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Bioaccumulation of Chromium in Different Organs of Some Freshwater Fishes Collected from Local Fish Markets of Patna, Bihar, India

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ABSTRACT

Water pollution can cause fish to be contaminated with heavy metals and lead to its accumulation in various organs. Heavy metals accumulation in various organs of fishes belonging to different feeding habits were extensively studied in different aquatic ecosystems. Such studies in connection with chromium (Cr) accumulation in fishes of local fish market of Patna, Bihar are scanty. In the present study plankton feeder fish, *Catla catla*, herbivorous fish, *Labeo rohita* and carnivorous fish, *Clarias batrachus* having good consumer preference and higher market value were collected from local fish markets of Patna for analysis of bioaccumulation of Cr in muscle, brain, liver, heart and gills. Fish samples were collected from four different sites of Patna (Raja Bazar fish market, Boring Road Chauraha fish market, Hartali Mod fish market and Patna City fish market) and analyzed for Cr concentration through Atomic Absorption Spectrophotometer in the Central Research Laboratory, Patna Women's College, Patna. Highest Cr concentration in *Labeo rohita*, (0.056±0.001 µg/g) was recorded in muscle tissues (Raza Bazar fish market), in *Clarias batrachus* highest Cr concentration (0.056±0.0051 µg/g) was seen in liver tissues (Patna City sites) whereas in *Catla catla* highest concentration of Cr (0.07±0.001 µg/g) observed in brain tissues (Raza Bazar fish market) and liver tissue (Hartali Mod fish market). However, the Cr concentration in all the studied fish samples were within the permissible levels and was safe for the human consumption. The two-way ANOVA results strongly demonstrate that chromium accumulation in all the three fish species was affected by both the specific organ and site of collection, and the pattern of accumulation varies depending on the organ-site combination.

Keywords Chromium concentration, *Labeo rohita*, *Clarias batrachus*, *Catla catla*, Patna.

INTRODUCTION

Heavy metal pollution is a serious issue to aquatic organisms and has brought about several harmful impacts on them. They have become of great concern over last few decades due to their toxicity, abundance and ability to accumulate in aquatic ecosystems and

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organisms (Golovanova 2008). Not surprising they are considered as a major aquatic environmental load (Peligro *et al.* 2016). Major sources of these heavy metals are tanneries, leather industries, paper industries, metal plating industries, electroplating industries, pesticides, mining operations, textile industry, (Ghosh and Saha 2022). As these heavy metals enter aquatic ecosystems, they accumulate in sediments, plants, and aquatic organisms (Dehkordi *et al.* 2024). Heavy metals enter the aquatic food chain either by direct intake of water and food or by non-dietary routes through permeable membranes such as gills, then invade fish organs by adsorption and absorption (Rajeshkumar and Li 2018). Ultimately, this leads to exposure to the human body through food chain and can lead to various disorders related to brain, kidney, liver, lungs and even cause carcinogenic effects (Jaishankar *et al.* 2014, Briffa *et al.* 2020).

Among heavy metals, chromium has been considered a highly toxic inorganic pollutant, introduced to the environment through various natural and anthropogenic sources (Zhigalenok *et al*. 2025). It damages the aquatic environment due to its toxic effect hence listed as the priority pollutant by many environment and health protection agencies such as the US Environmental Protection Agency (2024). According to International Standards for Drinking water recommendation the maximum tolerance for total chromium in water supplies is 0.05 mg/l (WHO 2022). Chromium is the twenty- first most commonly occurring element in the earth's crust with an average concentration of 100 mg/kg. The primary use of metallurgical grade chromium is in the production of ferrochromium alloys, which are used as additive in stainless steel and other specialized products. The EPA Toxics Releaze Inventory (TRI) estimated approximately 53 million pounds of chromium and chromium compounds released to surface water through various land releases (US EPA 2018). The water and sediments of the River Ganga have also been heavily contaminated by Cr in the industrial sections of the river (Beg and Ali 2008).

