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TRACE METALS ACCUMULATION IN TWO BRACKISH WATER FISHES *ETROPLUS SURATENSIS* AND *ARIUS ARIUS* WITH REGARD TO THEIR FEEDING HABITS IN A NATURAL ECOSYSTEM

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ABSTRACT

Trace metal concentrations (Fe, Ni, Zn, Cu, Pb, Cd and Cr) in the flesh, gill and livers of the two edible fishes, *Etroplus suratensis* and *Arius arius* collected from the Cochin backwaters were estimated. Metal accumulation in tissues of the two species is found to be varied with respect to their feeding habits. Irrespective of the species, metal accumulation was higher in the liver than gill or flesh. This may be primarily attributed to differences in the physiological role of each organ in fish to metal metabolism. Regardless of species and tissues, metal concentrations showed a maximum value for Fe and a minimum value for Cd.

Keywords: Trace metal, bioaccumulation, *Etroplus suratensis, Arius arius,* Cochin backwaters

INTRODUCTION

Marine pollution by trace metals in aquatic ecosystems have emerged as one of the most serious environmental issues of global concern because of its toxicity, persistence, cumulative effect and risk for humans **[1, 2]**. Anthropogenic activities on land release an increasing amount of trace metals in the environment, especially in aquatic ecosystems **[3]**. Chronic exposure to trace metals in the aquatic environment is a real threat to living organisms **[4]**. The main sources of trace metals in the aquatic ecosystems are industrial effluents, domestic sewage and agricultural run-off. The effluents discharged into the aquatic environment from industries without any treatment is a major source of water enriched with trace metals. The input of metals to the aquatic environment as a result of anthropogenic activities is difficult to measure separately due to very large natural inputs. The organisms that inhabit in an aquatic environment are considered as useful bioindicators to measure the presence of toxic trace metals **[5]**. The feeding behaviour of an animal often performs as an essential feature for governing the bioaccumulation of metals because one of the possible pathways for biomagnification is through the food that ingested from its surroundings **[6]**. Fishes are one of the most widely distributed organisms in the aquatic environment. They are being susceptible to metal contamination and hence metal concentrations in fish may reflect the extent of the biological effect of metal pollution in water **[7]**. Fishes are near the last loop of the aquatic feeding chain and are the very important food source for humans and are considered as bioindicators in the estuarine ecosystem for the estimation of trace metal pollution **[8]**.

As fishes are relatively long-lived and mobile, they occupy the same habitats in the same ecosystem with different feeding behaviours, providing the potential to study the influence of environmental and biological factors on the bioaccumulation of pollutants. Two species of fishes, *Etroplus suratensis* and *Arius arius* were selected for study because of their abundance, common distribution and market value. *E. suratensis* is locally called “Karimeen” which is designated state fish by the Government of Kerala in 2010. It is belonging to the order perciformes and family cichlidae. The fish is benthopelagic in natural habitat and omnivorous which mainly feeds on plants/ detritus, zooplankton, nekton, zoobenthos, finfish, bony fish, insects, other annelids, gastropods, algae etc. *A. arius* is locally known as “Koori”, belonging to the order Siluroformes and family Ariidae. The fish is demersal, amphidromous and carnivorous that feeds on benthic, hunting macrofauna, mainly animals, zoobenthos, benthos, invertebrates, etc. The aim of this study is to find the bioaccumulation of trace metals (Fe, Ni, Zn, Cu, Pb, Cd and Cr) in the flesh, gill and liver of two brackish water fishes (*Etroplus suratensis* and *Arius arius*) occupying different feeding habits in the same natural ecosystem.

MATERIALS AND METHODS

Study area

The Cochin backwaters form a complex network of shallow brackish water bodies ~

256 km^2. This water body was reported to be heavily polluted by metal waste discharges through industrial, agricultural and municipal sources **[3, 9, 10, 11, 12]**. Cochin backwaters receive domestic sewage and urban wastes, organic fertilizers and residues from agricultural lands, chemical wastes from fertilizer plants, effluents from other small industries, boatyards, dockyards, oil, paints, metal and paint scrapings from shipyard and port **[3]**. A large quantity of effluents come from the industries viz., Fertilizers and Chemicals Travancore Ltd (FACT), Hindustan Insecticides, Indian Rare Earths, Travancore Cochin Chemicals (TCC) Cochin Refineries Ltd, Zinc Alumina ore smelting (Hindustan Zinc and Aluminium Company) etc. **[13]**. Based on the special geographic features, anthropogenic activities and the inflow of pollutants from the different sources, five stations were selected between Cochin bar mouth and Thanneermukkom bund for the present study **(Figure 1)**.

