Journal of Environmental Biology

July 2007, 28(3) 637-643 (2007)

Heavy metal accumulation in certain marine animals along the East Coast of Chennai, Tamil Nadu, India

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(Received: August 05, 2005 ; Revised received: September 11, 2005 ; Accepted: October 29, 2005)

Abstract: *Heavy metals disposed through anthropogenic activities find their way into the oceans and seas through the rivers or through direct fall out from factory effluents. These heavy metals resuspend back into the water column along with the sediments and are known to affect the marine animals. Marine animals like fish, prawn, crab and mussel were collected along the East Coast (off Pulicat lake to Chennai Harbour) to evaluate trace metal concentrations in various tissues. The above specimens accumulated heavy metals such as Zn, Pb, Cu, Co, Cr, Ni and Cd. Fish, prawn, crab and mussel revealed higher concentration of heavy metals such as Zn, Pb, Cr, Co, Cu and Ni and Cd in low levels. The results revealed that the heavy metal concentrations in the marine animals are below the threshold levels associated with the toxicological effects and the regulatory limits. The bioconcentration factors revealed that the animals have accumulated heavy metals along the food chain rather than from the water column and sediment.*

Key words*: Heavy metals, Bioconcentration factor, Mussel, Prawn, Fish, Crab*
PDF file of full length paper is available with author

Introduction

Coastal belts are highly populated and urbanized with industries. Marine food such as fish, prawn, crab and mussel are delicacies and form an important staple part of daily food. The tendency of heavy metals to get accumulated in marine animals is of scientific interest in heavy metal chemistry. The bioavailability of trace metals is the key factor determining tissue metal levels in the marine biota. Trace metal uptake occurs directly from surrounding marine water across the permeable body surface and from food along with the seawater to the gut (Depledge and Rainbow, 1990). Fish, crab and prawn form an important link as possible transfer media to human beings. Information on the level of heavy metal pollution in coastal environment is important as they cause serious environmental health hazards (Nitta, 1992; Gupta and Srivastava, 2006; Shukla *et al.*, 2007).

Joseph and Srivastava (1993), worked on the mercury concentrations in the water, sediments and fish from the Ennore estuary during the period from 1982-1983. Their study showed that the uptake of mercury by fish was about 400 times higher than the water itself. The concentration of mercury was estimated to be 0.0012 mg/ml and of sediment as 0.06 mg/ml. Removal of dissolved fraction of trace metals in the estuary was inferred due to the suspended matter, colloidal organic ligands and co-precipitation with humic matter (Joseph and Srivastava, 1993).

Although considerable work has been carried out on heavy metal levels in various media and marine animal species, there is a paucity of information in the heavy metal concentrations in the food web along the coast of Chennai, India. The effect of various heavy metals entering the microbial food web is still not well understood. Hence a detailed study on the assessment of heavy metals in marine animals and sediments becomes inevitable. Evaluation of heavy metals along the food chain may throw light on the heavy metal input to the human body from sea food.

Materials and Methods

The study area along the East Coast, Chennai (Fig. 1), encompasses the stretch between Pulicat lake and Chennai Harbour. The Coastal Research Vessal "Sagar Paschimi" of NIOT, Chennai, was used to collect sediments and animal samples. The present study aims in understanding the bioaccumulation patterns to demonstrate the safety of sea food as a supplementary source of protein in diet. An attempt was made to evaluate the amount of various essential and non-essential elements like Zn, Cr, Co, Pb, Cu, Ni and Cd in certain marine animal samples.

The animal samples were collected and transported to the laboratory in ice boxes and stored at -10^{o}C until subjected for further analysis. The animals were dissected and care was taken to avoid external contamination to the samples. Rust free stainless steel kit was sterilized to dissect the animals. Double distilled deionised water was used for making up the samples and for analysis in the flame atomic absorption spectrophotometer (FAAS). The gut content, gills and muscles were separated and dried to a constant weight ands both wet and dry weights were recorded. Entire body of mussel was taken for analysis.

