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COMPARATIVE STUDY OF HEAVY METALS IN THE MUSCLE OF TWO EDIBLE FINFISH SPECIES IN AND AROUND INDIAN SUNDARBANS

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Abstract

We analyzed the concentrations of zinc, copper, and lead in the muscle of two commercially important finfish species namely, Pampus argenteus and Scatophagus argus in and around the World Heritage site of Indian Sundarbans from 8th to 15th July 2021 using an Atomic Absorption Spectrophotometer. The sequence of bioaccumulation of the selected metals is as per the order Zn > Cu > Pb irrespective of the species. The degree of metal accumulation showed variation between the species with the highest value in Scatophagus argus followed by Pampus argenteus, which may be related to the difference in their food habit or degree of exposure to ambient media contaminated with heavy metals.

Keywords: *Heavy metals, Pampus argenteus, and Scatophagus argus, bioaccumulation*

I. Introduction

The sea and more particularly the aquatic system (*e.g.*, estuaries) are mostly treated as the ultimate repository of human wastes. Wastes generated from industrial and domestic activities have high concentrations of heavy metals, which has the considerable possibility to pose a negative impact on the marine and estuarine biotic communities. There is no amplification to state at this point that very little progress has been achieved in the field of heavy metal control in the aquatic ecosystems, and this situation arises from the rising trends of individuals for a higher standard of living [XXIX].

There are a large number of rivers in the eastern, western, and southern parts of India, which mostly meet the sea and form estuaries at the zone of intersection between the rivers and sea that are noted for their rich productivity. The southern part of the maritime state of India has many rivers that ultimately flow to the Bay of Bengal and form productive estuaries on the way as seen in the case of Sundarbans, where tides act as important determining factors [XIII]. Along with unique planktonic and nektonic forms, a luxuriant benthic fauna is also displayed in the intertidal zone of the estuaries. But, coated with the beautiful covering of the diversity of life, a tragic chapter also lies within. This chapter has opened to meet the rising demand of the people in the sectors of industrial and urban development. In addition to the megacity of Kolkata, wastes are also contributed from the city of Howrah and the upcoming Haldia industrial belt adjacent to Indian Sundarbans [XXVI]. A large number of industrial units are located in the lower stretch of the Hooghly estuary preferably in the western bank that releases wastes mostly without treatment or partial treatment. The lower part of the estuary is the hotspot of several industries such as paper, textiles, chemicals, pharmaceuticals, plastic, shellac, food, leather, jute, tires, and cycle rims [XXVI]. These factories and industries release effluents in the adjacent estuarine systems that are not treated before their discharge. The concentrations of heavy metals present in these effluents result in bioaccumulation within the resident organisms that may have a far-reaching adverse impact on human health. The proliferation of a large number of tourism units is also another important cause of the deterioration of water bodies, which has a direct impact on human health [XVI]. The pollution of the estuarine environment by trace metals is a serious issue [XIX], as trace metals constitute some of the most hazardous substances that have the potential for bioaccumulation [XXV]. The phenomenon of bioaccumulation and subsequent biomagnifications through aquatic trophic levels causes a significant adverse impact on human beings in terms of their health security [XIV]. Indeed, many scientists will be familiar with the Minamata Bay disaster in Japan where Hg contamination and subsequently assimilation of Hg by aquatic organisms resulted in Hg poisoning including the death of many local people mainly fisherfolk. This example represents an extreme case of assimilation of toxic trace metals; however other very serious incidents of Hg assimilation have been reported in the Gulf of St. Lawrence, Canada [X], and Cr and Cd poisoning have been documented in Japan. Arsenic poisoning facilitated by the combustion of arsenic-rich coal has been recorded from Czechoslovakia. In contrast to the relatively recent recognition of the consequences of Hg and Cd assimilation, health disorder in humans including brain damage and mental deficiency, promoted by the direct bioaccumulation of Pb have been recognized for millennia [IX].

