JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

BIOACCUMULATION OF HEAVY METALS IN COMMERCIALLY IMPORTANT FRESHWATER AND MARINE FISHES FROM NAGAPATTINAM, INDIA

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Abstract

The present research study was designed to assess the concentrations of the heavy metals (Cd, Cu, Fe, Pb and Zn) in different tissues of six commercially important freshwater and marine fish species were caught in Nagapattinam region using inductively coupled plasma-mass spectrometry (ICP-OES). Various organs (liver, eye, kidney gill, gut, gonad, skin, and muscle) of six fish species, i.e., *Channa straiata (CS), Labeo rohita (LR), Mugil cephalus (MC), Oreochromis mossambicus (OM), Pangasius hypophthalmus (PH) and Rastreliger kanagurta,(RK)* from Nagapattinam were analyzed. Moreover, high concentration of heavy metals, especially Zn and Pb was noticed in the liver, kidney and gill tissues of the fishes which are higher than the WHO standards. Among the studied fishes, *CS* and *PH* showed higher levels of bioaccumulation in terms of toxic metals. The highest metal concentration was reported in the carnivore fishes as compared with the planktivore and omnivore.

Keywords:*Heavy metals, Bioaccumulation, Fish, Seafood, Food safety and Pollution.*

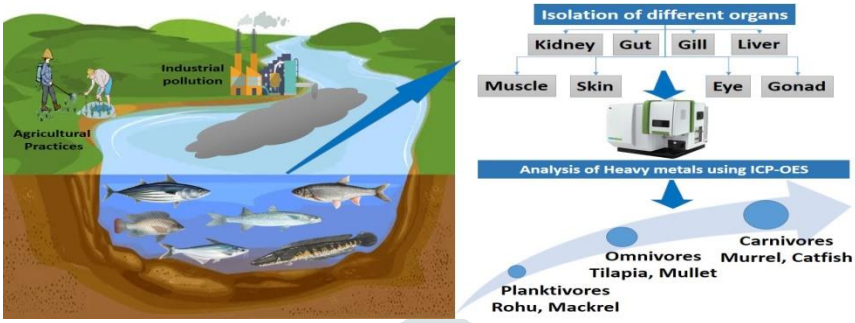
Introduction

Heavy metals are defined as “metallic elements that have an atomic mass greater than 20 and a density greater than 5 g/cm3” (Paschoalini and Bazzoli, 2021). The entry of metals into aquatic environments can occur naturally through atmospheric deposition and geological weathering, however, the discharge of industrial, rural, or urban effluents without proper treatment, are the main sources of metals in water bodies (Paschoalini and Bazzoli, 2021). The steady increase in toxic heavy metal concentration in the seawater raises significant concern about the ecological hazard to its habitat, and health risk to the dependent population (Kumar et al., 2020). Assessment of heavy metal contamination in the seawater is one of the vital steps toward ensuring seawater quality to perpetuate the wellbeing of marine habitats and sustenance of marine resources and to minimize the possible health risk to humans (Kumar et al., 2020).

During the past few decades, the natural aquatic systems are extensively contaminated with heavy metals released due to anthropogenic activities (Mohan et al., 2012). The objective of present study was to investigate

the presence of Cd, Cu, Fe, Pb and Zn in different organs, viz., liver, kidney, gills, gut, gonad, eye, skin and muscle of fishes namely, Channa straiata (CS), *Labeo rohita (LR), Mugil cephalus (MC), Oreochromis mossambicus (OM), Pangasius hypophthalmus (PH)* and *Rastreliger kanagurta,(RK)* residing at different trophic levels. Therefore, the outcome of our findings can be used for formulating management strategies for assessment of the risks posed by the fishes of that region to consumers.

Graphical Abstract



Materials and Methods

Three composite samples from the three locations within each station (creek) were analyzed. Fish species, namely Channa straiata (CS), *Labeo rohita (LR), Mugil cephalus (MC), Oreochromis mossambicus (OM), Pangasius hypophthalmus (PH)* were collected from each of the creeks with the help of local fshers at the same time. Five individuals per species were purchased from the local fishermen of the respective stations, and kept under iced condition and immediately transferred to the laboratory for further analysis. Length and weight were measured to the nearest 0.1 cm and 0.01 g using digital Vernier caliper and electronic weighing balance, respectively.

