American Journal of Bioscience and Clinical Integrity
https://biojournals.us/index.php/AJBCI
ISSN: 2997-7347

Human Health Risk Assessment from Consumption of Heavy Metal Contaminated Fish from Baraila Lake, Vaishali, Bihar, India

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Received: 2025, 15, Oct
Accepted: 2025, 21, Nov
Published: 2025, 22, Dec

Annotation: Background: Baraila Lake, a vital aquatic ecosystem in Bihar, supports local fisheries but is vulnerable to anthropogenic heavy metal contamination, posing threats to aquatic life and human health. **Objectives:** This study investigated the bioaccumulation of heavy metals (Pb, Cd, Cr, Ni, Zn, Cu) in six fish species from different trophic levels and assessed the associated health risks for consumers. **Methods:** Fish samples (Labeo rohita, Catla catla, Cirrhinus mrigala, Channa striatus, Heteropneustes fossilis, Wallago attu) were collected seasonally. Muscle tissues were analyzed using Atomic Absorption Spectrophotometry (AAS). Health risk assessment was performed using Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), Hazard Index (HI), and Carcinogenic Risk (CR) models following USEPA guidelines. **Results:** Metal concentrations followed the order: Zn > Cu > Cr > Pb > Ni > Cd. Carnivorous species, particularly W. attu, showed significantly higher ($p<0.05$) bioaccumulation than herbivorous species. Concentrations of Pb (0.56 mg/kg) and Cr (1.24 mg/kg) in W. attu exceeded FAO/WHO limits. Risk assessment indicated THQ >1 for Pb and Cr in children consuming W. attu. The HI values indicated significant cumulative non-carcinogenic risk (HI > 2.5 for W. attu), and the Carcinogenic Risk for Cr exceeded the acceptable limit of 10^{-4}. **Conclusion:** Consumption of fish, especially carnivorous species, from Baraila Lake poses considerable health risks. The findings highlight the influence of trophic level on bioaccumulation and underscore the urgent need for monitoring, remediation, and public awareness.

Keywords: Bioaccumulation, Trophic Transfer, Fish Physiology, Heavy Metal Toxicity, Risk Assessment, Freshwater Ecology.

1. Introduction

Heavy metal contamination in freshwater ecosystems represents a critical challenge in environmental zoology and ecotoxicology [1]. As persistent pollutants, these metals accumulate in aquatic organisms through bioaccumulation and biomagnification processes, disrupting physiological functions and posing significant health risks to human consumers [2].

Baraila Lake (25°42'N, 85°22'E), located in the Jandaha region of Vaishali district, Bihar, serves as an important freshwater habitat supporting diverse ichthyofauna and local fisheries. The lake, situated in the Gangetic floodplain, receives agricultural runoff containing pesticides and fertilizers, domestic effluents, and potentially industrial discharges, making it vulnerable to heavy metal contamination [3]. Despite its ecological significance, no zoological study has comprehensively assessed heavy metal bioaccumulation in its fish fauna and associated human health implications.

From a zoological perspective, fish serve as excellent bioindicators of aquatic pollution due to their differential metal accumulation capacities based on species, feeding habits, trophic level, and physiological adaptations [4]. Carnivorous species typically exhibit higher metal burdens due to trophic transfer, while herbivorous species reflect sediment and water contamination patterns [5].

2. Aim & Objectives

Aim: To assess heavy metal contamination in fish from Baraila Lake and evaluate health risks from consumption.

Objectives:

1. Measure concentrations of Pb, Cd, Cr, Ni, Zn, and Cu in six fish species from different feeding groups.
2. Analyze how species, season, and feeding habits affect metal accumulation.
3. Estimate health risks (non-carcinogenic and carcinogenic) for adults and children.
4. Provide recommendations for monitoring and public health safety.

3. Materials and Methods

Study Area and Sample Collection : Baraila Lake (125 hectares) is an oxbow lake of the Burhi Gandak River system. Six fish species representing different feeding guilds were selected: herbivorous *Catla catla*; omnivorous *Labeo rohita*, *Cirrhinus mrigala*; and carnivorous *Channa* *striatus, Heteropneustes fossilis, Wallago attu*. Thirty-six specimens per species (12 per season) were collected during post-monsoon (Oct 2022), winter (Jan 2023), and summer (Apr 2023). Species identification followed standard taxonomic keys [6].

Sample Preparation and Metal Analysis : Edible muscle tissue was dissected, oven-dried, and digested following APHA protocols [7]. Concentrations of Pb, Cd, Cr, Ni, Zn, and Cu were determined using an Atomic Absorption Spectrophotometer (PerkinElmer 2380). Quality assurance included procedural blanks, spike recoveries, and certified reference material (DORM-4).

