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Bioaccumulation of heavy metals in selected tissues of fish *Labeo calbasu* summer seasons Kollidam River Kumbakonam Taluk Thanjauvr district Tamil Nadu India

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Abstract

The River Cauvery is considered to be the main source of drinking water supply. Deterioration of drinking water quality continues to be a major problem. Hence, the present study aimed at analyzing toxic metals. Various environmental pollutants, including metals can cause toxicological effects on aquatic animals especially fish species. bioaccumulation patterns of Cr, Pb, Cu, Zn, Fe and Mn in summer seasons fish *Labeo calbasu*, Studies on bioaccumulation of pollutants in fish are important in determining the tolerance limits of fish species, effects of specific pollutants on fish, and biomagnification through food chains. Water pollution from toxic metals can have sever negative impacts on fish. Pollution might result from many sources, e.g., accidental spillage of chemical wastes, atmospheric precipitation contaminated with air-borne pollutants, discharge of industrial or sewerage effluents etc.,

Keywords: Heavy metal assessment, Kollidam River, Fish Tissues, Atomic Absorption Spectrophotometry and Environment.

Introduction

Heavy metal pollution in aquatic ecosystems is a global issue owing to its adverse impacts on both human well-being and the environment at large. Among these ecosystems, rivers stand out as particularly vulnerable to contamination, given their crucial role as essential water sources. Kollidam River is situated in Tamil Nadu, India, plays a vital role in supporting various aspects of life, including agriculture, drinking water supplies, and aquatic biodiversity. Unfortunately, the rapid pace of industrial expansion and urban development in the area has raised concerns about the potential discharge of heavy metals into this critical river system, thereby posing significant risks to its integrity.

The natural aquatic resources contamination of heavy metals released from industrial, domestic and other anthropogenic activities has become a matter of concern over the past few decades. This will give an indication of temporal and spatial extant of metal accumulation, as well as assessment of potential impact on human health (Ladipo *et al.*, 2012) [19]. Fish being the top consumer in the aquatic food chain accumulate large amounts of heavy metals in their body (Chezhian *et al.*, 2010) [8]. The heavy metals contamination is one of the vital factors for decline of water quality that has an obvious impact on fish diversity. Consumption of fish from the contaminated site poses a higher health risk to human. Many studies are being carried out to determine the level of metals in the fish since it is considered as one of the richest sources of protein and unsaturated omega-3 fatty acid for human (Yilmaz *et al.*, 2007) [31]. Kaveri River is running through three southern states of India. The objectives of the present study was to estimate the levels of metals in fish with different stations and also to find the accumulation pattern in different organs *viz.*, gill, liver. Muscle and brain of fishes *Labeo calbasu* from River Kollidam.

Drinking water is constantly associated with multitude of health-related concerns as a result of contamination by both chemical and biological pollutants. Due to the adverse effects on human and the environment, chemical pollutants such as heavy metals, pesticides, PCBs, PAHs are of foremost importance. Over the last few decades heavy metal pollution in rivers has become a matter of great concern, not only because of the threat to public water supplies, but also the risk arising due to human consumption of fishery resources as a result of accumulation through food chain (Terra *et al.*, 2008) [28]. Elevated levels of heavy metals in rivers, lakes and ponds are considered to be precarious because they are the main source of drinking water as well as habitat for aquatic ecosystem in the developing countries (Ochieng *et al.*, 2008)

In aquatic ecosystems, heavy metals have received considerable attention due to their toxicity and accumulation in biota (Dural *et al.*, 2006) [9]. Heavy metals from natural and anthropogenic sources are continually released into aquatic ecosystems, and they are a serious threat because of their toxicity, bioaccumulation, long persistence, and biomagnification in the food chain. Heavy metals, including both essential and non-essential elements, have a particular significance in ecotoxicology, since they are highly persistent and all have the potential to be toxic to living organisms (Storelli *et al*. 2006) [27]. Heavy metal discharges to aquatic environment are of great concern of all over the country.

Heavy metals enter in aquatic ecosystem from natural and anthropogenic sources. Anthropogenic activities continuously increase the amount of heavy metal in the aquatic ecosystem (Xu *et al.*, 2018) [30]. As heavy metals cannot be degraded, they are deposited, assimilated or incorporated in water, sediment and aquatic organisms and thus, causing heavy metal pollution in aquatic ecosystem (Kumar and Kumar, 2018 [17] and Farsani, *et al.*, 2019) [13]. The retention of heavy metal in the body of an organism depends on many factors such as the speciation of the metal concerned and the physical mechanism developed by the organism for the regulation, homeostasis, and detoxification of the heavy metal. The degree of bioaccumulation in different tissues of fish is generally different depending in the active tissue as liver, gills, and kidney have higher accumulation of the heavy metal than other tissues such as skin and muscles (Maurya *et al*., 2019 [20] and Ezekiel *et al.,* 2019) [12].

