CONTAMINATED CATCH: HEAVY METAL ACCUMULATION AND HUMAN HEALTH RISK ASSESSMENT THROUGH FISH CONSUMPTION FROM A RAMSAR WETLAND OF INDIA

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BACKGROUND

- Heavy metals from industrial effluents and agricultural runoff accumulate in aquatic biota, entering the human food chain via fish consumption. Over 70% of India's surface water is contaminated (CPCB, 2021).
- Cd, Pb, Ni & Hg: toxic even at low concentrations.
- Fish are key bioindicators of metal pollution.
- Prolonged consumption leads to neurotoxicity and nephrotoxicity.
- Harike Wetland lacked species-specific dietary risk data.
- Textile/electroplating/tannery effluents via Buddha Nullah.

STUDY SITE & SPECIES

1. Harike Wetland, Punjab, India (31.17°N, 75.2°E). Man-made wetland · ~4100 ha · Sutlej × Beas Rivers.
2. Fish Collection · n = 90 (30/species). Method used · AAS (Atomic Absorption Spectroscopy)
3. Species Analysed

- *Labeo rohita* · Rohu · Column feeder · 30-80 cm
- *Aorichthys seenghala* · Giant Catfish · Bottom · 36-102 cm
- *Notopterus notopterus* · Bronze Featherback · Mid · 24-32 cm

