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BIOACCUMULATION OF HEAVY METALS IN AQUATIC BIOTA- NEOTA DAM WATER RESERVOIR, JAIPUR, RAJASTHAN, INDIA

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ABSTRACT

Neota Dam, a historic water reservoir in Jaipur, Rajasthan, constructed in 1867, faces increasing environmental stress due to heavy metal pollution from nearby urban and industrial activities. This research paper investigates the bioaccumulation of heavy metals (such as lead, cadmium, copper, zinc, and chromium) in the aquatic biota of Neota Dam, focusing on fish, macroinvertebrates, and zooplankton. The study assesses metal concentrations in water and biota, evaluates bioaccumulation factors (BAF), and explores potential ecological and human health risks. Results indicate significant bioaccumulation of metals, particularly in fish liver and gills, with lead and cadmium exceeding permissible limits in certain species. The findings highlight the urgent need for pollution control measures to protect the dam's biodiversity and its role as a water resource for local communities.

Keywords: Contamination, Aquatic ecosystem, Heavy metals, Bioaccumulation

1. INTRODUCTION

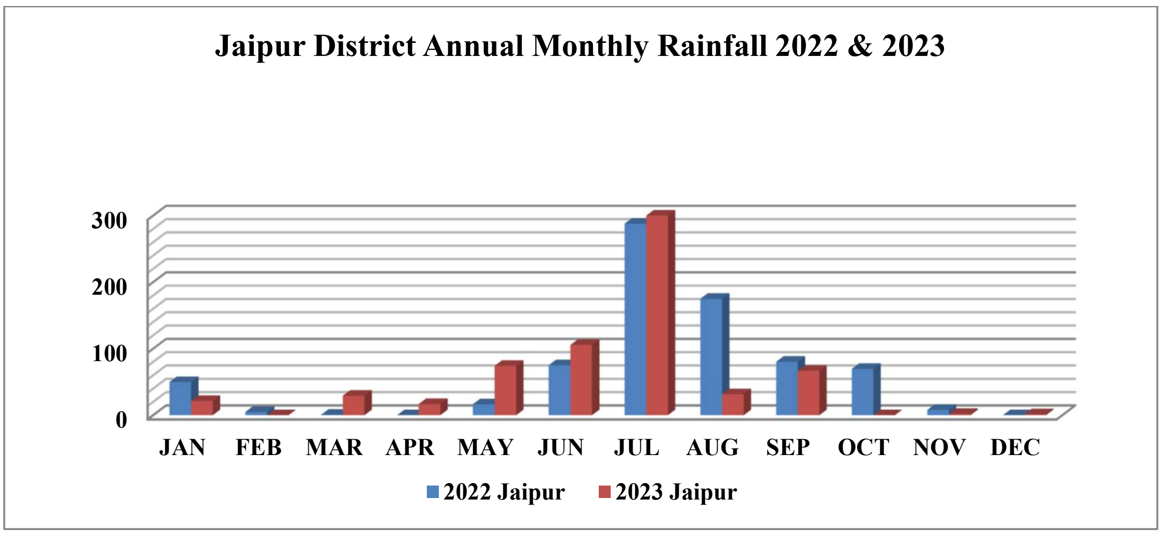
The Neota Dam Water Reservoir, located in Jaipur, Rajasthan, India, is a vital freshwater ecosystem supporting local biodiversity and human activities such as fishing, irrigation, and water supply. However, increasing anthropogenic pressures, including industrial discharges, agricultural runoff, and urban development, have raised concerns about heavy metal contamination in aquatic environments. Heavy metals, characterized by their persistence, toxicity, and potential for bioaccumulation, pose significant risks to aquatic biota and human health through the food chain **[1]**. These pollutants, including lead (Pb), cadmium (Cd), zinc (Zn), copper (Cu), and chromium (Cr), can accumulate in the tissues of aquatic organisms, leading to physiological impairments and biomagnification across trophic levels **[2, 3]**. In India, freshwater ecosystems like the Neota Dam are particularly vulnerable to heavy metal pollution due to inadequate waste management and regulatory enforcement **[4]**. Studies have shown that heavy metals in water and sediments can be absorbed by aquatic organisms, with fish, crustaceans, and other biota acting as bioindicators of environmental contamination **[5]**. For instance, research on reservoirs in Andhra Pradesh has demonstrated seasonal variations in heavy metal bioaccumulation in fish species, highlighting the influence of environmental factors such as pH and anthropogenic inputs. The nutritional quality **[6]** of fish, a key protein source, can be compromised by heavy metal accumulation, posing health risks to consumers **[7]**. Recent studies emphasize the global concern of heavy metal pollution in aquatic systems, with bioaccumulation in fish tissues linked to ecological and human health risks. In the context of the Neota Dam, limited research exists on the extent of heavy metal contamination and its impact on local aquatic biota. This study aims to investigate the bioaccumulation of heavy metals in key aquatic species (Fishes) of the Neota Dam Water Reservoir, assess their distribution in water, sediment, and biota, and evaluate potential ecological and health risks. By integrating physicochemical analyses and bioaccumulation assessments, this research seeks to provide baseline data to inform environmental monitoring and management strategies for sustainable ecosystem health. The Central Pollution Control Board **[4]** has emphasized the deteriorating water quality in Indian aquatic systems, highlighting the urgency of addressing pollution sources and their ecological consequences. Furthermore, understanding the nutritional composition and heavy metal content in edible fish species is essential for assessing their suitability for human consumption **[7-24]**. This study aims to investigate the concentration and distribution of heavy metals in the waters of Neota Dam evaluating their impact on aquatic biota and the potential risks to human health through fish consumption. By integrating physicochemical analyses and bioaccumulation studies, this research seeks to contribute to the broader understanding of heavy metal pollution and inform strategies for environmental management and public health protection.