All laboratory ware were soaked in 2M HNO_3 for 48 h, and rinsed several times with double-distilled water and deionized water before use. Organs such as eye, gill, gut, gonad, liver, skin, and muscle were separated and digested in Teflon containers using a microwave digester (Ethosplus High Performance Microwave lab station, Milestone, USA). Tissues were homogenized and 3.0 g of wet tissues were weighed into 100 ml Teflon vials and digested overnight with 7 ml of pure nitric acid (AR grade, specific gravity: 1.38, Merck, India) and 3.0 ml of hydrogen peroxide. It was then cooled until the temperature reached below 90 °C. The digested sample was transferred into separate polypropylene centrifuge tubes and the volume was made up to 25 ml by using MilliQ water. Inductively Coupled Plasma Optical Emission Spectrophotometer (ICP-OES, Optima 5300 DV, Perkin Elmer, Inc., USA) was used to determine the concentration of heavy metals. Metal concentrations are expressed as milligrams per kilogram dw (dry weight).

Statistical analysis

The results obtained from this study were analyzed using One way analysis of variance (ANOVA) Duncan multiple range test (DMRT) to identify the significant difference ($P<0.05$) in metal concentrations between the sampling locations using SPSS Version 22.0. The results of heavy metal concentrations were represented as means ± standard deviation. Data obtained from the experimental results were subjected to Correlation coefficient (r) to study the significant relationship between the different heavy metal concentrations observed in fish tissues. Results of Pearson correlation analysis were showed in Table 3.

Results and Discussion

The present work shows that heavy metal concentration is alarmingly high in fish tissue samples. And the principal cause of high metal concentration in the Cauvery water is due to anthropogenic sources (domestic, agricultural, and industrial effluents). In LR, the accumulation of zinc (65.65 ± 15.28) was more in gills, lead (16.12 ± 5.35), iron (31.66 ± 2.85) and copper (8.87 ± 0.82) was more in the liver, and cadmium was highest in

the eye (1.18 ± 0.23). The concentration of zinc was more in the gills (65.65 ± 15.28) followed by the gonad (59.02 ± 9.63), and eyes (45.05 ± 6.35). Lead accumulated more in the liver (16.12 ± 5.35), followed by the kidney (15.33 ± 5.95) and gills (13.44 ± 4.70). Iron accumulation was high in the liver (31.66 ± 2.85), followed by the gill (18.27 ± 2.79), and eye (14.93 ± 1.85). Copper accumulation was high in the liver (8.87 ± 0.82), followed by the kidney (6.12 ± 0.25), and muscle (1.96 ± 0.21). Highest level of cadmium was found in kidney (2.00 ± 0.18), followed by eye (1.18 ± 0.23) and liver (1.00 ± 0.20) (Table 1). In RK, the accumulation of zinc (41.99 ± 5.21) was more in the kidney (41.99 ± 5.21), copper (25.15 ± 2.11), Iron (193.45 ± 11.05) and lead (52.91 ± 9.41) was highest in the liver and concentration of cadmium was more in the eye (3.67 ± 0.41).

In PH, the accumulation of zinc (193.99 ± 21.40) was more in the liver, lead was highest in the eye (35.92 ± 7.64), the concentration of iron was more in the kidney (204.27 ± 13.37), copper was more in kidney (80.40 ± 5.76) and highest concentration of cadmium was present in liver (4.20 ± 0.40). In CS, the accumulation of Iron (52.22 ± 8.51), lead (22.71 ± 8.84), zinc (215.80 ± 36.20) and cadmium (14.70 ± 0.57) was more in the liver, whereas concentration of copper was more in the kidney (14.70 ± 0.57).