Cr exists in environment in divalent Cr (II), trivalent Cr (III) and hexavalent Cr (VI) oxidation states, of which Cr (III) and Cr (VI) are stable forms. Chromium (VI) which consists of 10%–15% total chromium usage, is principally used for metal plating ($H_2Cr_2O_7$), as dyes, paint pigments, and leather tanning. The hexavalent form is easily bioavailable and is thus highly toxic to aquatic organisms (Farag *et al.* 2006), having carcinogenic properties, leading to mutagenic and other congenital as well as physical abnormalities (Velma *et al.* 2009). Acute toxicity of hexavalent chromium to fish varies with species, age, and the physico-chemical parameters of water (Guertin 2005). Trivalent Cr is rather less toxic than hexavalent Cr to fish (Nisha *et al.* 2016). Fishes are susceptible to heavy metal contamination as they occupy various trophic levels in aquatic food webs and interact closely with water and sediment. In the heavy metals contaminated aquatic environment, fish appear to take up heavy metals from their environment (Adakole and Abolude 2009). Due to this, they are reliable bioindicators (Tenji *et al.* 2020) and serve as simplest biomarkers of pollution of the aquatic environment.

Effect of chromium on human

Chromium (VI) is known for its corrosive nature and its ability to trigger allergic reactions to the body. It can cause anemia, irritations and ulcers in the small intestine and stomach, damage sperm and male reproductive system. The allergic reactions due to chromium include severe redness and swelling of the skin. Exposure of extremely high doses of chromium (VI) compounds to humans can result in severe cardiovascular, respiratory, hematological, gastrointestinal, renal, hepatic and neurological effects and possibly death (Shekhawat *et al.* 2015).

Fish play a very important role in providing affordable nutrition worldwide. Being rich in quality animal protein, polyunsaturated fatty acids specially omega-3 eicosapentaenoic acid and several essential micronutrients fish are more affordable than other source of animal proteins (Mohanty *et al.* 2019). However, consuming fish could expose humans to heavy metals through the food chain. Due to its top level consumer in aquatic food chain, fishes are more prone to accumulate metals in various organs that affect the morphological, physiological and biochemical functions of fish and ultimately pose treat to human through food (Al-Yusuf *et al.* 2000, Mitra *et al.* 2017). It is reported that the average acute value of Cr (VI) in freshwater fishes is ranged from 30 mg/l to 139.9 mg/l (WHO 2011).

Metal accumulation in different body organs of fishes of various feeding habits were extensively studied in different aquatic ecosystem (Kiran *et al.* 2006). But, similar studies in fishes of local fish markets of Patna are scanty. The present study aimed to detect the Cr concentration in *Labeo rohita*, *Clarius batrachus* and *Catla catla* collected from local fish market of Patna, Bihar and to assess the possible health hazards caused from these fishes to the consumer. The species selected for the present study have good consumer preference and higher market value. They are commercially important and consumed as popular fish in Bihar, Uttar Pradesh, West Bengal and Andhra Pradesh.

MATERIALS AND METHODS

Study area

The fish samples were collected from four popular fish markets of Patna, Bihar namely, Raja Bazar fish market (25°36′17″N 85°05′07″E), Boring Road Chauraha fish market (25°36′47″N85°07′08″E), Hartali Mod fish market (25°36′20″N 85°07′01″E) and Patna City fish market (25°35′38″N 85°13′36″E) during March 2022.

Collection of fish samples

Three samples of each fish species (*Labeo rohita*, *Clarias batrachus* and *Catla catla*) were purchased from the four popular fish markets of Patna, weighed (g) and total length measured (Table 1).

All samples were kept separately in aluminum pouches and transported to Central Research Laboratory (CRL), Patna Women's College, in icebox. In the laboratory the fish samples were washed and liver, heart, gills, muscle and brain were dissected for further processing. Approximately 1 g of each fish organ sample was accurately weighed using an electronic balance and oven-dried to remove moisture. The dried composite samples were transferred into separate beakers and digested using a mixture of concentrated sulfuric acid (HNO_3) and hydrochloric acid (HCl) in a 1:1 ratio, with 5 mL of each acid added per sample. Following complete digestion, the samples were allowed to cool to room temperature. The digested solutions were then filtered through Whatman no. 42 filter paper and diluted to a final volume of 50 mL with double-distilled water in volumetric flasks.