The complete eradication of trace metal pollution cannot be a realistic approach as they form an integral part of the planet earth. The rocks, sand, and soil are composed of trace metals of various types. Their presence in fossil fuels causes recycles them to the planet earth after the process of burning the fossil fuels to derive energy. However, five major sources of heavy metals have been identified as (i) erosion of geological sources, (ii) industrial processing of ores and metals, (iii) the use of metals and metal compounds in industry, (iv) the burning of fossil fuels, and (v) leaching from refuse dumps. Heavy metals are classed as conservative pollutants in that they are not degraded by microbial action and remain available to flora and fauna, sometimes with adverse effects.

The contamination of natural systems by toxic metals is a global environmental concern particularly in the present century [XI]. Rapid urbanization and industrialization near the estuaries and coastal zones often result in the discharge of domestic and industrial wastes in these eco-sensitive zones. The nature of trace metals often exhibits changes depending on the physicochemical variables of the aquatic ecosystem that influence the process of compartmentation and speciation of the trace metals. The major impact of trace metals on the biotic community is mostly governed by the type of species of trace metals present in the aquatic ecosystem [XXII]. The heavy metals in the estuarine system deposit on the sediment bed or remain in a dissolved state in the water column, depending on the nature of chemical species which are strongly governed by physico-chemical factors like aquatic salinity, pH, etc. In this context, the findings of a major research activity along the South African coast can be consulted [IV]. The composition of minerals present in the rocks, soil, and sand along with the industrial activities in the region determine the nature of conservation of biodiversity in context to trace metal pollution [XII]. Anthropogenic activities are mainly responsible for the accumulation of toxic metals in the aquatic sediments [VII]. Heavy metals are not degraded by microbial actions and hence are conservative in nature. They persist in the environment in different forms and their presence and cycling in the mangrove ecosystem is a matter of great concern [XVII].

Most littoral marine pollution studies have been performed on subtidal near-shore environments [XXIII]. Fewer studies have examined the heavy metal pollutants in tidal flats or tidal marshes [XV], [XXVII].

Heavy metals entering the aquatic and sedimentary environments can do so in a variety of chemical forms [V]. Suspended matter tends to preferentially adsorb heavy metals in water and to provide the main mode of heavy metal emplacement in estuarine settings. The heavy metals that are present in other chemical forms will be distributed between the organic matter and hydrous manganese and iron oxides [VI].

In this pilot-scale research, we have monitored the finfish tissue (of *Pampus argenteus* and *Scatophagus argus*) in connection to bioaccumulation of heavy metals (Zn, Cu, and Pb) collected from Nayachar Island, Sagar Island region, Gosaba, and Satjelia Island in and around the Indian Sundarbans stretch during 8^{th} – 15^{th} July 2021.

II. Materials and Methods

Selection of the sampling stations

Two sampling sites were identified each in the western and central sectors of the lower Gangetic delta at the apex of the Bay of Bengal. The western sector of the deltaic lobe is hyposaline compared to the central sector. The presence of industries in the western sector of the lower Gangetic delta is another line of demarcation in context to anthropogenic activities as there is no industrial setup in the central sector. On this background, four sampling stations (two each in western and central sectors) were selected (Table 1) to analyze the concentrations of heavy metals in the muscles of common edible fishes collected during 8^{th} – 15^{th} July 2021.

Table -1 Sampling stations with coordinates and salient features

Station	Coordinates	Salient Features
Nayachar Island (Stn. 1)	88°15′24"E 21°45′24"N	It is located in the Hooghly estuary, adjacent to western Indian Sundarbans, and receives the exposure of industrial discharge of the Haldia port-cum-industrial complex.
Sagar Island South (Stn. 2)	88°01′47"E 21°39′04"N	The station is situated at the confluence of the River Hooghly and the Bay of Bengal on the western sector of Indian Sundarbans and is noted for Kapil Muni Ashram, where 15 -20 lakhs devotees gather every year to take the holy bath during Makar Sankranti in the mid-January.
Gosaba (Stn. 3)	88°39′46"E 22°15′45"N	The station is situated along the Matla estuarine stretch in the central sector of Indian Sundarbans
Satjelia Island (Stn. 4)	88°50′43"E 22°11′52"N	The station has rich mangrove diversity with minimum anthropogenic activities and is situated in the central part of Indian Sundarbans.