2. STUDY AREA

Neota Dam (coordinates: RM3H+9P7, Neota, Sanganer Tehsil, Jaipur, Rajasthan 302029) has a catchment area of 443,583 hectares and a storage capacity of 236.72 million cubic meters. The dam is surrounded by dense vegetation and supports diverse aquatic biota, including fish (e.g., *Cyprinus carpio*, *Labeorohita*), macroinvertebrates, and zooplankton, which serve as bioindicators of environmental health.Neota Dam is situated approximately 30 km from the city of Jaipur, 5 km from Muhana, and 7–13 km from Mansarovar, making it an accessible destination for both locals and tourists. The dam is located near the village of Neota (also spelled Nevta), at the coordinates RM3H+9P7, Neota, Sanganer Tehsil, Jaipur, Rajasthan 302029. The dam's total catchment area spans an impressive 443,583 hectares (1,096,120 acres), with a storage capacity of 236.72 million cubic meters at a gauge marker of 16 feet (4.9 meters). The surrounding region is characterized by the semi-arid climate typical of Rajasthan, with hot summers, mild winters, and a monsoon season that brings lush greenery to the area, particularly around the dam.

Rainfall pattern of Study area

Jaipur experiences a semi-arid climate with significant seasonal variations in rainfall. The majority of precipitation occurs during the monsoon months, typically from June to September. Over a period of 30 years Jaipur's average annual rainfall is approximately 635.4 mm with the bulk occurring between June and September during the monsoon season. In 2024, Jaipur district experienced a notable increase in rainfall, recording an average of 748 mm, which is about 68% higher than the previous year Rainfall in Jaipur is highly seasonal, with the majority occurring during the monsoon months. Here's a breakdown of average monthly rainfall: The remaining months experience less rainfall with November and December averaging around 3.9 mm and 4.2mm respectively. Despite its ecological and cultural value, Neota Dam faces challenges due to pollution from nearby urban and industrial activities. The water quality has deteriorated, impacting its utility for local communities. Additionally, the construction of the Ring Road and other infrastructure projects has reduced the dam's irrigation capacity, posing challenges for agriculture in the region. Conservation efforts are needed to preserve the dam's ecological balance and ensure its sustainability as a water resource and tourist destination. In 2023, the Rajasthan government approved a proposal to develop Neota Dam and the nearby Kanota Dam as eco-adventure tourism sites, with an investment of Rs 3.75 crore allocated for Neota Dam. Planned developments include improved road access and other infrastructure to enhance its appeal as a tourist destination.