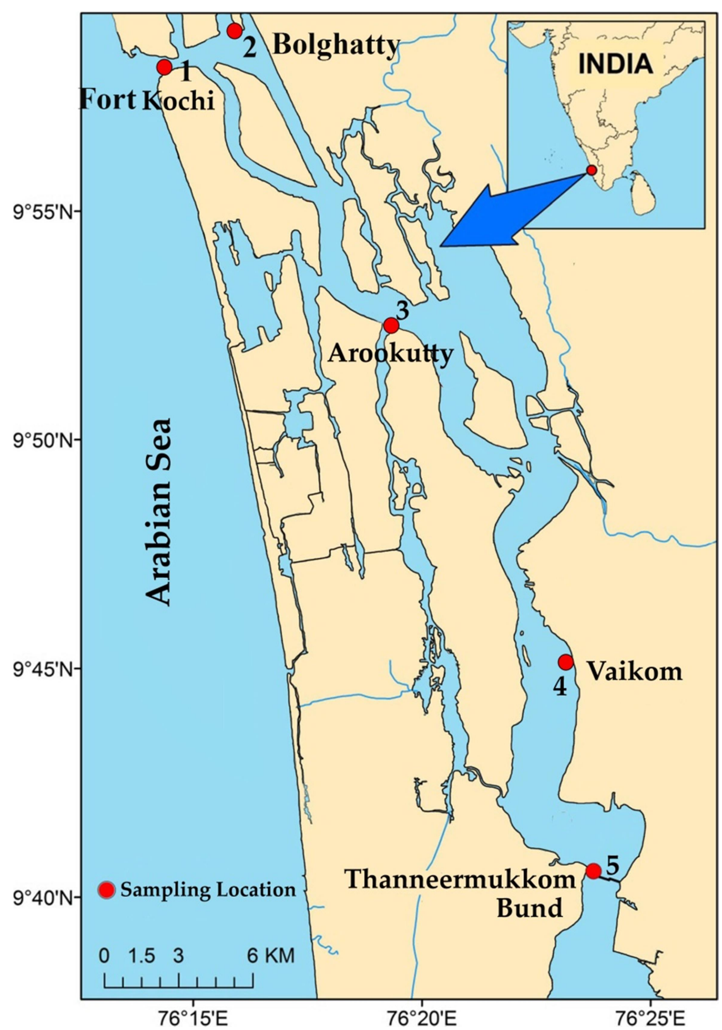

Figure 1: Sampling locations

Sample collection

The fishes were collected bimonthly during February 2017 to January 2018 from the five sites of Cochin backwaters. The fishes were collected with the help of local fisherman. Collected fishes were preserved in icebox packed with ice in order to maintain the freshness and later transported to the laboratory.

Analysis of fish samples

In the laboratory, fish samples were identified, weighed and the total length was recorded. *E. suratensis* (no. 77, length- 17.47 ± 2.11 and weight- 143.77 ± 52.45) and *A. arius* (no. 65, length- 23.02 ± 2.48 and weight 112.28 ± 34.87) were used for the present study. The flesh, liver and gills of the fish samples were dissected and washed thoroughly with distilled water. Then the sample organs were dried in an oven at 65 °C. The dried samples were powdered using mortar and pestle and stored in a vacuum desiccator. The aliquots of about 300 mg were digested for 3h at 80 °C with 3 ml HNO_3 (65% Merck, Suprapure) in Teflon beakers. Additional nitric acid was added if the samples were charred and 1ml $HClO_4$ (Merck Suprapure) was added to make the solution clear and evaporated to near dryness. Thick white fumes were evolved at the endpoint. The digests were cooled and diluted to 25 ml with double deionised water and kept in plastic vials. Atomic Absorption Spectrophotometer (AAS) Perkin Elmer India Pvt. Ltd. (Model: Pinaacle 900H) was used for the determination of trace metal concentration (Fe, Ni, Zn, Cu, Pb, Cd and Cr) in the flesh, liver and the gills. All the metal concentrations in the tissues are reported in ppm dry weight.

RESULTS AND DISCUSSION

Trace metals in different tissues of *E. suratensis* and *A. arius* (ppm dry weight) from the Cochin backwaters are given in the **Table 1**. The omnivore species, *E. suratensis* showed a comparatively higher level metal accumulation than the carnivore species, *A. arius*. The average trace metal concentration of Fe, Ni, Zn, Cu, Pb, Cd and Cr (ppm dry weight) in *E. suratensis* flesh was 290.39 ± 103.57, 23.52 ± 9.15, 84.85 ± 43.97, 11.24 ± 7.25, 8.33 ± 5.00, 4.00 ± 1.61 and 34.76 ± 20.08 respectively; in liver 820.89 ± 345.66, 40.67 ± 16.95, 252.94 ± 106.62, 51.17 ± 25.53, 28.29 ± 24.28, 7.33 ± 4.34 and 50.50 ± 20.84 respectively and in gills 712.45 ± 249.58, 45.75 ± 14.12, 210.05± 91.85, 24.50 ± 15.31, 17.04 ± 13.13, 7.86 ± 4.69 and 46.10 ± 22.33 respectively. The order of metal accumulation in *E. suratensis* flesh, liver and gills were Fe>Zn>Cr>Ni>Cu>Pb>Cd, Fe>Zn>Cu>Cr>Ni>Pb>Cd and Fe>Zn>Cr> Ni>Cu>Pb>Cd respectively.