Bioaccumulation of heavy metal in freshwater fish depends upon the various factors like age, size, sex, reproductive cycle, feeding behaviour, swimming pattern and geographical location (Egbeja *et al.,* 2019) [11]. The contamination of aquatic ecosystems with a variety of pollutants can be verified by analyzing water, sediments and aquatic organisms (Canli and Atli 2003) [6]. Fishes are key indicators of aquatic ecosystem health and are commonly used as bioindicators to assess the levels of metal contamination in water bodies (Hamada *et al.,* 2024) [14]. Fish accumulate metals primarily through the water and sediment, where they absorb dissolved metals through their gills or ingest metal-contaminated food items. The accumulation of metals in fish can occur both at the individual level, affecting specific organs and tissues and at the population level, influencing reproductive success, growth and overall fitness (Aborisade *et al.*, 2024) [1].

Metals such as mercury, cadmium, lead and arsenic, which are known for their toxicity, can accumulate in fish tissues over time, often reaching concentrations that exceed those found in the surrounding water or sediment (Singh and Sharma 2024) [24]. The bioaccumulation of metals in fish is influenced by several factors, including the type of metal, the fish species, the size of the fish, the duration of exposure, and the environmental conditions (Ray and Vashishth 2024) [22]. For instance, larger fish and those higher in the food chain, such as carnivorous species, tend to accumulate higher concentrations of metals due to biomagnification (Saidon *et al.*, 2024) [23].

The effects of metal accumulation on fish can range from sublethal to lethal, depending on the concentration and duration of exposure. Sublethal effects may include behavioral changes, impaired feeding, reduced growth rates, and altered reproductive success. At higher concentrations, metals can cause more severe effects such as organ damage, immune suppression, and neurological impairments (Bagheri *et al.*, 2024) [4]. For example, mercury, particularly in the form of methylmercury is known to accumulate in fish and cause neurotoxic effects, including tremors, abnormal swimming behavior and difficulty in predator avoidance. Chronic exposure to metals can also affect the immune system, making fish more susceptible to diseases and parasites (Singh and Sharma 2024) [24].

In addition to individual health impacts, the accumulation of metals in fish can have far-reaching consequences for fish populations and ecosystems. Reproductive failure, reduced survival rates, and genetic mutations can reduce the population size and biodiversity of fish species, affecting the food webs that depend on them (Ray and Vashishth 2024) [22]. The transfer of metals from fish to humans and wildlife through the consumption of contaminated fish further amplifies the problem, leading to potential public health risks.

The consensus seems to be that fishes in heavy metal-contaminated areas tend to absorb certain heavy metals in ionic forms from their immediate environment. However, during the past few decades, these activities have become intensive resulting in serious impacts on human health. Hence, the present study aimed at assessing heavy metals in water and sediment of River Cauvery and risk caused to the local human population and resident aquatic organisms through water

Materials and methods

The Kollidam River is an important tributary of the Cauvery River, located in Tamil Nadu, India, flowing through regions with agricultural, residential, and industrial activities. The study was conducted between Thirumanur and Anaikarai, spanning approximately 70 km. This stretch encompasses diverse influences, including agricultural runoff and municipal waste, potentially impacting water quality. The geographical coordinates of the sampling area range from 10°55'34.7"N to 11°08'08.9"N latitude and 79°06'15.2"E to 79°27'12.8"E longitude.

Sampling Stations

Four stations were selected to assess the heavy metal content (Cr, Pb, Cu, Zn, Fe and Mn) in the Kollidam River:

- **Station1(S1)**
  Located at Thirumanur (W4G3+GM8), this site represents upstream agricultural runoff with limited industrial influence. Coordinates: 10°55'34.7"N, 79°06'15.2"E.

- **Station2(S2)**
  Situated near Vazhkai (X7M9+87R), this station is influenced by domestic effluents and agricultural inputs. Coordinates: 10°59'00.1"N, 79°16'05.4"E.

- **Station3(S3)**
  Located at Kollidam Bridge, Madhanadhur (29X5+FX7), this site is characterized by significant industrial discharge. Coordinates: 11°02'56.3"N, 79°21'35.4"E.

- **Station4(S4)**
  The Anaikarai Bridge at Ukkarai (4FP3+8CF) marks the downstream endpoint of the study, reflecting cumulative impacts from upstream sources. Coordinates: 11°08'08.9"N, 79°27'12.8"E.