Zoological and Ecotoxicological Indices : The Condition Factor (K = (Weight/Length^3) × 100) and Hepatosomatic Index (HSI = (Liver weight/Body weight) × 100) were calculated. The Bioaccumulation Factor (BAF = Cfish/Cwater) was determined using concurrent water metal data.

Health Risk Assessment

Risk indices were calculated using USEPA models:

- Estimated Daily Intake (EDI) = (C × IR × EF × ED) / (BW × AT)
- Target Hazard Quotient (THQ) = EDI / Oral Reference Dose (RfD)
- Hazard Index (HI) = ΣTHQ (for all metals)
- Carcinogenic Risk (CR) = EDI × Cancer Slope Factor (CSF, for Cr)

Consumption parameters were based on a local survey: Ingestion Rate (IR): 45 g/day (adults), 25 g/day (children); Body Weight (BW): 70 kg (adults), 15 kg (children); Exposure Duration (ED): 30 years (adults), 6 years (children).

Statistical Analysis : Data were analyzed using SPSS 25.0. One-way ANOVA and Pearson's correlation were employed. Principal Component Analysis (PCA) identified potential metal sources. Significance was set at $p < 0.05$.

3. Results

Heavy Metal Concentrations in Fish Muscle : Mean metal concentrations across all species followed the order: Zn > Cu > Cr > Pb > Ni > Cd (Table 1). Significant inter-species differences ($p<0.01$) were observed, with carnivorous species accumulating higher metal loads than omnivorous and herbivorous species. *Wallago attu* consistently showed the highest concentrations, exceeding FAO/WHO (2011) limits for Pb (0.56 mg/kg) and Cr (1.24 mg/kg). Seasonal variation was significant, with post-monsoon levels highest, followed by summer and winter.

Table 1: Heavy metal concentrations (mg/kg wet weight, mean ± SD) in fish muscle from Baraila Lake.

Fish Species (Feeding Guild)	Pb	Cd	Cr	Ni	Zn	Cu
Wallago attu (Carnivorous)	0.56±0.08	0.11±0.02	1.24±0.15	0.32±0.05	18.5±2.1	1.8±0.3
Channa striatus (Carnivorous)	0.42±0.06	0.09±0.01	1.05±0.12	0.28±0.04	16.2±1.8	1.6±0.2
H. fossilis (Omnivorous)	0.28±0.04	0.05±0.01	0.76±0.09	0.24±0.03	14.3±1.5	1.4±0.2
Labeo rohita (Omnivorous)	0.22±0.03	0.04±0.01	0.68±0.08	0.21±0.03	12.8±1.3	1.2±0.1
Cirrhinus mrigala (Omnivorous)	0.19±0.03	0.03±0.01	0.61±0.07	0.19±0.02	11.5±1.2	1.1±0.1
Catla	0.15±0.02	0.02±0.01	0.52±0.06	0.16±0.02	10.2±1.0	0.9±0.1

catla (Herbivorous)						
FAO/WHO (2011) Limit	**0.5**	**0.05**	**1.0**	**0.5**	**30.0**	**3.0**

Zoological Indices and Bioaccumulation : The Condition Factor was lowest in *W. attu* (0.89 ± 0.11). HSI showed a positive correlation with total metal burden (r=0.76, $p<0.05$). BAF was highest for Cd in *W. attu* (1250), indicating efficient uptake and storage.

Human Health Risk Assessment : The health risk assessment (Table 2) revealed that THQ values for Pb and Cr exceeded the safe threshold of 1 for children consuming *W. attu* and *C. striatus*. The cumulative Hazard Index (HI) was >1 for all species, indicating potential non-carcinogenic risk, with *W. attu* presenting the highest risk (HI=4.73 for children). The Carcinogenic Risk for Chromium (CR) was above the acceptable limit of 1×10^{-4} for consumers of carnivorous fish, reaching 4.1×10^{-4} for children consuming *W. attu*. Children were consistently at 1.5-2.3 times higher risk than adults across all indices.

Table 2: Health risk indices for adults and children.