For this study fish, *Caranx hippos* of Carangidae family, prawn, *Solenocera crassicornis* of Solenoceridae family, crab, *Scylla serrata* of Portunidae family and mussel, *Perna viridis* of Mytilidae family were collected and analysed for heavy metals in possible target tissues. All samples were oven dried to a constant weight and coarsely homogenised and packed in polyethylene packs. The samples were dry-ashed at 450°C for 4 hr in high-form porcelain crucible in a muffle furnace until a white or grey-white ash was obtained. The residue was dissolved in 25% nitric acid, wherever necessary, the samples were slowly heated to dissolve the residue. The solutions were then transferred to a 25 ml volumetric flask and made upto the mark with double deionised water following Vaidya and Rantala (1996). Entire gills and the gut and its content of the fish alone were taken, as these samples were less than 1mg for further analyses. All samples were analyzed for Zn, Cr, Cd, Pb, Co, Ni and Cu concentration using flame atomic absorption spectrophotometer (FAAS), GBC Make, Australia, at the Department of Geology, Anna University, Chennai. Chemical standards from MERCK were used as standards. 25% nitric acid was used as blank samples accompanied every run of the analyses. Each sample was analysed in triplicate to ensure accuracy and precession for the analytical procedure. Tissue level concentration of various animals was analyzed for heavy metals and is graphically presented in the Fig. 2 to 5.

Results and Discussion

Heavy metals entering the fish have a possibility to get accumulated in different parts of the body and the residual amount can build up to a toxic level. The fish, *Caranx hippos* is economically important and they form a large part of the fish catch in the study