Sample collection and Fixation

Fish *Labeo calbasu* were collected from the Kollidam River on the spot from different sites. The collected samples were brought to the laboratory in an ice box condition and then washed with distilled water and dissected for Gill, liver, muscle and Brain tissues packed in polyethylene bags and stored at -20^{0}C until analysis. The process of collecting fish samples for bioaccumulation studies. In this case, fish species such as *Labeo calbasu*. Usually these fishes are collected in the morning (8-10 A.M.) to ensure minimal stress on the specimens. Once collected, the fishes are immediately euthanized and dissected. The specific tissues (such as Gills, liver, muscle and brain) are carefully separated and preserved in 10% formalin to maintain tissue integrity during transportation to the laboratory (Dybem 1983) [10].

Sample Processing

Upon arrival in the laboratory, the fixed tissues are placed in an oven at approximately 120°C for drying. The drying process can take up to two days, ensuring that the tissue achieves a constant weight. Once dried, the tissues are ground into a fine powder. A specific amount of this powdered tissue (usually around 0.5g) is then treated with a mixture of concentrated nitric acid and perchloric acid (in a 3:1 ratio) as suggested by Toopping (1973) to break down the tissue and release the accumulated metals. After digestion, the solution is diluted with distilled water and analyzed for metal content using Atomic Absorption Spectrophotometry (AAS). This methodology ensures that the metals (such as Cr, Pb, Cu, Zn, Fe and Mn) can be accurately quantified in the different fish tissues by APHA (1989) [2].

Results

Metal concentrations in *Labeo calbasu* on summer season

The analysis of metal concentrations in various organs of the fish species *Labeo calbasu* sampled from four stations (S1, S2, S3 and S4) of the Kollidam River, Thanjavur, during the summer season from 2023-2024 revealed varying levels of contamination across different organs and sampling stations (Table 1 and Table 2). The metals measured included Cr, Pb, Cu, Zn, Fe and Mn. The concentrations of these metals were determined in selected organs: Gill, liver, muscle and brain.

Chromium concentrations in *Labeo calbasu* on summer season

In the year 2023, at Station 1 (S1), chromium levels in the gills were recorded at 0.47±0.06 µg/g, with the liver showing slightly lower concentrations at 0.36±0.03 µg/g. Muscle tissue had the lowest chromium concentration at 0.05±0.005 µg/g, while the brain also showed a minimal value of 0.05±0.006 µg/g. At Station 2 (S2), chromium concentrations were slightly higher, with the gills containing 0.52±0.01 µg/g and the liver 0.33±0.007 µg/g. The muscle and brain tissues at (S2) had concentrations of 0.04±0.006 µg/g and 0.06±0.008 µg/g, respectively. At Station 3 (S3), the gills exhibited the highest chromium concentration among the stations, reaching 0.60±0.09 µg/g. The liver at S3 had 0.46±0.06 µg/g, while muscle and brain concentrations were at 0.03±0.002 µg/g and 0.05±0.007 µg/g, respectively. At Station 4 (S4), chromium levels in the gills were recorded at 0.53±0.09 µg/g, the liver showed 0.38±0.003 µg/g, muscle had 0.06±0.001 µg/g, and the brain had 0.05±0.003 µg/g. Overall, chromium concentrations were relatively low across all stations, with gills showing the highest concentrations (Table 1).

In the year 2024, Cr concentrations were generally low across all organs, with the muscle and brain showing the lowest concentrations, ranging from 0.04 µg/g to 0.07 µg/g. The gills exhibited the highest chromium levels, particularly at stations S1 and S4, where concentrations reached 0.59 µg/g and 0.63 µg/g, respectively. The liver and brain showed slightly higher chromium concentrations than the muscle, with liver levels ranging from 0.32 µg/g at S2 to 0.40 µg/g at S3 and brain concentrations between 0.05 µg/g and 0.06 µg/g. These findings suggest that chromium tends to bioaccumulate more in the gills, which may be related to its uptake from the surrounding water, with localized contamination at S1 and S4 (Table 2).

Lead concentrations in *Labeo calbasu* on summer season

Lead is another hazardous pollutant found in freshwater ecosystems. It is known to accumulate in aquatic organisms, leading to toxic effects on their health and the overall ecosystem. In the year 2023 of study, lead concentrations in the gills ranged from 0.73±0.02 µg/g.d.wt. at S1 to 1.05±0.23 µg/g.d.wt. at S3. The liver consistently had higher levels of lead, with concentrations ranging from 3.54±0.28 µg/g.d.wt. at S4 to 4.12±0.78 µg/g.d.wt. at S2. Muscle and brain tissues had lower concentrations, with lead levels in the muscle ranging from 0.18±0.01 µg/g.d.wt. at S2 to 0.38±0.08 µg/g.d.wt. at S3 and brain concentrations from 0.55±0.03 µg/g.d.wt. at S2 to 0.73±0.02 µg/g.d.wt. at S1 (Table 1).

