Summer	Monsoon
Pb	0.03 \pm 0.002**	0.03 \pm 0.003**	0.02 \pm 0.002	0.02 \pm 0.002*	0.02 \pm 0.003*	0.03 \pm 0.002
Cd	0.01 \pm 0.004** *	0.004 \pm 0.001** *	0.08 \pm 0.004	0.003 \pm 0.001** *	0.004 \pm 0.001** *	0.06 \pm 0.003
As	0.01 \pm 0.001** *	0.003 \pm 0.001** *	0.15 \pm 0.01	0.002 \pm 0.001** *	0.002 \pm 0.001** *	0.11 \pm 0.001

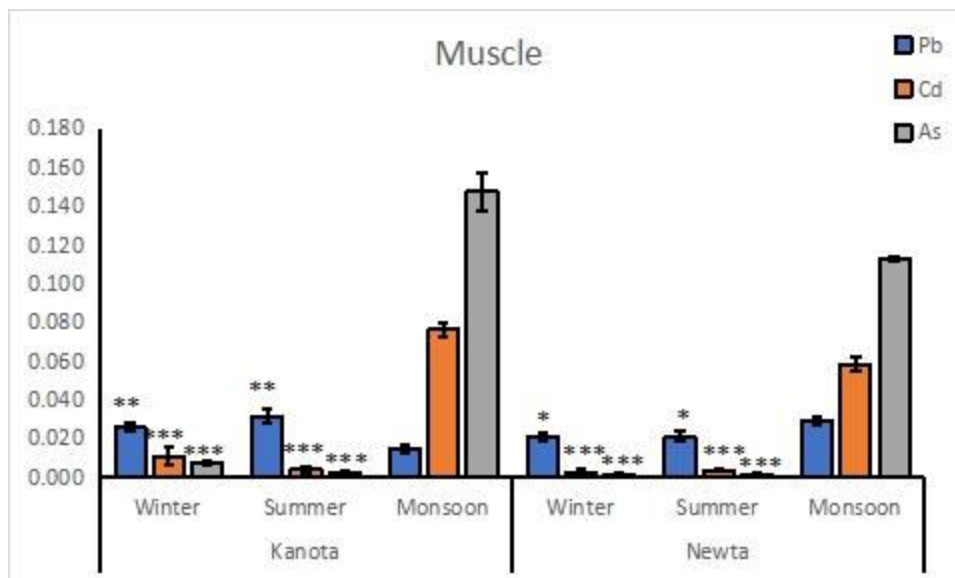


Figure 1.4 Traces of heavy metals in muscle tissues of *Labeo rohita* collected from Kanota and Newta dams during investigated seasons. Variations in the numerical values are compared against variables of monsoon season. * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

In muscles of *Labeo rohita* from both Kanota and Newta dams, Pb showed seasonal fluctuations—rising in winter at Kanota but declining in winter and summer at Newta. Cd and As levels, however, consistently declined significantly during winter and summer compared to monsoon at both sites. This indicates that muscle tissue is more sensitive to seasonal variations in heavy metal accumulation, particularly for Cd and As.

Cadmium and Lead both are carcinogenic heavy metal and as such they serve no biological purpose and both show their bad effects on aquatic biota and human health. Arsenic accumulation in all the tissues of *L. rohita* was also higher in fish of Kanota dam as compared to Newta dam. Among three of the tissues it follows following order Gills > Liver > Muscles, this pattern reflects the roles of different tissues in physiological processes and their interaction with the external environment, gills shows close relationship with the external environment additionally, as stated by Roesijadi, G.(1992). Organs like the liver often have higher levels of metal-binding proteins (e.g., metallothioneins) that sequester heavy metals, contributing to greater accumulation in these tissues. And as we compare individually in different tissues liver and gills are having highest Arsenic and lowest Lead in both water site *L. rohita*. In Muscles, the Lead is highest and arsenic is lowest in both Newta and Kanota dam.

The concentration of heavy metals differed in the two different water sites of same district because of different type of catchment area characteristics, sources of contamination, sediment composition, human activities, water managements and biological activities. Both liver and gills accumulated higher heavy metals because gill work as a depot tissue and are in direct contact with water and liver is the primary organ for storage and detoxification. There is an assimilation of heavy metals in these organs as also noted by Yilmaz (2005) and Nsikak et al. (2007).

IV. CONCLUSION

Proportion of metal found in the edible tissue of these fish are within the limits proposed by Nauen (1983) and are not significantly contaminated by metals, according to the samples that were taken from the sites. However, given the current investigation's findings that the water site's aquatic life, especially fish, is impacted by heavy metal contamination and there is evident accumulation of heavy metal, in the future things could get worse in times to come so, a scientific approach to dam water detoxification is necessary to enhance the health of fish and, eventually, the humans who eat them.

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