EXPERIMENTAL DESIGN & WORKFLOW

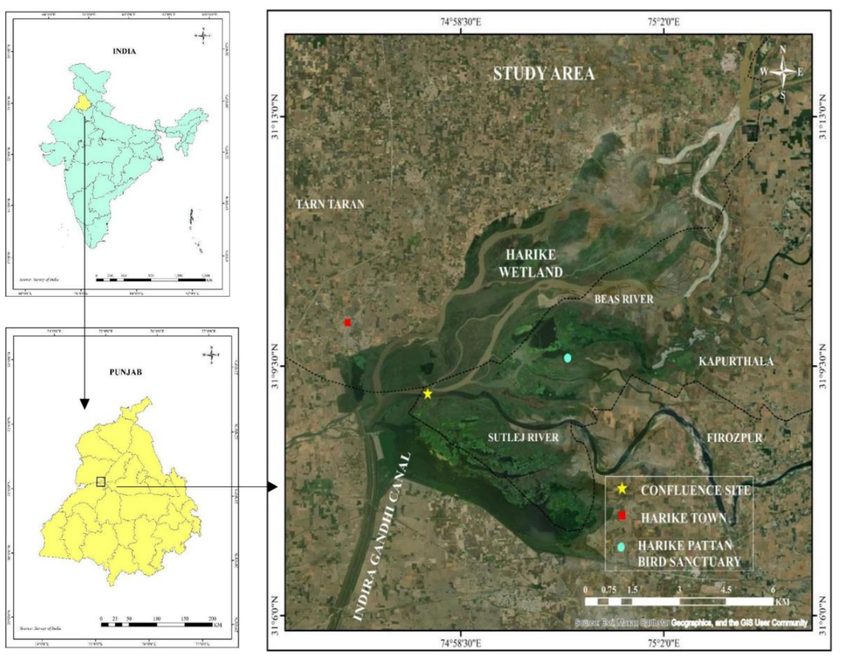


Figure 1. Location and map of the Harike wetland in Punjab, India

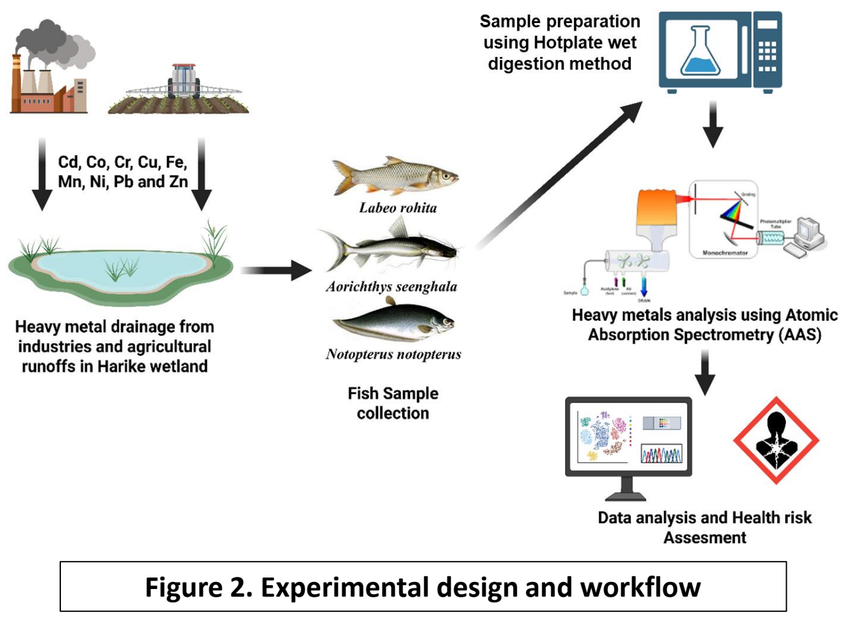


Figure 2. Experimental design and workflow

OBJECTIVES AND METHODS

1. Quantify nine heavy metals in the epaxial muscle of three commercially important species.
2. Assess human health risk using USEPA indices: EDI, THQ, HI, LCR.
3. Identify species-specific accumulation via PCA & hierarchical clustering.
4. Compare findings with global wetland studies and Indian food safety limits.

SAMPLING
- Feb–Apr 2020
- Harike wetland market
- Authorized contractor

DIGESTION
- Wet acid digestion
- HCl + HNO_3
- Muffle furnace 450°C

ANALYSIS
- AAS (Varian FS 240)
- Recovery 90–110%
- $R^2 \geq 0.999$

STATISTICS
- PCA
- Hierarchical clustering
- Spearman correlation
- Python / R

FIR = 9 g/person/day (India Fisheries Handbook 2018)
BW = 60 kg (FAO 2006)
Exposure 365 days/yr for 60 years

RESULTS

Heavy Metal Concentration

- All three species exceed the FAO/WHO limit (<100 mg/kg) for combined metal burden.
- Fe, Pb, and Zn were dominant contaminants.
- Total Metal Burden: *L. rohita* > *N. notopterus* > *A. seenghala*

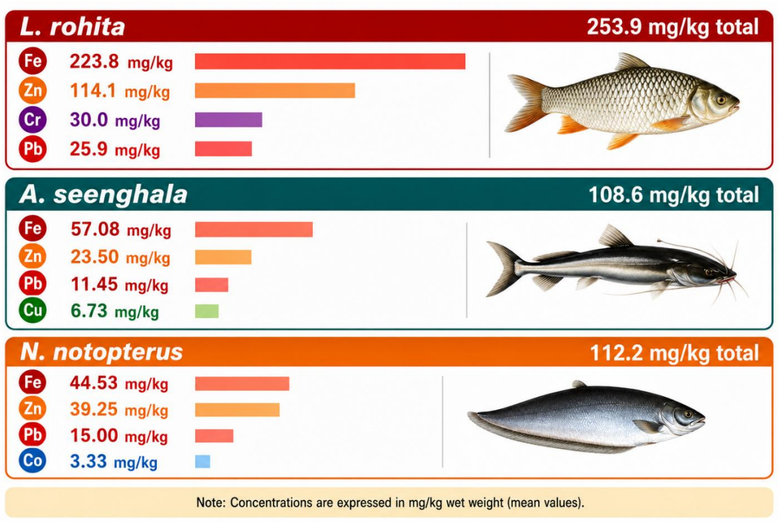


Table 1. Comparative heavy metal burden among fish species

Target Hazard Quotient - Non-Carcinogenic Risk

- THQ > 1 indicates a significant non-carcinogenic health risk (USEPA 2010).