Graph 1: Annual rainfall comparison (All values in mm)

Table 1: Annual Rainfall data of Jaipur (source- IMD Jaipur)

1S.NO.	DISTRICTS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2022	Jaipur	49.79	4.84	0.68	0	16.42	75.22	287.87	175.09	80.35	69.57	8	0
2023	Jaipur	21.48	0	29.33	16.74	74.13	105.58	315.5	31.54	66.71	0.13	1.88	1.52

3. MATERIALS AD METHODS

Fish samples were collected and were washed with distilled water and kept in an ice box and then brought to the laboratory. Samples were measured (length, breadth and weigh) after getting it to room temperature and dissected with stainless steel knife and kept in a freezer at -4°c. All the laboratory equipment were washed thoroughly and then soaked in a 2% nitric acid sol. and rinsed with double distilled water prior to experimentation to avoid contamination. Five grams of the homogenized spineless muscle tissue of each fish was taken into a beaker and then 7ml of supra pure HNO_3 (65% v/v) and 3ml of H_2O_2 (30% v/v) 3 ml (1:3 ratio) were added to it **[11]**; APHA 2005) and covered it using watch glass and kept it overnight. The mixture was placed on thermostatically controlled hot plate maintainedat70̊c for 45 minutes. The clear solution was cooled down and filtered through waltz men filter paper and make up to 25 ml using double distilled water (APHA 2014). The concentration of heavy metals was measured using Inductively Coupled Plasma Mass Spectrometry (ICP-MS - Agilent 7700 series USA) results are expressed in µg/g per wet weight. All the digested samples and blank were run parallelly using standard solution acid mixture.

Table 2: Characteristics of the Fishes and types

S. No.	Scientific name	Common name	Feeding habit	length
1	Lobeo Rohita	Rohu	Surface feeder, filamentous algae and sand	0.5m
2	Catla Catla	Catla	Surface feeder, zooplanktons	3.5 m
3	Luciobarbus Esocinus	Mangar	Zooplanktons and small fishes, insects	2.3 m

Table 3: Heavy Metal Concentrations in Neota Dam Water samples

Heavy metal	Water sample 1	Water sample2	Water sample 3	Unit
Zinc(Zn)	0.83–3.5 mg/L	0.73–3.4 mg/L	0.83–2.5 mg/L	Mg/l
Cadmium(Cd)	0.02–1.14 mg/L	0.02–1.24 mg/L	0.02–1.04 mg/L	Mg/l
Lead(Pb)	0.05–0.59 mg/L	0.06–0.49 mg/L	0.06–0.79 mg/L	Mg/l
Manganese(Mn)	1.2–2.04 mg/L	1.2–2.44 mg/L	1.2–2.54 mg/L	Mg/l

Table 4: Heavy Metal Concentrations in Fishes

Heavy metal	Lobeo Rohita	Cala Catla	Luciobarbus Esocinus	Unit
Lead (Pb)	3.08 µg/g	0.0352µg/g	1.00 µg/g	Mg/l
Copper (Cu)	1.88 µg/g	2.97µg/g	2.93µg/g	Mg/l
Zinc(Zn)	59.89 µg/g	42.87 µg/g	42.87 µg/g	Mg/l
Manganese(Mn)	1.02 µg/g	0.86 µg/g	1.14 µg/g	Mg/l