In OM, the accumulation of zinc (123.55 ± 15.47) was more in the eye, lead (10.45 ± 2.02), and cadmium (6.52 ± 1.75) was highest in the liver, the concentration of iron (196.61 ± 6.51) and copper (6.29 ± 1.33) was more in the gill. In MC, the accumulation of zinc (275.42 ± 9.45) was more in the kidney, lead (14.41 ± 2.22) was more in eye, iron (55.92 ± 6.67) was more in gill, copper (37.63 ± 7.93) was more in gill and and cadmium (9.39 ± 0.83) was highest in the gonad. A comparison of the heavy metal concentrations in the organisms indicated that the sum of heavy metals in different species followed the order: CS > PH > OM> MC > RK > LR.

In our study, six different fish species commonly available in Nagapattinam region, have been selected as representative species and analyzed for heavy metals. As fishes basically planktivores, omnivores and carnivores in nature and they present on the top of the food chain, they are considered one of the most common bioindicators for pollutants (Idriss and Ahmad, 2015; Authman et al., 2015).

Over time, the bioaccumulation of metals in organisms is closely related to the process of biomagnification of those elements in the food web, i.e., the higher the organism's trophic level, the greater the exposure to metals (Paschoalini and Bazzoli, 2021). In general, these pollutants tend to accumulate in metabolically active tissues such as the liver, spleen, gills, and kidneys and can affect enzymatic and metabolic activity, leading to biochemical and morphological disorders in the body. The accumulation of metals in fish can vary according to the degree of exposure, i.e. the concentration of pollutants, the duration of exposure, and water parameters, such as pH, hardness, organic matter, temperature, and salinity. In addition, the levels of metals can also vary according to the biological characteristics of the fish, i.e. age, length, weight, feeding habits, habitat, and metabolic status (Ali and Khan, 2018; Paschoalini and Bazzoli, 2021).

Among the three sites studied, the XX is the most contaminated, indicating the influence of upstream anthropogenic sources. Metal content in fish samples reveal that major accumulation has taken place in gills, liver and kidney. High concentrations of Cu, and observed in *C. straiata and P.hypothalammus* suggest risk for human consumption. Pb, Cr and Zn level in most of the fish samples exceeded the FAO/WHO food standards.

CRediT authorship contribution statement

Shanmugam Sudarshan: Conceptualization, Methodology, Formal analysis, Writing - original draft. **Vetri Vijayarahavan**: Writing - review & editing, Formal analysis, Software. **Venkatesan Alamelu**: Resources, Writing - review & editing. **Natarajan Krishnaveni:** Methodology, Resources, Writing - review & editing. **Andiappan Muthiah:** Methodology, Resources, Writing - review & editing. **Subbaiyah Balasundari** - Conceptualization, Methodology, Resources, Writing - original draft, Writing - review & editing.

Acknowledgments

We acknowledge the Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Nagapattinam for the continuous support during the research work.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table 1. Morphometric characteristics, feeding habits and fishery importance of selected fish species.