Metal	RID mg/kg/d	*L. rohita* THQ	*A. seenghala* THQ	*N. notopterus* THQ	Status
Lead (Pb)	0.00016	24.31 ■	10.75 ■	14.06 ■	■ CRITICAL
Zinc (Zn)	0.30	0.057	0.012	19.63 ■	■ HIGH (Nn)
Cobalt (Co)	0.0003	1.51 !	1.31 !	1.67 !	■ ELEVATED
Nickel (Ni)	0.011	0.106	0.030	0.027	■ MODERATE
Cadmium (Cd)	0.001	0.051	0.029	0.039	■ MODERATE
Copper (*Cu*)	0.04	0.093	0.025	0.008	■ LOW
Iron (Fe)	5.6	0.006	0.002	0.001	■ LOW (EDI↑)
HAZARD INDEX (HI)	—	26.1	12.2	35.4	■ ALL > 1

Table. 2. Human health risk indices associated with fish consumption

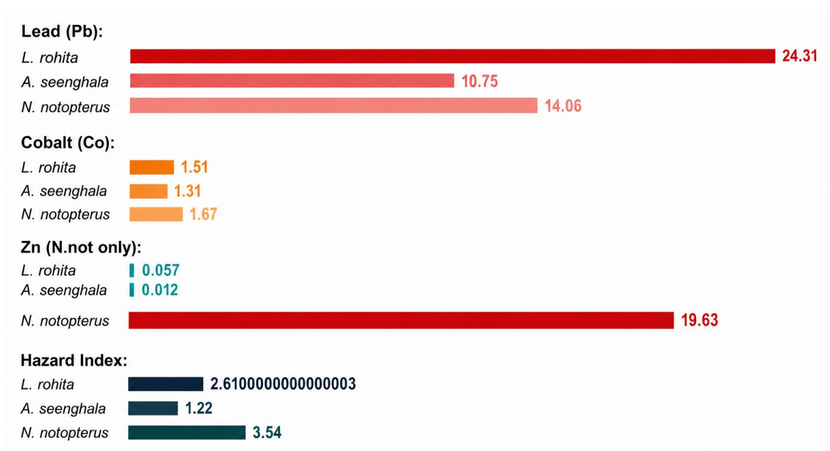


Figure 3. THQ and Hazard Index (HI) values of key metals in *L. rohita*, *A. seenghala*, and *N. notopterus*, with bar lengths proportional to THQ values.

Lifetime Cancer Risk (LCR)

- According to USEPA guidelines, Cr showed the highest LCR in all fish species, indicating a serious carcinogenic risk, while Pb in *L. rohita* also exceeded the acceptable safety limit.

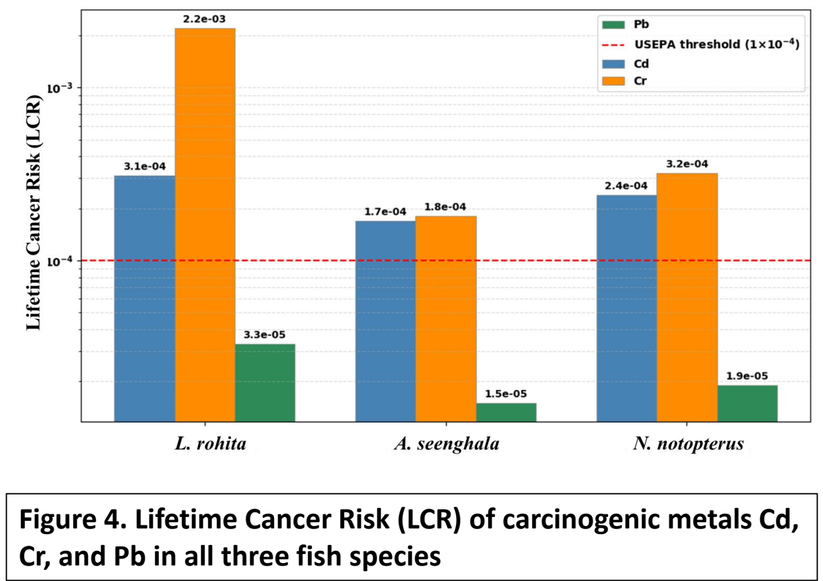


Figure 4. Lifetime Cancer Risk (LCR) of carcinogenic metals Cd, Cr, and Pb in all three fish species