In the year 2024, lead concentrations showed similar trends, with the highest concentrations found in the gills. At station S1, the gills contained 0.85±0.01 µg/g.d.wt. of lead, decreasing to 0.74±0.01 µg/g.d.wt. at station S4. The liver also exhibited significant lead accumulation, especially at station S3, where concentrations reached 5.26±0.09 µg/g.d.wt. This suggests that the liver plays a key role in metabolizing and storing lead, potentially mitigating its toxic effects on other tissues (Table 2).

Copper concentrations in *Labeo calbasu* on summer season

Copper is an essential trace element required for various metabolic processes but can be toxic at high concentrations. During the study period of year 2023, copper concentrations in the gills ranged from 4.26±1.07 µg/g.d.wt. at S1 to 14.05±3.11 µg/g.d.wt. at S3 in the first year. The liver consistently showed higher copper levels, ranging from 17.45±4.01 µg/g.d.wt. at S2 to 18.56±4.05 µg/g.d.wt. at S3. Muscle and brain concentrations were relatively lower, with values ranging from 5.22±1.25 µg/g.d.wt. in muscle at S2 to 6.17±1.20 µg/g.d.wt. at S3, and from 3.21±0.98 µg/g.d.wt. in the brain at S2 to 4.26±1.07 µg/g.d.wt. at S1 (Table 1).

In the following year 2024, copper levels varied significantly between organs and stations. The gills exhibited the highest copper concentration, ranging from 6.56±1.52 µg/g.d.wt. at S2 to 7.75±1.62 µg/g.d.wt. at S4. The liver also had high copper levels, peaking at 16.46±0.9 µg/g.d.wt. at station S3. Copper levels in muscle were lower, ranging from 3.85±0.73 µg/g.d.wt. (S3) to 5.01±1.05 µg/g.d.wt. (S4), and the brain exhibited the lowest copper concentrations, ranging from 2.24±0.16 µg/g.d.wt. (S1) to 2.94±0.01 µg/g.d.wt. (S4) (Table 2). These findings suggested that copper is primarily processed and stored in the liver and gills due to their roles in metabolic regulation and detoxification.

Zinc concentrations in *Labeo calbasu* on summer season

Zinc is an essential metal involved in numerous biological processes, including enzyme function and immune response. In both years of the study, zinc concentrations were consistently high across all organs, with notable variations between sampling stations. In the year 2023, the gills showed zinc concentrations ranging from 65.81±5.24 µg/g.d.wt. at S2 to 90.85±10.14 µg/g.d.wt. at S3. The liver exhibited the highest zinc concentrations, ranging from 170.47±6.21 µg/g.d.wt. at S1 to 190.96±19.63 µg/g.d.wt. at S4. Muscle and brain tissues also showed considerable zinc levels, with muscle concentrations ranging from 68.31±9.95 µg/g.d.wt. at S2 to 80.96±7.19 µg/g.d.wt. at S3, and brain levels ranging from 28.14±7.35 µg/g.d.wt. at S2 to 38.75±3.11 µg/g.d.wt. at S4 (Table 1).

In the year of 2024, the zinc concentrations in the liver were again the highest, peaking at 190.12±15.62 µg/g.d.wt. at station S2. The gills showed moderate levels, ranging from 60.96±4.78 µg/g.d.wt. (S3) to 72.14±5.86 µg/g.d.wt. (S4). Zinc levels in the muscle ranged from 60.77±4.15 µg/g.d.wt. (S1) to 75.73±2.01 µg/g.d.wt. (S4), and the brain contained the lowest levels, ranging from 28.74±6.03 µg/g.d.wt. (S3) to 40.96±5.76 µg/g.d.wt. (S1). This suggests that zinc plays an important physiological role, particularly in the liver and gills, where it may be involved in enzyme function and metabolic regulation (Table 2).

Iron concentrations in *Labeo calbasu* on summer season

Iron is an essential nutrient for various biological processes, including oxygen transport and cellular respiration. During both years of the study, iron levels were highest in the liver and gills, with notable variations across stations. In the first year, iron concentrations in the gills ranged from 120.54±9.18 µg/g.d.wt. at S1 to 230.35±19.12 µg/g.d.wt. at S3, with the highest concentration recorded at S3. Similarly, the liver exhibited significant iron accumulation, with concentrations ranging from 125.21±11.61 µg/g.d.wt. at S1 to 140.95±7.86 µg/g.d.wt. at S2. Muscle and brain tissues had lower iron levels, ranging from 95.44±5.99 µg/g.d.wt. at S2 to 120.49±9.65 µg/g.d.wt. at S3 in muscle, and from 12.41±4.11 µg/g.d.wt. at S3 to 16.84±3.58 µg/g.d.wt. at S2 in the brain (Table 1).