The prepared samples were analyzed in triplicate for chromium (Cr) concentration using an Atomic Absorption Spectrophotometer (GBC Savant AA, Australia). Calibration was performed with standard Cr solutions of 1, 2, 4 and 8 ppm concentrations. The metal concentrations were expressed as micrograms per gram (µg/g) dry weight of each organ.

Statistical analysis

Statistical analysis was carried by using MS excel and

Table 1. Physical measurement of fish samples collected from local fish markets of Patna, Bihar.

	Raja Bazar	Boring Road	Hartali Mod	Patna City
Labeo rohita				
Weight (in g)	800±200	216.66 ±28.86	210± 36.05	603± 105.03
Length (in cm)	36.8±1.2	24.2±1.1	24±1.4	34.7±2.2
Clarias batrachus				
Weight (in g)	250±26.45	190±43.58	200±26.45	206.6±30.55
Length (in cm)	23.3±1.15	21±1.73	21.3±1.15	21.3±1.52
Catla catla				
Weight (in g)	1116.7± 225.4	1410±356.8	1243.3±376.4	700±229.13
Length (in cm)	42.7± 2.85	45.3±3.48	43.56±3.86	36.4±3.108

statistical software-Graph Pad prism 7.0 to evaluate metal content in various tissues of the studied fishes. The results are expressed as mean ± standard deviation (SD). The means of the replicates and evaluation of significant differences between different samples were determined using descriptive statistics and analysis of variance (ANOVA), respectively. Two-way analysis of variable (ANOVA) were used to test for significant differences in the concentrations of heavy metals in the samples and organs and sites. Results of the test were considered significant if the calculated values were $p<0.05$.

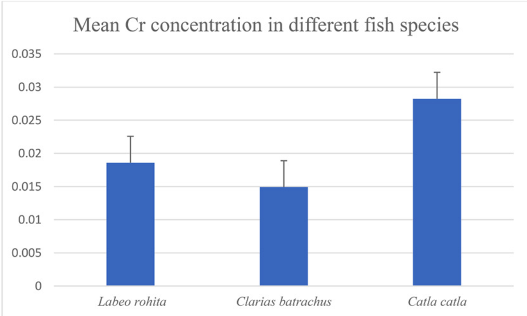

Fig. 1. Overall concentration of Cr in *Labeo rohita*, *Clarias batrachus* and *Catla catla* from 4 studied sites.

RESULTS AND DISCUSSION

Contamination and pollution of aquatic environments with heavy metals from natural and anthropogenic sources are issues of public concern as fishes from these water bodies have been reported to be unfit for human consumption due to presence of high concentration of heavy metals in their tissues (Tyokumbur and Okorie 2014). The most common metals in fish are Chromium (Cr), Lead (Pb), Cadmium (Cd) and Mercury (Hg). These heavy metals display extreme toxicity even at very low (metal) exposure levels to all life forms (Rajeshkumar and Li 2018). The present study documents bioaccumulation of Cr in some very economically important fishes, collected from four famous fish markets of Patna, Bihar during March 2022. Fish species selected for the present study were *Labeo rohita*, *Clarias batrachus* and *Catla catla*, each representing a different ecological niche and exhibiting distinct feeding habits. Specifically, *L. rohita* is omnivorous column feeder fish (Bakhtiyar *et al.* 2018) consuming both plant and animal matter, *C. batrachus* is carnivorous and feeds on zooplankton, insect larvae, fish larvae. Ramesh and Kiran (2016) and *C. catla* is herbivorous surface feeder, primarily feeds on phytoplankton and zooplankton (Kumar and Sharma 2015). Cr accumulation varies with the species of fish and depend upon physiological requirement, feeding habits and habitat of a specific fish (Aftabuddin *et al.* 2008). In the present study, species wise accumulation pattern of Cr showed highest concentration in *Catla catla* followed by *Labeo rohita* and *Clarias batrachus* (Fig.1). Ecological niche occupied by fish might play crucial role in bioaccumulation of Cr in fish. *C. catla* is a surface feeder and plankton feeder fish. It may have accumulated Cr mostly from water. Though, its juveniles feed on aquatic insects, detritus and phytoplankton. Similar results have been reported by Sanyal *et al.* (2017) who observed maximum Cr accumulation in *C. catla* followed by *L. bata* and *P. sarana*. They concluded exposure period as an important factor for the distribution of Cr in environment and its accumulation in fish. However, Rajeshkumar and Li (2018) recorded highest bioaccumulation in carnivorous species (*P. fulvidraco*), followed by omnivorous (*C. carpio*) species. The Cr concentrations in the present study was under the permissible limits of World Health Organization (2011) for fish (0.15 µg/g). Sharma *et al.* (2021) has reported Cr concentration in tissues of *Labeo rohita* collected from Yamuna river significantly above the permissible limits and ranged between 9.63 to 1.25 µg/g. Maurya *et al.* (2019) detected Cr concentration in the tissues of *C. mrigala*, *C. catla*, *L. rohita*, *C. latius*, *C. garua* and *M. tengara* above the permissible limits proposed by EU (1 µg /g).