Table 1: Average concentrations of trace metals in different tissues of *E. suratensis* and *A. arius* (ppm dry weight) from the Cochin backwaters

Fishes	Trace metals	Flesh	Liver	Gills
E. suratensis	Fe	290.39 ± 103.57	820.89 ± 345.66	712.45 ± 249.58
	Ni	23.52 ± 9.15	40.67 ± 16.95	45.75 ± 14.12
	Zn	84.85 ± 43.97	252.94 ± 106.62	210.05 ± 91.85
	Cu	11.24 ± 7.25	51.17 ± 25.53	24.50 ± 15.31
	Pb	8.33 ± 5.00	28.29 ± 24.28	17.04 ±13.13
	Cd	4.00 ± 1.61	7.33 ± 4.34	7.86 ± 4.69
	Cr	34.76 ± 20.08	50.50 ± 20.84	46.10 ± 22.33
A. arius	Fe	266.01 ±118.97	719.95 ± 188.80	610.06 ± 200.06
	Ni	21.20 ± 7.60	31.00 ± 11.25	29.76 ± 8.45
	Zn	62.98 ± 23.22	196.89± 68.42	166.03 ± 51.62
	Cu	9.37 ± 5.87	45.24 ± 21.20	17.86 ± 9.84
	Pb	9.67 ± 4.35	15.69 ± 8.18	19.30 ± 9.44
	Cd	3.51 ± 1.52	6.69 ± 3.83	6.86 ± 3.64
	Cr	19.02 ± 9.32	47.45 ± 18.55	40.18 ± 20.81

In carnivorus *A. arius,* the average trace metal concentration of Fe, Ni, Zn, Cu, Pb, Cd and Cr in flesh was 266.01 ± 118.97, 21.20 ± 7.60, 62.98 ± 23.22, 9.37 ± 5.87, 9.67 ± 4.35, 3.51 ± 1.52 and 19.02 ± 9.32 respectively, in liver 719.95 ± 188.80, 31.00 ± 11.25, 196.89 ± 68.42, 45.24 ± 21.20, 15.69 ± 8.18, 6.76 ± 3.83 and 47.45 ± 18.55 respectively and in gills 610.06 ± 200.94, 29.76 ± 8.45, 166.03 ± 51.62, 17.86 ± 9.84, 19.30 ± 9.44, 6.86 ± 3.64 and 40.18 ± 20.81 respectively. The metal accumulation in flesh, liver and gills of *A. arius* were in the order of Fe>Zn>Ni>Cr>Cu>Pb>Cd, Fe>Zn>Cr>Cu> Ni>Pb>Cd and Fe>Zn>Cr>Ni>Cu>Pb>Cd respectively.

Several fish species that living in the same habitat may exhibit different intra- and inter-specific body concentrations of trace metals **[14]**. The excessive uptake of essential and non-essential metals causes an accumulation in the body organs of fishes to higher concentrations with changes in physiological and biological activities **[8, 15, 16]**. The trace metal accumulation in the three organs of *E. suratensis* was in the order of liver> gills> flesh in Fe, Zn, Cu, and Cd but in the case of Ni, Pb and Cr it was in the order of gills> liver> flesh. In *A. arius* the trace metal accumulation of Fe, Zn, Cu, Pb, Cd and Cr in the three organs were in the order of liver> gills> flesh but in Ni the accumulation showed as gills> liver> flesh. Depending on the structure and function of tissues, the degree of accumulation of trace metals in various tissues of fish is generally different. Generally, metabolically active tissues such as gills, liver and kidneys have a higher accumulation of trace metals than the other tissues like muscles and skin **[17]**.

The possible ways of trace metal entry into the fish body are skin, gills and through oral route **[18]**. Metals are taken up by fish from food and water, distributed throughout the fish body by blood and eventually accumulated in the target organs **[19]**. Some tissues such as the liver are considered as target organs for the accumulation of metals **[20]**. It is observed that there is a trend in the accumulation of different metals in various organs at different concentrations which may be primarily attributed to the difference in physiological role of each organ and regulatory activity. The accumulation of metals in flesh, liver and gills showed a considerable degree of variation in the concentration of trace metals. In the study, the concentration of trace metals was reported to be maximum in the liver and gills rather than flesh in both of the fishes.