In the year of 2024, the highest iron concentrations were again found in the liver, with the highest recorded value of 250.25±22.61 µg/g.d.wt. at S1. The gills also contained significant levels of iron, ranging from 200.63±17.61 µg/g.d.wt. (S3) to 230.93±12.77 µg/g.d.wt. (S4). Muscle and brain levels were comparatively lower, with muscle concentrations ranging from 95.64±15.21 µg/g.d.wt. (S3) to 115.42±9.13 µg/g.d.wt. (S4), and brain concentrations ranging from 13.47±1.54 µg/g.d.wt. (S1) to 15.24±1.26 µg/g.d.wt. (S3). The liver and gills appear to be key organs for iron storage and regulation (Table 2).

Manganese concentrations in *Labeo calbasu* on summer season

Manganese is another essential trace element that plays a critical role in various metabolic processes, including the metabolism of carbohydrates, lipids, and proteins. Manganese concentrations were relatively consistent across the organs of Labeo calbasu, with some fluctuations between sampling stations. In the during year 2023, manganese concentrations in the gills ranged from 6.59±1.05 µg/g.d.wt. at S2 to 7.89±1.89 µg/g.d.wt. at S4. The liver showed higher levels, with concentrations ranging from 19.13±2.21 µg/g.d.wt. at S4 to 22.13±4.01 µg/g.d.wt. at S2. Muscle and brain concentrations were relatively lower, with muscle levels ranging from 3.32±0.72 µg/g.d.wt. at S4 to 4.40±0.99 µg/g.d.wt. at S2, and brain concentrations ranging from 2.87±0.33 µg/g.d.wt. at S4 to 3.72±0.74 µg/g.d.wt. at S2 (Table 1). These results suggest that manganese is preferentially stored in the liver, potentially due to its involvement in detoxification and metabolic processes.

In the year 2024, manganese concentrations were highest in the liver at station S2, with values of 16.55±3.04 µg/g.d.wt. Other organs showed relatively lower manganese concentrations, with gills ranging from 5.63±1.52 µg/g.d.wt. at station S2 to 6.86±1.56 µg/g.d.wt. at station S1. Muscle and brain tissues exhibited lower manganese levels, ranging from 3.16±0.89 µg/g.d.wt. (S1) to 3.26±0.56 µg/g.d.wt. (S2) in muscle and from 2.56±0.09 µg/g.d.wt. (S2) to 3.63±0.07 µg/g.d.wt. (S4) in brain (Table 1). These results suggest that manganese is more evenly distributed across different organs compared to other metals, which may reflect its broader role in cellular functions.

Table 1: Concentration of metals (µg/g.d.wt.) in selected organs of fish *Labeo calbasu* sampled from four sampling stations of Kollidam River, Thanjavur during Summer season 2023.

Period of the year 2023 in Summer season								
Species	**Stations**	**Organ**	**Chromium**	**Lead**	**Cupper**	**Zinc**	**Iron**	**Manganese**
Labeo calbasu	S1	Gill	0.59±0.06	1.0±0.005	14.0±1.26	90.64±9.83	230.35±19.12	7.26±1.09
		Liver	0.35±0.04	3.92±0.35	18.5±4.05	170.47±6.21	125.21±11.61	20.88±3.55
		Muscle	0.05±0.002	0.34±0.02	6.15±2.03	80.78±8.05	120.54±9.18	4.06±0.98
		Brain	0.06±0.009	0.73±0.02	4.26±1.07	35.32±7.07	12.87±3.21	3.44±0.65
	S2	Gill	0.50±0.007	0.88±0.01	9.37±3.09	65.81±5.24	200.21±21.56	6.59±1.05
		Liver	0.32±0.05	4.12±0.78	17.45±4.01	180.71±16.26	140.95±7.86	22.13±4.01
		Muscle	0.06±0.001	0.18±0.01	5.22±1.25	68.31±9.95	95.44±5.99	4.40±0.99
		Brain	0.06±0.006	0.55±0.03	3.21±0.98	28.14±7.35	16.84±3.58	3.72±0.74
	S3	Gill	0.57±0.03	1.05±0.23	14.05±3.11	90.85±10.14	230.24±21.61	7.26±0.82
		Liver	0.40±0.07	3.94±0.91	18.56±4.05	170.74±13.75	125.37±9.14	20.81±3.51
		Muscle	0.04±0.006	0.38±0.08	6.17±1.20	80.96±7.19	120.49±9.65	4.80±0.48
		Brain	0.05±0.009	0.72±0.02	4.25±0.81	35.74±6.39	12.41±4.11	3.34±0.83
	S4	Gill	0.63±0.01	0.95±0.04	10.24±3.04	75.14±5.93	180.91±11.73	7.89±1.89
		Liver	0.38±0.03	3.54±0.28	15.86±3.24	190.96±19.63	135.17±8.62	19.13±2.21
		Muscle	0.07±0.005	0.25±0.01	4.87±0.86	70.37±8.75	110.61±10.82	3.32±0.72
		Brain	0.05±0.001	0.68±0.07	3.45±0.92	38.75±3.11	15.93±4.21	2.87±0.33

