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Study on Accumulation of Heavy Metal Concentrations in the Tissues of Aquatic Species from Ennore Estuary

C. Mathu Mitha[1], V. Mohan Raj*[2], R. Sangeetha[3], Susan George[4] and M. Ragumaran[5]

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ABSTRACT

Rapid industrialization along with advanced agricultural activities led to the contamination of aquatic environment with heavy metals. Heavy metals ultimately pass into human body through aquatic animals. The aim of the present study was to determine the concentrations of heavy metals such as cadmium (Cd), mercury (Hg) arsenic (As) chromium (Cr) and lead (Pb), in the tissues of fish, shrimp, crab, mussel and lobster from the Ennore estuary. The result shows that all the tested animals were highly exposed to heavy metal concentration in the Ennore estuary. Higher metal contamination in Ennore estuary is posing considerable ecological risk as per environmental quality indices, exposing to heavy metals at higher concentrations might be toxic to fish species as well as humans.

Key words: Toxicology, Concentrations, Fishes, Shrimp, Crab, Cadmium, Mercury

The increase in agricultural and industrial activities has caused an increase in contamination of water resources. Pollution of aquatic environment by heavy metals is a world-wide problem due to the persistent and continuing accumulation of metals in the environment [1]. Heavy metals are naturally found at very low concentrations in the water environment, but their concentrations have increased due to anthropogenic activities. In general, studies on heavy metals can be important in two main aspects, public health point of view and the aquatic environment view point. Heavy metals are present in the aquatic environment where it can accumulate along the food chain. Moreover, small amounts of heavy metals are either absorbed and stored in a metabolically available form for essential biochemical processes or detoxified into metabolically inert forms and retained in the body either temporarily or permanently [2-3]. Generally, the effect of heavy metals on aquatic organisms ranges from slight reduction in growth rate to death; severe imbalances in concentration can lead to death, while marginal imbalances may cause poor health and retarded growth [4].

Excessive concentration of heavy metals in the marine environment can affect marine biota and pose risk to human consumers of sea food [5]. Degree of heavy metals in seawater and their distribution play an important role in influencing the productivity of marine ecosystem [6-7]. The concentration of heavy metals in aquatic organisms is higher than that present in water due to the effect of bio-concentration and bioaccumulation and eventually threaten the health of human by sea food consumption [8]. Toxicological studies of the pollutants upon aquatic organisms are very important from the point of environmental consequences. Fishes are often forced to encounter in the highly contaminated water especially in areas where the dilution rate of waste water is low [9].

Heavy metals such as copper, iron, chromium and nickel are essential metals that play an important role in biological systems. Cadmium and Lead are non-essential metals that are toxic, even in trace amounts [10]. For the normal metabolism of the fish, the essential metals are taken up from water, food or sediment [11]. These essential metals can produce toxic effects when the metal intake is excessively elevated [12]. Bioaccumulation is the indication of bioavailability and it could be a biomarker of metal pollution. Bio-indicator organisms are able to bio-accumulate metals from contaminated ambient environments [13]. Hence, it is important to establish the levels of heavy metals in these organisms to assess whether the concentration is within the permissible level and will not pose any hazard to the consumers [14].

Fishes are generally considered to be important bio indicators of aquatic environments and are an important source of protein in human nutrition. Fish, which usually is a constituent in the last ring of the food chain, are considered to be one of the important groups for transferring metals to humans. Of late interest in the consumption of aquatic organisms, especially fish, has increased dramatically in different parts of the world due to high protein content and

* V. Mohan Raj
drvmraj@gmail.com

[1-5] P. G. and Research Department of Zoology, Sir Theagaraya College, Chennai - 21, Tamil Nadu, India

low saturated fats [15]. Fish, shrimp, crab, bivalve are used in metal accumulation tests because they are vital organisms and are usually eaten by man [16]. It is important to determine the metal levels in fish and shrimp tissues because they reflect the concentrations of metals found in water and sediments.