Chromium (VI) gets associated with the plasma protein and involves in transportation after passing the cell membrane through sulfate ion channel (Dhara 2014). Then the metal gets accumulated in various organs. Liver plays a vital role in detoxification, redistribution, and transformation of heavy metals (Zhao *et al.* 2012) and acts as a main site for metal metabolism due to the presence of binding proteins such as metallothioneins (MT). The affinity of metals with metallothioneins leads to their higher accumulation in the liver and gills as reported by Negi and Maurya (2015) for *L. rohita* and *H. molitrix*. Organ wise accumulation of Cr in the present study showed

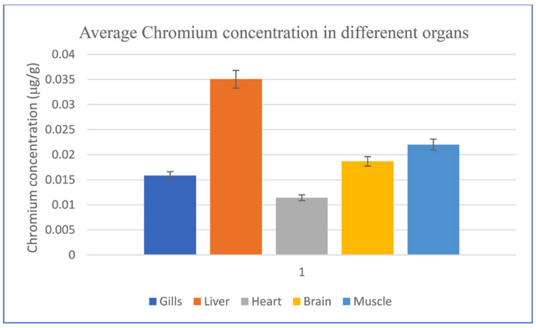

Fig. 2. The average concentration of Cr (µg/g) in different organ samples of the three fish species.

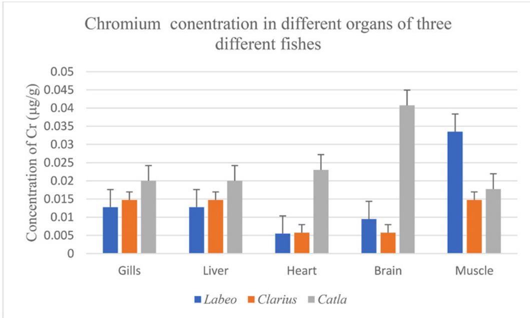

Fig. 3. Mean Cr concentration in different organs of *L. rohita*, *C. batrachus* and *C. catla* during the present study.

most of the accumulation was in liver (Fig. 2). Several studies consistent with our results reported high levels of Cr, in fish liver, gill and muscle tissues (Sharma *et al.* 2021, Ray *et al.* 2025). The muscle tissue is important because it is the main edible portion of fish which provide nutrition to human. The present study reported lower concentration of Cr in muscle tissues except for *L. rohita* (Fig. 3). Muscle tissue acts as a major storage organ, where limited detoxification capacity results in bioaccumulation (Vieira *et al.* 2021). In *L. rohita*, highest Cr concentration (0.056±0.001 µg/g) was recorded in muscle tissues of Raza Bazar fish market and lowest (0.002±0.002 µg/g) was recorded in heart tissue of Boring Road fish market and in heart and gills tissue of Patna City fish market (Table 2). In *C. batrachus* highest Cr concentration (0.056±0.0051 µg/g) was seen in liver tissues of Patna City site whereas lowest concentration was recorded

Table 2. Cr concentration (µg/g dry weight) in organs of fish collected from local fish markets of Patna, Bihar. All the values are mean values of three replicates presented as mean±SD.