	OM	MAC	LR	CS	MC	PH
Feeding habit	Omnivorous	Omnivorous	Planktivorous	Carnivorous	Detritus feeder	Carnivorous
Fishery importance	Commercial	Commercial	Commercial	Commercial	Commercial	Commercial
Total length (cm)	17.28 ± 2.98	22.27 ± 1.72	34.23 ± 1.78	17.95 ± 2.70	14.97 ± 0.50	16.53 ± 1.88
Fork length (cm)	17.28 ± 2.98	19.87 ± 1.39	28.83 ± 1.97	17.95 ± 2.70	14.20 ± 0.56	14.00 ± 1.76
Standard length (cm)	13.90 ± 2.39	18.53 ± 1.16	25.10 ± 1.04	14.43 ± 2.35	12.23 ± 0.45	13.27 ± 1.68
Breadth (cm)	5.60 ± 0.85	6.30 ± 0.44	7.87 ± 0.32	3.95 ± 1.00	3.20 ± 0.26	3.80 ± 1.06
Weight (g)	104.90 ± 53.43	157.10 ± 5.99	345.90 ± 16.11	68.73 ± 40.62	36.23 ± 3.07	55.77 ± 34.15
Caudal length (cm)	3.08 ± 0.17	4.77 ± 0.15	5.73 ± 0.38	3.00 ± 0.62	3.00 ± 0.20	3.20 ± 0.26
Caudal width (cm)	3.80 ± 0.81	7.23 ± 0.12	6.77 ± 0.32	2.95 ± 0.86	3.20 ± 0.36	3.40 ± 0.78
Head (cm)	4.73 ± 1.14	5.87 ± 0.15	6.73 ± 0.38	4.90 ± 0.86	2.93 ± 0.25	3.60 ± 0.46
Dorsal fin (cm)	8.38 ± 0.92	3.90 ± 0.10	7.70 ± 0.44	8.45 ± 1.40	2.13 ± 0.15	2.67 ± 1.04
Pectoral fin (cm)	5.10 ± 1.37	2.93 ± 0.06	5.20 ± 0.20	2.63 ± 0.62	2.03 ± 0.15	2.43 ± 0.51
Pelvic fin (cm)	4.05 ± 0.66	2.43 ± 0.12	4.80 ± 0.26	1.88 ± 0.46	1.83 ± 0.25	1.63 ± 0.25
Anal fin (cm)	3.40 ± 0.39	2.30 ± 0.10	5.13 ± 0.21	6.25 ± 1.09	1.73 ± 0.15	2.23 ± 0.40
Eye diameter (cm)	1.05 ± 0.24	1.37± 0.06	1.43 ± 0.12	0.63 ± 0.05	0.47 ± 0.06	0.50 ± 0.10

Table 2. Concentration of heavy metals in various tissue systems of six selected fish species.

		Heavy Metal content Mean ± standard deviation (µg/g, dry weight)					
	Organ	*Labeo rohita (LR)*	*Rastreliger kanagurta (RK)*	*Mugil cephalus (MC)*	*Oreochromis mossambicus (OM)*	*Channa straiata (CS)*	*Pangasius hypophthalmus (PH)*
Cd	Liver	1.00 ± 0.20	2.87 ± 0.59	5.79 ± 1.43	6.52 ± 1.75	14.70 ± 0.57	4.20 ± 0.40
	Kidney	2.00 ± 0.18	2.50 ± 0.66	3.05 ± 0.88	5.44 ± 0.76	10.50 ± 0.56	1.82 ± 0.56
	Gill	0.72 ± 0.54	0.93 ± 0.13	0.09 ± 0.13	0.07 ± 0.09	11.99 ± 0.32	4.13 ± 1.19
	Gonad	0.14 ± 0.13	1.09 ± 0.06	9.39 ± 0.83	4.63 ± 1.12	3.55 ± 0.78	1.78 ± 0.21
	Gut	0.24 ± 0.04	0.89 ± 0.13	8.39 ± 3.07	0.91 ± 0.18	0.11 ± 0.01	1.05 ± 0.29
	Muscle	0.54 ± 0.14	1.61 ± 0.22	0.07 ± 0.09	1.62 ± 0.56	0.14 ± 0.01	0.61 ± 0.53
	Skin	0.25 ± 0.28	2.27 ± 0.19	0.79 ± 0.32	1.72 ± 0.25	1.17 ± 0.05	0.21 ± 0.18
	Eye	1.18 ± 0.23	3.67 ± 0.41	2.59 ± 4.21	1.05 ± 0.34	4.37 ± 0.07	0.80 ± 0.23
Cu	Liver	8.87 ± 0.82	25.15 ± 2.11	12.35 ±4.45	4.20 ± 0.45	15.49 ± 1.03	16.26 ± 4.16
	Kidney	6.12 ± 0.25	11.55 ± 1.82	13.84 ± 2.32	4.79 ± 1.80	49.02 ± 9.91	80.40 ± 5.76
	Gill	1.79 ± 0.16	7.39 ± 1.37	37.63 ± 7.93	6.29 ± 1.33	7.15 ± 2.47	79.16 ± 9.46
	Gonad	0.03 ± 0.04	1.21 ± 0.33	2.13 ± 0.16	1.04 ± 0.28	3.36 ± 0.08	16.26 ± 4.80
	Gut	0.76 ± 0.18	2.09 ± 0.05	3.89 ± 0.30	0.06 ± 0.08	0.03 ± 0.04	2.03 ± 0.31
	Muscle	1.96 ± 0.21	1.75 ± 0.18	17.27 ± 2.42	1.65 ± 0.52	4.17 ± 0.18	10.58 ± 3.20
	Skin	1.14 ± 0.10	3.51 ± 0.21	13.43 ± 3.15	1.50 ± 0.68	3.19 ± 0.12	1.01 ± 0.28
	Eye	1.04 ± 0.24	2.64 ± 0.45	21.89 ± 9.72	0.26 ± 0.06	4.02 ± 0.30	1.87 ± 0.16
Fe	Liver	31.66 ± 2.85	193.45 ± 11.05	26.27 ± 7.17	121.95 ± 13.87	52.22 ± 8.51	105.59 ± 10.14
	Kidney	11.24 ± 1.44	162.79 ± 28.76	48.57 ± 4.20	88.78 ± 4.50	41.59 ± 14.69	204.27 ± 13.37
	Gill	18.27 ± 2.79	99.17 ± 3.01	55.92 ± 6.67	196.61 ± 6.51	31.73 ± 5.84	88.31 ± 5.40
	Gon	6.34 ± 0.66	13.82 ± 2.06	54.75 ±	8.07 ± 7.43	13.33 ± 1.60	30.57 ± 6.14