Estuarine and coastal areas are complex and dynamic aquatic environment. India has a long coastline of 8,129 km and of this 6,000 km is rich in estuaries, creeks, brackish water, lagoons and lakes. The southeast coast of India is an important stretch of coastline, where many major rivers drain into the Bay of Bengal and they are also richer in marine fauna and flora [17]. Estuaries, the important contributors of fisheries in India, suffer from severe loss of fish production due to increased industrialization and urbanization along the coastal zone by continuous discharge of industrial effluents [18-19]. Ennore creek was once encompassed with rich biodiversity comprising the mangroves, reptiles, turtles and rare fishes which have been totally wiped out by the deleterious impact of effluents pumped into the Ennore Creek, consequently the natural wealth is eroded to mere sewage channel and biological productivity of the coast has come down [20]. Thus, the aim of this study was to assess the more common heavy metal concentrations, cadmium (Cd), mercury (Hg) arsenic (As) chromium (Cr) and lead (Pb), in the tissues of fish, shrimp, crab, mussel and lobster from the Ennore estuary.

MATERIALS AND METHODS

Ennore creek is a backwater located in Ennore, latitude**:** 13.2146° N longitude**:** 80.3203° E of Chennai along the Coromandel Coast of the Bay of Bengal. It has been estimated that about 4, 49, 000 litres / day of industrial effluents carrying heavy metals are let out in this estuary by the industrial establishments [21]. The study area is also surrounded by three industrial belts namely the Manali, Ennore-Thiruvottriyur and Ambattur padi complexes [22].

Assorted sea food samples which include fishes, shrimps, crabs, mussels and lobsters were collected from the Ennore estuary. Later the samples were brought to the laboratory rinsed with distilled water and sealed in sterile polythene zip lock covers and were preserved at -20°C for further analysis. The samples were thawed and dissected on a clean polypropylene board to separate the muscle tissue. Four grams of sample was weighed and the tissues were diluted overnight with 7ml of pure nitric acid and 3 ml of hydrogen peroxide. Sample digestion was done using microwave digester (Ethos plus High Performance Microwave Lab station, Milestone, USA). The microwave parameters were 800 W powers for 45 min (15 min temperature increasing, 15 min temperature holding and 15 min ventilation). The digested sample was made upto 100ml with double distilled water and analyzed by using Atomic Absorption Spectrophotometer (GBC 932AA, GBC Scientific Instruments, Australia) following the AOAC method [23].

RESULTS AND DISCUSSION

Ennore estuary has been affected by coastal pollution for more than two decades and has been identified as a hotspot of metal contamination [24]. Information about heavy metal concentration in different sea food types is important with respect to both the ecosystem management and human consumption. The concentrations of different metals detected in the edible portion of muscle of fish, shrimp, crab, mussel and lobster are shown in the Table. In the present study remarkable differences of heavy metal concentrations are observed in the muscles of fish, shrimp, crab, mussel and lobster (Fig 1). The presence of heavy metal concentrations on an average was highest in prawn compared to other animals.

In all the samples cadmium content was much above the legal permissible limit of 1 mg/kg meat [25]. Among the heavy metals the cadmium content of in shrimp was the highest 12.004mg/kg and lowest in lobster 1.011mg/kg (Table 1). The threshold concentration of cadmium in fish muscles design for human consumption set by the European Commission is 0.1mg/gw.w, the guideline limit set for Cd by FAO [26] is 0.05 mg/kg for fish. In the present study the level of Cd recorded in all the five animals of study were above the permissible limit, the maximum cadmium concentration was found in the tissues of shrimp 12.004 mg/kg. Likewise, the cadmium content in edible tissues of the brown shrimp *Crangon crangon* collected from Samsun coasts in the Black Sea coast of Turkey was 0.219 ppm to 0.491 ppm [27].

Table 1 Heavy metal concentration in aquatic species mg/kg

Metals	Fish	Shrimp	Crab	Mussel	Lobster
Cd	1.541 ± 0.02	12.004 ± 0.01	1.044 ± 0.02	1.087 ± 0.02	1.011 ± 0.03
Hg	4.123 ± 0.01	3.193 ± 0.03	1.351 ± 0.01	2.040 ± 0.04	1.985 ± 0.04
As	2.013 ± 0.03	10.388 ± 0.04	2.856 ± 0.05	4.566 ± 0.02	3.221 ± 0.05
Cr	3.017 ± 0.01	9.009 ± 0.05	6.259 ± 0.05	5.325 ± 0.01	3.569 ± 0.01
Pb	1.901 ± 0.01	12.023 ± 0.02	1.160 ± 0.03	1.319 ± 0.05	1.240 ± 0.05