Sampling of Specimen

Two species of finfish, namely *Pampus argenteus and Scatophagus argus* were collected during high tide conditions from the selected stations during 8^{th} – 15^{th} July 2021. The collected fish samples (mostly of the same size to avoid the error caused by size difference) were stored in ice and transferred to the Kolkata laboratory for analysis of heavy metals through AAS.

Analysis of Physico-chemical Variables of Water

- ✓ **Temperature:** Measured by direct dipping a 0^0-100^0C mercury thermometer during the high tide period, preferably around 12:00 noon.

- ✓ **Salinity:** The surface water salinity from the respective sampling stations was assessed in the field using a refractometer, and re-checked in the laboratory by employing Mohr- Kundson method [XXIV].
- ✓ **pH:** *In situ* measurement was conducted through a portable pH meter (sensitivity = ± 0.02).
- ✓ **Dissolved oxygen (D.O):** The DO meter was used in the field to measure the dissolved oxygen level in high tide conditions and subsequently re-checked in the laboratory by standard method [XXVIII].

Heavy metal analysis in finfish tissue

1 gm of oven-dried tissue of finfish sample (separately for each species) was digested with nitric acid and blank was prepared without the sample (fish specimen). The digested samples along with the blank were aspirated in Atomic Absorption Spectrophotometer (AAS) [*Model Perkin Elmer Type 2380*] and concentrations of the selected metals (Zn, Cu, and Pb) were expressed in ppm (µg/gm dry wt. basis) after the blank correction.

III. Results and Discussions

Metals find their way in the water bodies of different categories through geological processes like erosion, landslides, etc., and also through anthropogenic activities [XX]. Estuaries act as the conveyor belt of transferring pollutants from the land to the sea and are the zone of intersection between saline and freshwater [III]. Anthropogenic factors playing in coastal zone causes deterioration of water quality, along with algal bloom and low oxygen level [II]. The release of wastes saturated with heavy metals results in the bioaccumulation in the body of estuarine resident organisms, which includes seaweeds, halophytes, fishes, etc. [VIII]. In countries like India, the demand for protein is accelerating at a rapid rate due to population explosion at an uncontrolled rate. However, the annual per capita fish consumption in India is only 4 kg, which is substantially low against the recommended figure of 31 kg as stated by the Nutritional Advisory Committee on human nutrition [XXI]. Aquaculture has become a protein bank in the present millennium, which involves culturing of aquatic organisms obeying scientific guidelines [XVIII]. Hence, proper quality control through estimation of heavy metal levels is of utmost importance in this domain.

Irrespective of species the pattern of concentration of different metals exhibits a uniform sequence with the highest concentration of Zn followed by Cu and Pb (Tables 2a, 2b, and 2c). The range of Zn varied from 25.92 ppm (in *Pampus argenteus* at Stn. 4) to 87.50 ppm (in *Scatophagus argus* at Stn. 1) while that of Cu and Pb were from 16.93 ppm (in *Pampus argenteus* at Stn. 4) to 71.14 ppm (in *Scatophagus argus* at Stn. 1) and 6.02 ppm (in *Pampus argenteus* at Stn. 4) to 13.02 ppm (in *Scatophagus argus* at Stn. 1) respectively. The pattern of concentration was in the order of Zn > Cu> Pb. The species-wise variation was uniform for all the metals. Zn, Cu, and Pb accumulated as per the order *Scatophagus argus* > *Pampus argenteus*, which may be due to different food habits or periods of exposure.

All the heavy metals are not toxic, *e.g.*, Zn and Cu are needed to boost up growth and metabolic activities, but the toxic impact of Pb is considerable on the organism. Zn originates and mixes with the estuarine water of the study area from galvanizing units, pharmaceutical units and battery manufacturing units, antifouling paints for repairing trawlers and boats, etc. Hence highest concentrations of Zn were documented in the fish muscles around station 1, which faces towards the Haldia port and industrial complex.