4. RESULT AND DISCUSSION

The analysis of heavy metal concentrations in three fish species from Neota Dam *Labeo rohita*, *Catla catla*, and *Luciobarbus esocinus* revealed varying levels of bioaccumulation for lead (Pb), copper (Cu), zinc (Zn), and manganese (Mn). *Labeo rohita* exhibited the highest Pb concentration at 3.08 µg/g, significantly exceeding *Catlacatla* (0.0352 ± 0.0069 µg/g) and *Luciobarbus esocinus* (1.00 µg/g). For Cu, *Catla catla* showed the highest accumulation (2.97 µg/g), closely followed by *Luciobarbus esocinus* (2.93 µg/g), while *Labeo rohita* had a lower concentration (1.88 µg/g). Zn concentrations were notably elevated across all species, with *Labeorohita* recording the highest at 59.89 µg/g, compared to 42.87 µg/g in both *Catla catla* and *Luciobarbus esocinus*. Mn levels were relatively low, with *Luciobarbus esocinus* showing the highest concentration (1.14 µg/g), followed by *Labeo rohita* (1.02 µg/g), and *Catla catla* (0.86 µg/g). These concentrations, measured in mg/L equivalent for water, indicate significant bioaccumulation, particularly for Pb and Zn in *Labeobrohita*. The elevated Pb concentration in *Labeo rohita* (3.08 µg/g) suggests a higher bioaccumulation potential compared to the other species, likely due to its bottom-feeding behavior, which increases exposure to contaminated sediments where heavy metals tend to accumulate. The low Pb level in *Catla catla* (0.0352 µg/g) may reflect its surface-feeding habits, reducing contact with sediment-bound metals. Cu and Zn levels were more evenly distributed across species, with *Catla catla* and *Luciobarbus esocinus* showing comparable Cu accumulation, possibly due to their shared mid-water feeding zones where dissolved metals are prevalent. The high Zn concentrations across all species (42.87–59.89 µg/g) indicate widespread contamination in the Neota Dam ecosystem, likely from agricultural runoff and industrial effluents from nearby Mahindra World City. Mn levels, though lower, still pose a concern, particularly in *Luciobarbus esocinus*, which may be linked to its metabolic uptake efficiency. These findings underscore the ecological risk to Neota Dam's aquatic biota and potential human health concerns through fish consumption, necessitating further investigation into pollution sources and remediation strategies

5. CONCLUSION

Heavy metal bioaccumulation in *Labeo rohita*, *Catla catla*, and *Luciobarbus esocinus* from Neota Dam reveals significant contamination, with *Labeo rohita* showing the highest accumulation of lead (3.08 µg/g) and zinc (59.89 µg/g), likely due to its bottom-feeding behavior, while *Catla catla* and *Luciobarbus esocinus* exhibited elevated copper (2.97–2.93 µg/g) and zinc (42.87 µg/g) levels. These findings indicate pervasive heavy metal pollution in the dam's ecosystem, driven by anthropogenic sources such as industrial effluents and agricultural runoff. The high metal concentrations, particularly lead and zinc, pose ecological risks to aquatic biota and potential health hazards for human consumers, highlighting the urgent need for pollution control measures, regular monitoring, and remediation efforts to safeguard Neota Dam's biodiversity and its role as a vital water resource. This study confirms significant bioaccumulation of heavy metals, particularly Pb and Cd, in the aquatic biota of Neota Dam, driven by anthropogenic pollution. The high BAF values in fish and macroinvertebrates highlight the potential for biomagnification, posing risks to the ecosystem and human health. Urgent measures, including stricter regulation of industrial discharges, regular water quality monitoring, and sediment remediation, are recommended to mitigate pollution. Future research should focus on seasonal variations in metal accumulation and the role of zooplankton as early bioindicators to inform comprehensive conservation strategies.

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