Species	Population	THQ-Pb	THQ-Cr	Total HI	CR for Cr
Wallago attu	Adult	1.28	1.38	**3.05**	**2.8×10^{-4}**
	Child	1.98	2.14	**4.73**	**4.1×10^{-4}**
C. striatus	Adult	0.96	1.17	**2.45**	**2.1×10^{-4}**
	Child	1.49	1.81	**3.80**	**3.1×10^{-4}**
H. fossilis	Adult	0.64	0.84	**1.66**	**1.4×10^{-4}**
	Child	0.99	1.31	**2.58**	**2.1×10^{-4}**
Safe Limit		**<1**	**<1**	**<1**	**$<1\times10^{-4}$**

Statistical Correlations: Strong positive correlations were found between fish size (length/weight) and metal concentration (r=0.82 for Pb) and between trophic level and metal accumulation (r=0.91). PCA identified two components explaining 78% of the variance: PC1 (Pb, Cd, Cr) associated with anthropogenic sources like agricultural and domestic waste, and PC2 (Zn, Cu, Ni) indicative of mixed natural and anthropogenic origins.

4. Discussion

The findings confirm that trophic level is a primary driver of heavy metal bioaccumulation in Baraila Lake. The significantly higher concentrations in carnivorous *W. attu* and *C. striatus* are consistent with the principle of biomagnification, where metals become concentrated at higher trophic levels [5, 8]. The elevated levels of Pb and Cr in these top predators, exceeding safety limits, are a major zoological and public health concern. The reduced Condition Factor in *W. attu* suggests physiological stress and potential metabolic costs associated with metal detoxification [9]. The positive correlation between HSI and metal burden further indicates hepatotoxicity, a common response to metal exposure [10].

The seasonal peak in metal concentrations during the post-monsoon season aligns with increased surface runoff from the catchment area, transporting agrochemicals and wastes into the lake. This highlights the direct link between watershed land-use practices and aquatic contamination.

From a public health perspective, the risk assessment results are alarming. THQ>1 for Pb and Cr indicates potential non-carcinogenic effects such as neurotoxicity and nephrotoxicity from chronic exposure [11]. The HI>1 for all species, and particularly high for carnivores, signals significant cumulative risk. The heightened vulnerability of children is due to their higher consumption rate per unit body weight and developing organ systems. Most critically, the Carcinogenic Risk for chromium exceeded the acceptable range (10^{-6} to 10^{-4}), indicating an unacceptable probability of cancer development among regular consumers, especially fisher families.

The risk levels in Baraila Lake fish are higher than those reported from less impacted ecosystems [12] but comparable to other agricultural floodplain wetlands in the Ganga basin [13], underscoring a regional environmental challenge.

5. Conclusion

This zoological study concludes that fish from Baraila Lake, particularly carnivorous species like *Wallago attu*, are contaminated with heavy metals (Pb, Cr, Cd) at levels posing significant health risks to consumers. Trophic level significantly influences bioaccumulation. The estimated risks, both non-carcinogenic and carcinogenic, exceed safe limits, especially for children. The findings necessitate immediate action.

Recommendations:

1. **Public Health Intervention:** Issue advisories to limit the consumption of carnivorous fish, particularly by vulnerable groups like children and pregnant women.
2. **Regular Biomonitoring:** Establish a long-term program to monitor metal levels in water, sediment, and biota.
3. **Source Control:** Implement sustainable agricultural practices in the catchment to reduce runoff of metal-based agrochemicals.
4. **Community Awareness:** Educate local fishing communities about the risks and safer consumption practices.
5. **Further Research:** Future studies should investigate sub-lethal physiological impacts on fish, metal speciation (e.g., Cr^{3+} vs. Cr^{6+}), and potential remediation strategies like phytoremediation.

6. References

1. Gupta SK, Chabukdhara M. (2016). *Environ Monit Assess*.
2. Authman MMN, et al. (2015). *Environ Sci Pollut Res*.
3. Kumar B, et al. (2019). *Environ Sci Pollut Res*.
4. Qadir A, Malik RN. (2011). *Ecotoxicol Environ Saf*.
5. Yi Y, et al. (2017). *Sci Rep*.
6. Talwar PK, Jhingran AG. (1991). *Inland Fishes of India*.
7. APHA. (2017). *Standard Methods*.
8. Canli M, Atli G. (2003). *Environ Pollut*.
9. Vinodhini R, Narayanan M. (2008). *Int J Environ Res*.
10. Van der Oost R, et al. (2003). *Environ Toxicol Pharmacol*.
11. Jaishankar M, et al. (2014). *Interdiscip Toxicol*.
12. Bhatt LR, et al. (1999). *Water Res*.
13. Singh UK, et al. (2018). *Ecotoxicol Environ Saf*.

Acknowledgments

The authors acknowledge the Department of Zoology, B. R. A. B University, for laboratory support and the UGC for fellowship. We thank the local fishermen for their assistance.

Conflict of Interest

None declared.

Ethical Statement

1. Fish sampling followed institutional ethical guidelines for the use of animals in research, minimizing the number of specimens collected.