Cu originates from aquaculture farms, where it is used as an algaecide and also from antifouling paints. This is the reason why Cu was detected in the fish samples of stations 3 and 4, where there is no existence of industries. The complete siltation of the Bidyadhari River also does not permit the industrial effluents released in the Hooghly estuary to mix with the estuaries in the central sector of the deltaic complex.

Pb is highly toxic that enters the aquatic ecosystem from atmospheric fallout, paint manufacturing factories, battery manufacturing units, antifouling paints, etc. Among all the stations selected in the present study, station 1 is most vulnerable to Pb pollution as the industrial effluents directly reach the area from Haldia industrial belt. The presence of station 2 along the Hooghly estuarine stretch and more preferably within the navigational route has made it vulnerable to Pb pollution. Also, in this station large number of trawlers and fishing boats operate that are frequently coated with paints to avoid the settlement of biofuels on the outer surface. These paints are the major sources of Pb contamination in the area. Stations 3 and 4 are relatively less polluted due to their locations adjacent to the reserve forest area of Indian Sundarbans. In these stations, occasional tourism during the postmonsoon season is observed and practically no factories and industries are present in and around these two stations. The minimum footprints of anthropogenic disturbances are the major factors of relatively less pollution in these stations due to which the fishes sampled from these stations contain less concentration of heavy metals in their body tissues. Our core findings point towards the vulnerability of stations 1 and 2 in context to heavy metal levels in the muscles of the edible fishes, and hence demands regular monitoring.

The metal levels in biological samples depend on the ambient environmental variables. Therefore the common hydrological parameters were also analyzed (Table 3) during high tide conditions. However such one-time analysis cannot predict the inter-relationship between tissue metal and hydrological parameters. A more detailed and long-term analysis may generate sound scientific findings.

The present investigation has been carried out during the lockdown phase of COVID -19 in the state of West Bengal when the industrial activities and subsequent release of effluents in the estuarine system were less compared to the normal scenario. It is expected that these values will hike manifold when the situation in the country will be restored after the pandemic phase is over.

Table- 2a Concentration of Zn (in ppm dry wt.) in finfish muscles

Species	Stn. 1	Stn. 2	Stn. 3	Stn. 4
Pampus argenteus	97.44	73.36	50.90	25.92
Scatophagus argus	103.81	81.19	57.15	35.69

Table- 2b Concentration of Cu (in ppm dry wt.) in finfish muscles

Species	Stn. 1	Stn. 2	Stn. 3	Stn. 4
Pampus argenteus	53.63	43.03	26.29	16.93
Scatophagus argus	71.14	51.02	29.49	20.53

Table- 2c Concentration of Pb (in ppm dry wt.) in finfish muscles

Species	Stn. 1	Stn. 2	Stn. 3	Stn. 4
Pampus argenteus	11.25	10.46	7.43	6.02
Scatophagus argus	13.02	11.66	9.24	8.45

Table- 3 Physico-chemical variables

	Nayachar Island (Stn. 1)	Sagar Island (Stn. 2)	Gosaba (Stn. 3)	Satjelia (Stn. 4)
Surface water temperature (^{o}C)	34.0	35.3	34.1	34.1
Surface water salinity (PSU)	2.95	11.80	12.95	12.10
Surface water pH	7.80	8.06	8.02	8.05
Dissolved oxygen (ppm)	4.94	5.99	5.17	5.06

IV. Conclusion

Coastal pollution is increasing significantly over the last few decades. The discharges of industrial wastes have resulted in high metal concentrations in the local marine environment. The present study is important not only from the human health point of view, but it also presents a comparative account of heavy metals in edible fin fishes from two different sectors of the Gangetic delta (western and Central sectors) that are physico-chemically different. The high concentrations of heavy metals in fin fishes sampled from Nayachar Island (Station 1) is a cause of concern and requires regular monitoring of water quality around the point sources of the Haldia port-cum-industrial complex mostly concentrated opposite the western bank of the Nayachar island.

Conflict of Interest:

There was no relevant conflict of interest regarding this paper.

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