Table 3. Correlation between heavy metal contents in tissues of studied fishes from Nagapattinam, India

Labeo rohita (LR)

	Cd	Cd	Cd	Cd	Cd
Cd	1.0000	0.6402	0.2943	0.6105	-0.3567
Cu	0.6402	1.0000	0.7246	0.6374	-0.3711
Fe	0.2943	0.7246	1.0000	0.4940	0.1242
Pb	0.6105	0.6374	0.4940	1.0000	-0.0627
Zn	-0.3567	-0.3711	0.1242	-0.0627	1.0000

Rastrelliger kanagurta (RK)

	Cd	Cd	Cd	Cd	Cd
Cd	1.0000	0.3820	0.2607	0.4572	0.3792
Cu	0.3820	1.0000	0.8618	0.8828	0.3123
Fe	0.2607	0.8618	1.0000	0.9249	0.6354
Pb	0.4572	0.8828	0.9249	1.0000	0.6295
Zn	0.3792	0.3123	0.6354	0.6295	1.0000

Mugil cephalus (MC)

	Cd	Cd	Cd	Cd	Cd
Cd	1.0000	0.6638	-0.0729	0.6341	-0.0743
Cu	0.6638	1.0000	0.0419	0.4133	-0.0409
Fe	-0.0729	0.0419	1.0000	0.5435	0.3208
Pb	0.6341	0.4133	0.5435	1.0000	0.2318
Zn	-0.0743	-0.0409	0.3208	0.2318	1.0000

Oreochromis mosambicus (OM)

	Cd	Cd	Cd	Cd	Cd
			-		
Cd	1.0000	0.2552	0.0503	0.4201	0.2522
Cu	0.2552	1.0000	0.8156	0.2934	0.1803
Fe	-0.0503	0.8156	1.0000	0.4325	0.0848
Pb	0.4201	0.2934	0.4325	1.0000	0.7264
Zn	0.2522	0.1803	0.0848	0.7264	1.0000

Pangasius hypothalamus (PH)

	Cd	Cd	Cd	Cd	Cd
Cd	1.0000	0.5529	0.4455	-0.1306	0.8737
Cu	0.5529	1.0000	0.7546	-0.5545	0.5365
Fe	0.4455	0.7546	1.0000	-0.0737	0.7191
Pb	-0.1306	-0.5545	-0.0737	1.0000	0.0429
Zn	0.8737	0.5365	0.7191	0.0429	1.0000

Channa straiata (CS)

	Cd	Cu	Fe	Pb	Zn
Cd	1.0000	0.5529	0.9532	0.7365	0.9076
Cu	0.5529	1.0000	0.6750	0.6555	0.4697
Fe	0.9532	0.6750	1.0000	0.7513	0.9214
Pb	0.7365	0.6555	0.7513	1.0000	0.8327
Zn	0.9076	0.4697	0.9214	0.8327	1.0000

Table 4. Evaluation of toxic metals (µg/g) concentration in different tissues of *Labeo rohita* in earlier studies.