Fish/organs	Raja Bazar	Boring Road	Hartali Mod	Patna City
Labeo rohita				
Gills	0.014±0.002	0.017±0.002	0.018±0.001	0.002±0.003
Liver	0.034± 0.001	0.011±0.0002	0.045±0.002	0.037±0.002
Heart	0.012±0.0024	0.002±0.002	0.006±0.0032	0.002±0.003
Brain	0.01±0.001	0.008±0.001	0.010±0.003	0.01±0.001
Muscle	0.056±0.001	0.034±0.001	0.027±0.002	0.017±0.002
Clarias batrachus				
Gills	ND	0.006±0.0044	0.009±0.0037	0.044±0.006
Liver	0.050±0.0028	0.023±0.0042	0.0056±0.0039	0.056±0.0051
Heart	0.009±0.0029	0.005±0.0038	0.006±0.0029	0.003±0.0044
Brain	ND	0.011±0.0031	0.006±0.0039	0.006±0.0045
Muscle	0.045±0.0045	0.005±0.0036	ND	0.009±0.0042
Catla catla				
Gills	0.009±0.001	0.003±0.001	0.06±0.002	0.008±0.001
Liver	0.061±0.001	0.008±0.001	0.07±0.001	0.02±0.002
Heart	0.01±0.004	0.011±0.004	0.03±0.002	0.041±0.001
Brain	0.070±0.0009	0.023± 0.0011	0.050±0.0021	0.020±0.0023
Muscle	0.020±0.0007	0.009±0.002	0.034±0.0019	0.008±0.0025

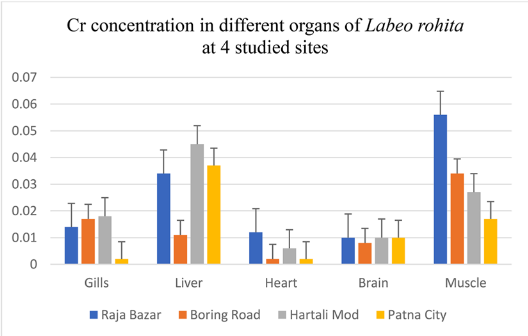

Fig. 4. Cr concentration (µg/g) in different organs of *Labeo rohita* at the 4 studied sites.

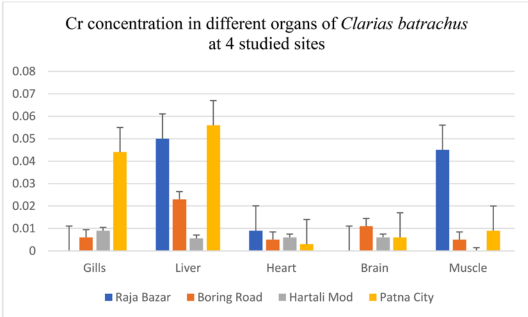

Fig. 5. Cr concentration (µg/g) in different organs of *Clarias batrachus* at the 4 studied sites.

in Patna City fish market (0.003±0.0044 µg/g) in heart tissues. The concentration of chromium was below the detection limit in gills and brain tissues at Raza Bazar site and in muscles at Hartali Mod site. In *C. catla* highest concentration of Cr (0.07± 0.001µg/g) observed in brain tissues of Raza Bazar and liver tissue of Hartali Mod and lowest (0.003±0.002 µg/g) in gill tissues of Boring Road site (Table 2). According to Kumar and Singh (2024) the bioaccumulation pattern in *C. batrachus* generally followed the trend: Liver > kidney > gill > muscle. The results observed in present study were in good agreement with the above findings.

Based on the mean concentration of Cr detected in various tissues of *L. rohita* at different fish markets, the sequence seems to be as follow: Gills, Hartali Mod>Boring Road>Raza Bazar>Patna City ; liver, Hartali Mode>Patna City>Raza Bazar>Boring Road; Heart, Raza Bazar>Hartali Mod>Patna City=Boring Road, brain, Raza Bazar=Hartali Mod=Patna City>-Boring Road; muscle, Raza Bazar>Boring Road>Hartali Mod>Patna City (Fig. 4). The mean concentration of Cr in various tissues of *C. batrachus* at different fish markets was detected in the following sequence: Gills,

Table 3. Comparison of Cr concentration in fish samples (µg/g) observed by different authors.