Values expected in Mean±SD of three replicates

Table 2: Concentration of metals (µg/g.d.wt.) in selected organs of fish *Labeo calbasu* sampled from four sampling stations of Kollidam River, Thanjavur during Summer season 2024

Period of the year 2024 in Summer season								
Species	**Stations**	**Organ**	**Chromium**	**Lead**	**Cupper**	**Zinc**	**Iron**	**Manganese**
Labeo calbasu	S1	Gill	0.47±0.06	0.85±0.01	6.76±0.08	68.25±3.56	250.25±22.61	6.86±1.56
		Liver	0.36±0.03	4.12±0.05	12.7±0.01	160.62±14.66	125.14±.16.12	16.55±3.04

		Muscle	0.05±0.005	0.24±0.01	4.05±0.03	60.77±4.15	105.66±18.16	3.16±0.89
		Brain	0.05±0.006	0.56±0.01	2.24±0.16	40.96±5.76	13.47±1.54	3.08±0.92
	S2	Gill	0.52±0.01	0.77±0.01	6.56±1.52	65.74±6.86	18.14±2.76	5.63±1.52
		Liver	0.33±0.007	3.44±0.93	14.24±3.96	190.12±15.62	120.57±21.16	13.64±4.21
		Muscle	0.04±0.006	0.25±0.01	4.24±1.51	72.74±8.46	110.95±19.03	3.26±0.56
		Brain	0.06±0.008	0.62±0.01	3.02±0.07	38.96±3.56	12.14±1.32	2.56±0.09
	S3	Gill	0.60±0.09	0.68±0.01	7.26±0.05	60.96±4.78	200.63±17.61	6.44±0.97
		Liver	0.46±0.06	5.26±0.09	16.46±0.9	180.74±11.56	130.66±21.16	14.49±1.66
		Muscle	0.03±0.002	0.18±0.01	3.85±0.73	65.16±8.75	95.64±15.21	3.08±0.16
		Brain	0.05±0.007	0.55±0.01	2.67±0.26	28.74±6.03	15.24±1.26	2.91±0.42
	S4	Gill	0.53±0.09	0.74±0.01	7.75±1.62	72.14±5.86	230.93±12.77	6.23±0.76
		Liver	0.38±0.003	4.57±0.51	15.67±1.84	170.91±3.46	120.84±15.26	14.84±2.16
		Muscle	0.06±0.001	0.31±0.01	5.01±1.05	75.73±2.01	115.42±9.13	3.25±0.06
		Brain	0.05±0.003	0.65±0.01	2.94±0.01	33.28±4.55	14.81±2.94	3.63±0.07

Values expected in Mean±SD of three replicates

Discussion

To mitigate the ecological impacts of heavy metal pollution in the Kollidam River, it is recommended that regulatory authorities implement more stringent controls on industrial and agricultural discharges, particularly in the upstream areas where contamination levels are highest. Additionally, efforts to restore riparian vegetation and improve sediment management could further reduce metal accumulation in sediments and prevent the re-suspension of contaminants during high-flow events. Long-term monitoring programs should continue to track the trends in metal concentrations, ensuring that any improvements in water quality are maintained and that emerging sources of contamination are addressed promptly.

The accumulation of heavy metals in aquatic organisms is a critical environmental concern, as these metals can bioaccumulate in tissues, leading to toxic effects not only on the organisms but also on higher trophic levels, including humans. This study investigates the seasonal variations in the concentrations of six heavy metals Cr, Pb, Cu, Zn, Fe and Mn in the tissues of freshwater fish *Labeo calbasu*, during the year (2023-2024). The study provides insight into the trends of metal accumulation across summer season and compares the metal concentrations across both species and years, shedding light on the possible environmental and ecological implications.

The metal concentrations in the tissues of both fish species were significantly influenced by the season, with the highest concentrations observed during the summer months (Chainy *et al.,* 2016) [7]. In this study seasonal variations were observed in all tissue types, including the gills, liver, muscle and brain of both *Labeo calbasu.*

During the summer season of both years (2023-2024), the metal concentrations in the fish tissues were the highest. This is a commonly observed pattern in aquatic organisms, as elevated temperatures and reduced water levels in many water bodies can increase the bioavailability and concentration of metals (Kahlon *et al*., 2018) [15]. High summer temperatures often accelerate chemical reactions, causing an increase in the solubility of metal ions, which may be taken up more readily by organisms (Soomro *et al.*, 2023) [25]. Additionally, the reduced flow of water and low dilution capacity in summer could contribute to the increased concentration of metals in the aquatic environment (Barletta *et al*., 2019) [5].