	Eye	Gill	Gut	Gonad	Liver	Skin	Muscle	Kidney
Cd	-	0.96 ± 0.08	-	BDL	0.31± 0.02	-	1.27±0.12	-
Cu	-	0.27 ±0.12	1.72 ±1.05	0.46± 0.07	60.46 ± 1.34	0.76 ±0.32	0.02 ± 0.02	-
Fe	18.08± 1.92	21.87 ±5.37	19.94 ± 4.13	12.90 ± 0.99	87.92 ± 10.0	9.03 ± 3.67	6.64 ± 1.43	-
Zn	81.28 ± 8.6	83.7± 9.41	71.12 ± 4.84	98.66 ±0.02	26.26 ± 2.83	16.96 ±2.22	9.86 ±1.31	-

Table 5. Evaluation of toxic metals (µg/g) concentration in different tissues of *Pangasius hypophthalmus* in earlier studies

	Eye	Gill	Gut	Gonad	Liver	Skin	Muscle	Kidney
Cu	-	0.22 ±0.08	0.55 ± 0.15	-	12.66 ±0.61	0.10 ±0.10	-	-
Fe	15.95 ±7.77	30.26 ± 30.26	58.29 ± 4.74	28.27 ±15.68	142.46 ±10.97	51.96 ±2.82	13.48 ±0.74	-
Zn	54.83 ±34.48	21.68 ± 3.56	21.9 ± 6.69	7.1 ±2.92	43.16 ±6.28	24.05 ±0.65	3.66 ±0.93	-

Table 6. Maximum permissible limits of heavy metals in fish (µg/g)

Sl. No	Cd	Cu	Fe	Pb	Zn
1.	0.5	30	100	0.5	40

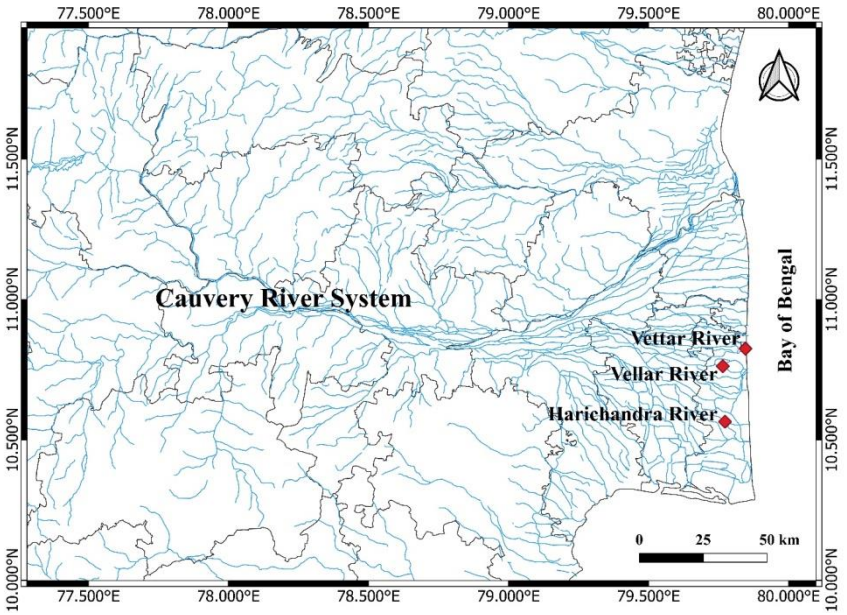

Fig. 1. Sampling sites chosen for this study along the Cauvery river delta region.