Sample	Description	Organs/tissues	Cr	Reference
1	Patna, Bihar fish samples	Gill	0.015	Present study
		Liver	0.035	
		Heart	0.011	
		Brain	0.018	
		Muscle	0.022	
2	Zemplinska sirava reservoir, Slovakia fish samples (mg kg^{-1} wet wt)	Muscle	0.168	Tímea *et al*. (2025)
		Liver	0.205	
3	Durg district, Chhattisgarh, India	Liver	3.89	Kumar and Singh (2024)
		Kidney	1.57	
		Gill	0.92	
		Muscle	0.51	
4	Taihu lake fish samples	Muscle	0.34	Rajeshkumar and Li (2018)
		Gill	0.16	
		Liver	0.35	
		Kidney	0.07	
		Intestine	0.15	
5	Pulicat lake, India	Muscle	0.02	Prabhu *et al.* (2008)
		Gill	0.2	
		Liver	0.3	
		Kidney	–	
		Intestine	0.02	

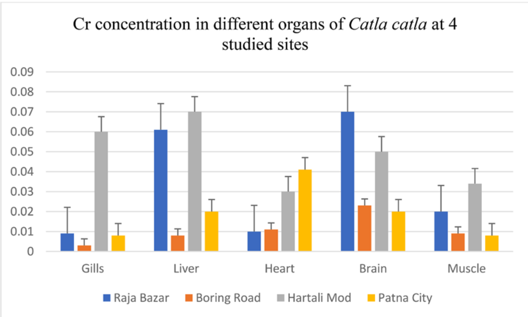

Fig. 6. Cr concentration (µg/g) in different organs of *Catla catla* at the 4 studied sites.

Patna City>Hartali Mod>Boring Road ; liver, Patna City>Raza Bazar>Boring Road>Hartali Mod ; Heart, Raza Bazar>Hartali Mod>Boring Road>Patna City; Brain, Boring Road>Hartali Mod=Patna City; muscle, Raza Bazar>Patna City>Boring Road (Fig. 5). The sequence for Cr concentration in various organs of *C. catla* at different sites was recorded as follow: Gills, Hartali Mod>Raza Bazar>Patna City>Boring Road; liver, Hartali Mod>Raza Bazar>Patna City>-Boring Road; heart, Patna City>Hartali Mod>Boring Road>Raza Bazar; brain, Raza Bazar>Hartali Mod>-Boring Road>Patna City; muscle, Hartali Mod>Raza Bazar>Boring Road>Patna City (Fig. 6).

The two-way ANOVA results strongly demonstrate that chromium accumulation in all the three fish species was affected by both the specific organ and site of collection, and the pattern of accumulation varies depending on the organ-site combination. All factors and their interaction have statistically significant effects on the chromium concentration in the fish tissue sample at the 5% significant level. This indicates that environmental and biological factors combine to influence Cr accumulation distinctly across organs and sites.

In conclusion, it is evident from the above discussion that Cr accumulate in different organs of *Labeo rohita, Clarias batrachus* and *Catla catla* collected from all four fish markets of Patna during the present study. Significant differences were identified among gill, liver, heart, brain and muscle of the fishes (*Labeo rohita, Clarias batrachus* and *Catla catla*) in view of the bioaccumulation of the Cr from different fish markets of Patna. The concentration of Cr was found below the limited value prescribed by WHO (2011) and also compared with other studies shown in Table 3 from all the sites, in all the organs of the studied fish species. Though, the level was under the permissible limit but people should be aware of the possible threats in the near future as more accumulation of Cr causes serious health issues. The maximum accumulation was found in liver which could be avoided for consumption, they may represent good bio-monitor of Cr in the aquatic ecosystem. The result of this study demonstrate that more study should be done on monitoring of aquatic environment and remediation efforts to reduce metal contamination of water bodies.

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