The metal concentrations in the summer season of 2023 were notably higher compared to the same period in 2024, suggesting a possible year-to-year variation influenced by factors such as industrial discharge, anthropogenic activities and climatic conditions. While both years showed high metal accumulation in the fish tissues, the 2023 period had substantially higher concentrations of metals, particularly in the gills, liver, and muscles. This might be attributed to higher pollution levels or more intense industrial discharge in that year, contributing to a more significant input of metals into the aquatic environment. Similar results were reported by Arumugam *et al*., 2024 [3].

The elevated levels of metals such as Cr, Pb, Cu, Zn, Fe, and Mn in fish tissues during summer indicate a possible ecological risk, as these metals can cause physiological disruptions, such as oxidative stress, impaired osmoregulation, and damage to cellular structures (Kovacik *et al.,* 2019) [16]. The liver and gills are particularly vulnerable to heavy metal accumulation due to their roles in detoxification and respiration, respectively (Kwong, 2024) [18]. The higher accumulation of metals in these tissues might be indicative of bioaccumulation, a process where metals gradually accumulate in an organism over time, potentially leading to toxicological effects (Stankovic *et al.*, 2014) [26].

Conclusion

In conclusion, this Environmental pollution has become a global problem and heavy metals are considered as one of the most contaminants due to their bioaccumulation nature. When the concentration of heavy metals is higher than the threshold limit, they can be toxic. The results of the present study underscore the urgent need for sustainable environmental management practices to address heavy metal pollution in aquatic ecosystems. Regular monitoring of metal levels, stricter enforcement of pollution control regulations, and public awareness campaigns are imperative to protect aquatic life and ensure food safety. Future research should focus on the long-term ecological and health effects of metal bioaccumulation and explore innovative remediation technologies to mitigate contamination. This research contributes to a deeper understanding of freshwater pollution dynamics and the critical role of bioindicators like *Labeo calbasu* in monitoring aquatic ecosystem health.