Values expressed are mean ± SD

The results show that all the commercial species used in this study contain detectable amounts of Hg in tissue samples, whereas the observed ranges of Hg was 1.351mg/kg in crab. Similar observation was found in the omnivorous giant crab (*S. seratta*), collected from estuarine mud-flats; mostly feeds on a variety of detritus materials settling from the water column as well as small benthic species available on the sediment surface, has an intermediate range of Hg concentration of 105 ± 3.0 µg/kg [28]. In the present study the amount of Hg 4.123mg/kg in fish tissue samples have exceeded the limits for human consumption, recommended by several international and national agencies like [29] (500 µg/kg of Hg and 300 µg/kg of MeHg), EPA (0.5 ppm or 500 µg/kg of Hg) (USEPA

1997), US Food and Drug Administration (1000 µg/kg of Hg) [30], European Commission [31] (EC, 2005). Hg accumulation in mussel was found to be 2.040 mg/kg, similar observation was made in *Pernaviridis* (Green mussel) in Karwar estuary estimated to be 34.2 µg/kg [32]. Thus, bio-accumulation of Hg may also differ depending on the availability of Hg in natural habitat.

Most arsenic in our diet is present in organic form. The present study of arsenic was in between 0.16±0.24 and 1.07±0.03 [33]. Although total arsenic levels in these species mostly exceeded 1.0 µg/g with the highest value of 3.1µg/g wet wt, they may not constitute a risk for human health since most arsenic in marine organisms is in the non-toxic organic form (70-95%) [34]. The maximum level of arsenic was recorded in tissues of shrimp 10.388mg/kg.

The permissible limits set for chromium by WHO [35] and FEPA [36] are 0.05 and 0.15 mg/kg respectively. Cr content observed in muscles of *Clarias gariepinus* exceeds this limit. The observation made in muscles of *Oreochromis mossambicus* and *Cyprinus carpio* [37-38] showed maximum concentration of Cr. Likewise in this study the maximum concentration of Cr was 9.009 mg/kg found in shrimp.

Lead is considered as a toxic metal which also implies that it has no known function in biochemical processes. Lead induces reduced cognitive development and intellectual performance in children and increased blood pressure and cardiovascular disease in adults [25]. In the present study minimum accumulation of lead was noticed in crab tissue 1.160 mg/kg whereas in the prawn it was noted as 12.023 mg/kg. Likewise, Pb content was in the range of 0.33 to 0.93 mg/kg in muscle tissues of fish in Black and Aegean seas [39]. Similarly, Dural *et al*. [40] have also reported that the Pb contents were in the range of 0.40 to 2.44 mg/kg in muscle tissues of fish of Tulza Lagoon. The aquatic organisms are sensitive to heavy metals when the concentrations of the metals reach a significant level in the water and sediment.