Among all the seven trace metals, Fe exhibits the highest concentration in all the tissues analysed for both fishes. This may be due to the formation of the hydrated ionic conditions and may form a variety of complexes with inorganic and organic ligands **[21]**. Fe usually enters from the dumped wastes into the aquatic ecosystem **[22]**. Contamination due to the organic and inorganic solid wastes and industrial effluents that discharged into the aquatic ecosystem also results in a rise of Fe concentrations in the backwaters. Followed by Fe, Zn is the element that showed the highest concentration in all the tissues, especially in the liver and gills. This is also reported by **[23]** in *Clarisa gariepinus* and **[24]** in four different species of fishes. Then Cr, Ni and Cu whereas Pb and Cd showed the lowest concentration. The trace metal toxicity in both of the fishes was in the order Fe>Zn>Cr>Ni>Cu>Pb>Cd.

The flesh is a major tissue of interest under the routine monitoring of metal contamination as it is the chief edible part of the fish. In the flesh tissue comparatively low level of metal accumulation was observed **[25]**. The flesh does not make direct contact with the metals as it is covered externally by skin which acts as a barrier for the penetration of trace metals and it is not an active site for detoxification and therefore the transport of trace metals to muscle does not seem to arise **[26]**. In flesh tissue, the order of bioaccumulation in the flesh of *E. suratensis* was Fe>Zn>Ni>Cr>Cu>Pb>Cd and in *A. arius* was Fe>Zn>Ni>Cr>Cu>Pb>Cd. In both the fishes, the flesh has the highest concentration of Fe followed by Zn. **[24]** also reported the same pattern of trace metal accumulation in the flesh of various species from the coastal waters off Kochi. Many researchers also reported that fish muscle generally showed the lowest amounts of trace metals **[27, 28, 29]**. The liver is designated as the chief target organ for the accumulation of trace metals. This may be due to the role of metals in the physiological activities of organs and Fe, Zn, Cu, Pb and Cr showed maximum accumulation in the liver. **[21]** reported the accumulation of Fe, Zn and Cu were maximum in the liver. The order of bioaccumulation in the liver of *E. suratensis* was Fe>Zn>Cu>Cr>Ni>Pb>Cd and in *A. arius* Fe>Zn>Cr>Cu>Ni>Pb>Cd. Considering the detoxifying function of the liver, it tends to accumulate metals that bind those elements to polypeptides called metallothionein **[30]**. For this reason, this organ has been identified as the best environmental indicator of water pollution and chronic exposure to trace metals **[31]**. In fishes, gills are one of the most important organs that serve as the functions of gas exchange, ion transport, excretion of ammonia and urea **[32]** and have direct interaction with water and pollutants. The adsorption of metals onto the gill surface as the first target for pollutants in water could also be a significant influence on the total metal levels of the gills. In the present study the accumulation of trace metals in *E. suratensis* and *A. arius* follows the same order: Fe>Zn>Cr> Ni>Cu>Pb>Cd.

In the present study, the highest accumulation of all the trace metals; Fe, Ni, Zn, Cu, Pb, Cd and Cr was recorded in *E. suratensis.* This may be due to the benthopelagic nature of *E. suratensis* so that it could get the feeding availability from both benthic and pelagic zones of the backwaters. The fish is omnivorous predominantly feeds on filamentous algae, detritus and other items such as aquatic plants, diatoms, molluscan shells etc **[33]**. While carnivorous *A. arius* feeds on prawns, crabs, small fishes, molluscs, semi-digested matters, mud, etc. **[34]**. **[26]** reported that the major sources of metals in the fish species are food and feeding habits the concentrations of trace metals detected in the organs of two fishes indicate different bioaccumulation potentials. Compared with the muscles, the liver, and gills act as the main organs for metabolism and respiration. Metal levels in the liver rapidly increase during exposure and remain high for a long time of depuration **[19]**. Of the two species, *E. suratensis* is truly benthopelagic in habit providing an increased pathway for the uptake of contaminants through the gills from sediment and water and also it is an omnivore. *A. arius* is a carnivore and demersal fish that mainly feeds in invertebrates and small fishes **[34]**. Earlier studies elsewhere also noted omnivorous fishes had higher levels of trace metals than carnivorous or planktivorous fishes **[25]**. Thus, the results reflecting differences in diet may result the variation of trace element accumulation patterns between the various fish species from the Cochin backwaters.

CONCLUSION

Metal accumulation of two fishes, *E. suratensis* and *A. arius* were found to be varied with respect to their feeding habits. The present data reflecting differences in diet may result the variation of trace element accumulation patterns between fish species from the same habitats. The degree of accumulation of trace metals in various tissues of fish is generally different due to difference in structure and function of tissues. Gills, liver and kidneys of fishes have a higher accumulation of trace metals than the other tissues.

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