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References

1. Aborisade AB, Adegbola PI, Adetutu A. Review on Heavy Metals in Freshwater Fish: Source, Distribution Pattern, Accumulation Levels and Human Health Risk Assessment in Major Rivers in Nigeria. Asian Journal of Research in Biosciences,2024:6(1):49-70.
2. APHA. Standard methods for examination of water and wastewater. American Public Health Association. Washington DC, 1989.
3. Arumugam S, Sakthivadivel S, Ibrahim SSM, Murugan P, Ramaiah S, Ramaiah M, Chinnathambi A, Alharbi SA. Evaluation of the toxic metals, proximate composition and length–weight relationships of selected fish species from the Gadananathi River, Southern Tamil Nadu. Environmental Monitoring and Assessment,2024:196(5):1-13.
4. Bagheri S, Gholamhosseini A, Hoseinifar SH, Banaee M. Investigation of the effects of heavy metals (*copper*, *cobalt*, *manganese*, *selenium*, and *zinc*) on fish immune systems: an overview. Annals of Animal Science,2024.
5. Barletta M, Lima AR, Costa MF. Distribution, sources and consequences of nutrients, persistent organic pollutants, metals and microplastics in South American estuaries. Science of the Total Environment,2019:651:1199-1218.
6. Canli M, Atli G. The relationships between heavy metal (*Cd*, *Cr*, *Cu*, *Fe*, *Pb*, *Zn*) levels and the size of six Mediterranean fish species. *Environmental Pollution,2*003:121:129–136.
7. Chainy GBN, Paital B, Dandapat J. An overview of seasonal changes in oxidative stress and antioxidant defence parameters in some invertebrate and vertebrate species. *Scientifica,2*016:2016(1):6126570.
8. Chezhian N, Kabilan T, Kumar TS, Senthamilselvan D. Impact of Chemical Factory Effluent on the Structural Changes in Gills of Estuariane Fish, *Mugil cephalus*. World Applied Sciences Journal,2010:9:922-927.
9. Dural M, Göksu MZL, Özak AA. Investigation of heavy metal levels in economically important fish species captured from the Tuzla lagoon. *Food Chemistry,2*007:102(1):415-421. doi:10.1016/j.foodchem.2006.03.001.
10. Dybem B. Field sampling and preparation subsamples of aquatic organisms for analysis metals and organochlorides. FAO Fisheries Technical Paper,1983:212:1-13.
11. Egbeja TL, Onoja AO, Kadiri JU, Samson MO. Assessment of heavy metals of dried *Clarias gariepinus* and *Oreochromis niloticus* purchased from Anyigba major market, Kogi state, Nigeria. International Journal of Fisheries and Aquatic Studies,2019:7(5):14-18.
12. Ezekiel B, Annune PA, Solomon SG. Concentrations of heavy metals in selected fish species from Dadin Kowa Dam, Gombe state, Nigeria. International Journal of Fisheries and Aquatic Studies,2019:7(3):279-284.
13. Farsani NM, Haghparast JR, Naserabad SS, Moghadas F, Bagheri T, Gerami H. Seasonal heavy metals monitoring of water, sediment and common carp (*Cyprinus carpio*) in Aras Dam Lake of Iran. International Journal of Aquatic Biology,2019:7(3):123-131.
14. Hamada NH, Ali RA, El-Tabakh MA, Bream AS. Environmental monitoring: Tobara fish as bioindicators of heavy metal pollution in a coastal ecosystem. *Regional Studies in Marine Science,2*024:69:103335.
15. Kahlon SK, Sharma G, Julka JM, Kumar A, Sharma S, Stadler FJ. Impact of heavy metals and nanoparticles on aquatic biota. Environmental Chemistry Letters,2018:16:919-946.
16. Kovacik A, Tvrda E, Miskeje M, Arvay J, Tomka M, Zbynovska K, *et al*. Trace metals in the freshwater fish *Cyprinus carpio*: effect to serum biochemistry and oxidative status markers. *Biological Trace Element Research,2*019:188:494-507.
17. Kumar A, Kumar V. Heavy metal pollution load in the sediment of the River Mahananda within Katihar District, Bihar, India. International Journal of Basic and Applied Research,2018:8(11):515-532. www.pragatipublication.com.
18. Kwong RW. Trace metals in the teleost fish gill: biological roles, uptake regulation, and detoxification mechanisms. Journal of Comparative Physiology B, 2024, 1-15.
19. Ladipo MK, Ajibola OV, Oniye SJ. Spatiotemporal assessment of metal concentration in fish and periwinkles in selected locations of Lagos Lagoon, Nigeria. Journal of Environmental Chemistry and Ecotoxicology,2012:4:161-169.
20. Maurya PK, Malik DS, Yadav KK, Kumar A, Kumar S, Kumar H. Bioaccumulation and potential sources of heavy metal contamination in fish species in River Ganga basin: possible human risks evaluation. Toxicology Reports,2019:6:472-481.
21. Ocheing EZ, Lalah JO, Wandiga SO. Water quality and trace metal distribution in a Pristine Lake in the Lake Basin in Kenya. Bulletin of Environmental Contamination and Toxicology,2008:80:362-368.
22. Ray S, Vashishth R. From Water to Plate: Reviewing the Bioaccumulation of Heavy Metals in Fish and Unraveling Human Health Risks in the Food Chain. Emerging Contaminants,*2*024: p100358.
23. Saidon NB, Szabó R, Budai P, Lehel J. Trophic transfer and biomagnification potential of environmental contaminants (*heavy metals*) in aquatic ecosystems. Environmental Pollution,2024:340:122815.
24. Singh G, Sharma S. Heavy metal contamination in fish: sources, mechanisms and consequences. *Aquatic Sciences,2*024:86(4):1-21.
25. Soomro SEH, Shi X, Guo J, Ke S, Hu C, Asad M, Jalbani S, Zwain HM, Khan P, Boota MW. Are global influences of cascade dams affecting river water temperature and fish ecology? *Applied Water Science,2*023:13(4):106.
26. Stankovic S, Kalaba P, Stankovic AR. Biota as toxic metal indicators. Environmental Chemistry Letters,2014:12:63-84.
27. Storelli MM, Barone G, Storelli A, Marcotrigiano GO. Trace metals in tissues of mugilids (*Mugil auratus*, *Mugil capito*, *Mugil labrosus*) from the Mediterranean Sea. Bulletin of Environmental Contamination and Toxicology,2006:77:43-50.
28. Terra BF, Araujo FG, Caiza CF, Lopes RT, Teixeira TP. Heavy metals in tissues of three fish species from different trophic levels in a tropical Brazilian River. Water, Air and Soil Pollution,2008:187:275-284.
29. Topping G. Heavy metals in fish from Scottish waters. *Aquaculture,1*973:1:373-377.

30. Xu J, Chen Y, Zheng L, Liu B, Liu J, Wang X. Assessment of Heavy Metal Pollution in the Sediment of the Main Tributaries of Dongting Lake, China. Water,*2*018:1(1060):1-16. doi: 10.3390/w10081060.
31. Yilmaz F, Ozdemir N, Demirak A. Tuna of heavy metal in water, sediment and fish (*O. niloticus* and *C. Anguillaris*), in Rosetta branch of the River Nile, Egypt. African Journal of Biotechnology,2007:11(17):14204-14216. doi: 10.5897/AJB11.3745.