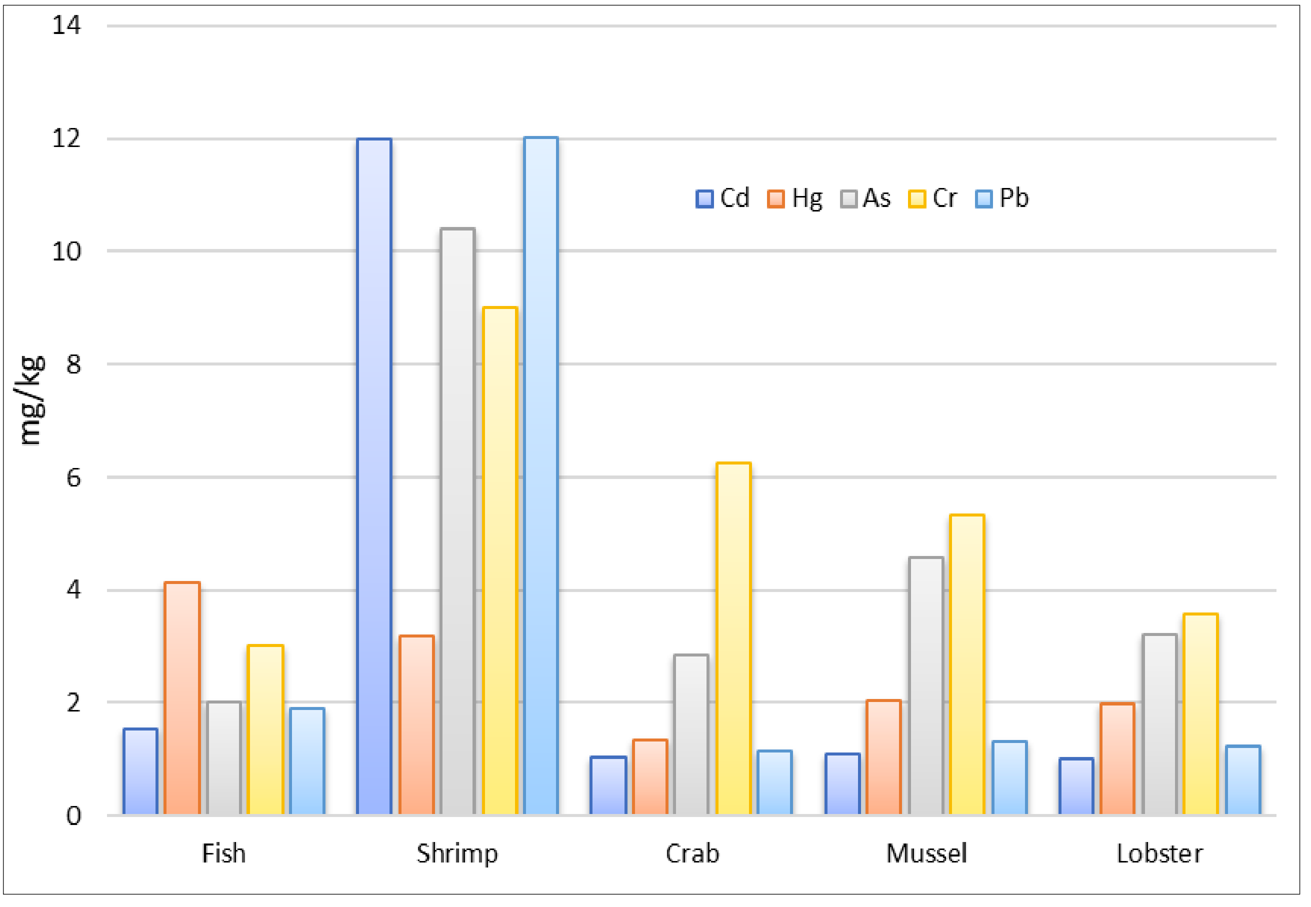

Fig 1 Heavy metal concentration in aquatic species

Accumulation of metal in different species is the function of their respective membrane permeability and enzyme system, which is highly species specific and because of this fact metals are accumulated in different orders in the animals of study (Table 1). In general, it has been reported that except shrimp the least accumulation of heavy metals was found in fish, crab, mussel and lobster tissues. Crabs and shrimps tend to accumulate more heavy metals than fish as a result of differences in the evolutionary strategies adopted by various phyla [41]. The higher concentration of metals in aquatic ecosystems affect biota by modifying the metabolic activities due to metal uptake through gills and skin, elimination through excretion, and storage as metallothioneins [42]. Higher levels of cadmium (Cd), mercury (Hg) arsenic (As) chromium (Cr) and lead (Pb) in the ambient waters can cause physiological and genetic effects to fish due to their accumulation [43]. The Shrimp, crabs and mussel were found to have higher metal content than fish which illustrates their dietary preference and exposure to contaminated sediment substratum. The seasonal variation of metal concentrations in marine organisms could result from factors such as stage in the life cycle, rate of metabolism, age, feeding habit, and ambient temperature. These factors are influenced by salinity, biogeochemical cycle and bioavailability of metals [44].

CONCLUSION

These results confirmed that Ennore estuary is under moderate to considerable ecological risk of heavy metal pollution. The higher levels of heavy metal content in the Ennore estuary are attributed to higher enrichment and contamination of non-essential heavy metals like Cd, Hg, As, Cr and Pb discharged from various sources through anthropogenic activities. The results indicate higher bio-accumulation of these non-essential metals in commercially important edible marine organisms in Ennore estuary. Higher metal contamination in Ennore estuary is posing considerable ecological risk as per environmental quality indices. The long-term monitoring of metal distribution, bioaccumulation and risk assessment may provide the information for devising pollution management strategies particularly for estuaries in the region and elsewhere in general.

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