Multivariate Analysis

- PCA explained 99.56% variance, clearly separating fish species by metal accumulation.
- *N. notopterus* was associated with Zn, while *A. seenghala* showed a stronger association with Fe.
- *L. rohita* and *A. seenghala* clustered closely due to similar Cd, Co, Cr, Cu, Mn, Ni, and Pb profiles.

Figure 5. Principal Component Analysis (PCA) of heavy metal accumulation among three freshwater fish species.

- Strong Pb-Cr correlation in *L. rohita* indicated possible co-accumulation.
- Cd-Cr relationships varied among species, showing species-specific metal uptake.
- Metal accumulation was influenced by feeding behaviour and metabolism.

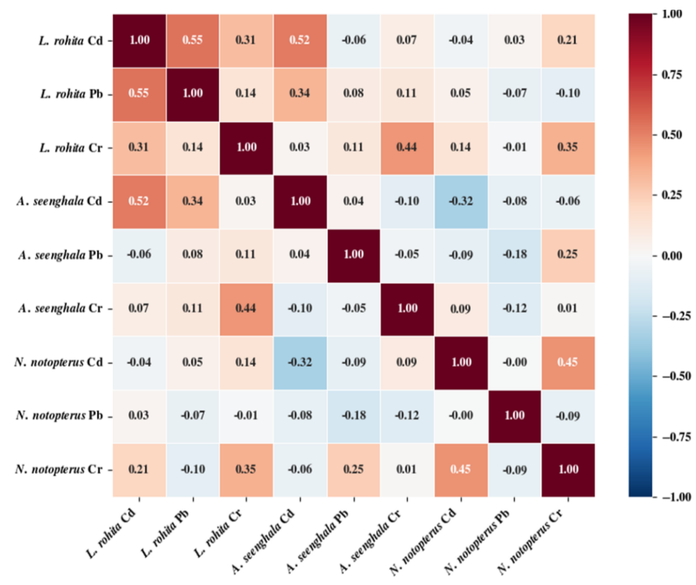


Figure 6. Spearman correlation matrices of heavy metal concentration.

Point-source contamination gradient dominates, with Zn and Fe as major discriminating metals, indicating direct industrial discharge pathways into the Harike wetland.

KEY FINDINGS

- All species exceed FAO/WHO metal limits, first time shown for the Harike Wetland.
- Cr levels (2.41–29.99 mg/kg) >> Ganga River fish(0.15–1.74 mg/kg); Pb levels (11.45-25.93 mg/kg) >> Lake Phewa, Nepal (1.9 mg/kg).
- PCA axis 1 explains 96.37% variance, similar to Ganga basin patterns.
- HI > 1 in all species indicates cumulative synergistic toxicity risks.
- Pb + Co leads to neurological disorders, renal failure, and fetal development risk.

CONCLUSION AND FUTURE DIRECTIONS

HEALTH RISK
- All three fish species pose significant carcinogenic risks; Cr showed the highest LCR in all species, while Pb in *L. rohita* exceeded the safety limit.

PRIORITY METALS
- Cr is the most critical metal of concern, followed by Pb and Cd due to their elevated risk potential.

MONITORING
- Regular monitoring of Cr, Pb and Cd in fish species is essential to ensure food safety in the studied aquatic ecosystem.

REGULATION
- Enforce stricter regulations on metal discharges and adhere to guideline values such as USEPA limits for safe consumption.

REMEDIATION
- Implement remediation strategies at the source to reduce metal inputs and bioaccumulation in fish tissues.

COMMUNITY
- Raise awareness among local communities about the risks of heavy metal exposure and promote safe fish consumption practices.

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