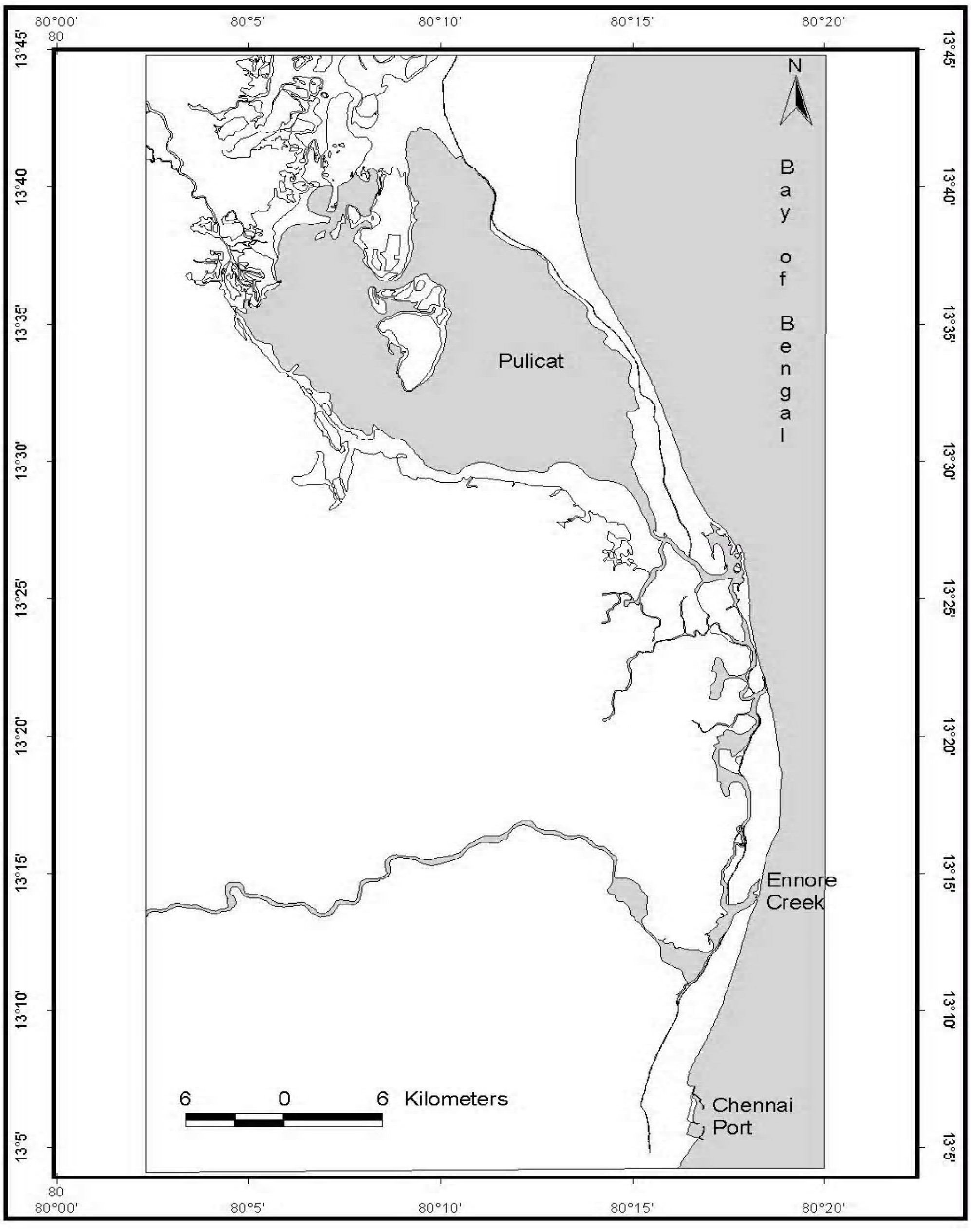

Fig. 1: Location map of the area

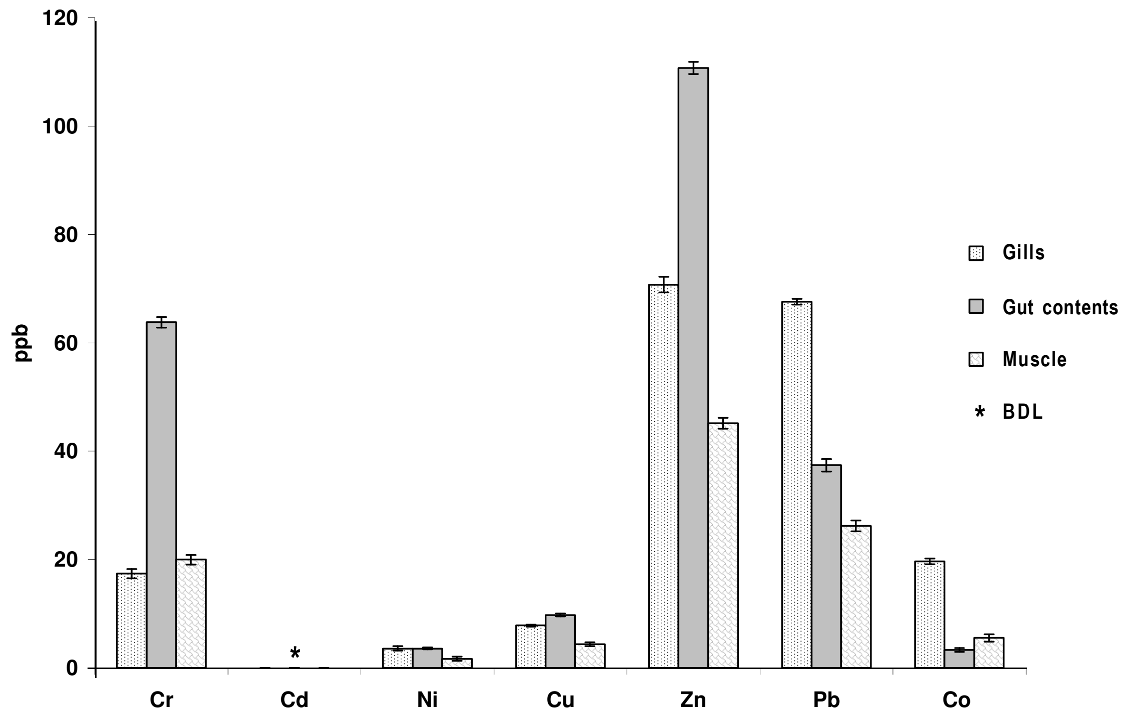

Fig. 2: Distribution of heavy metals in fish, *Carnix hippos*

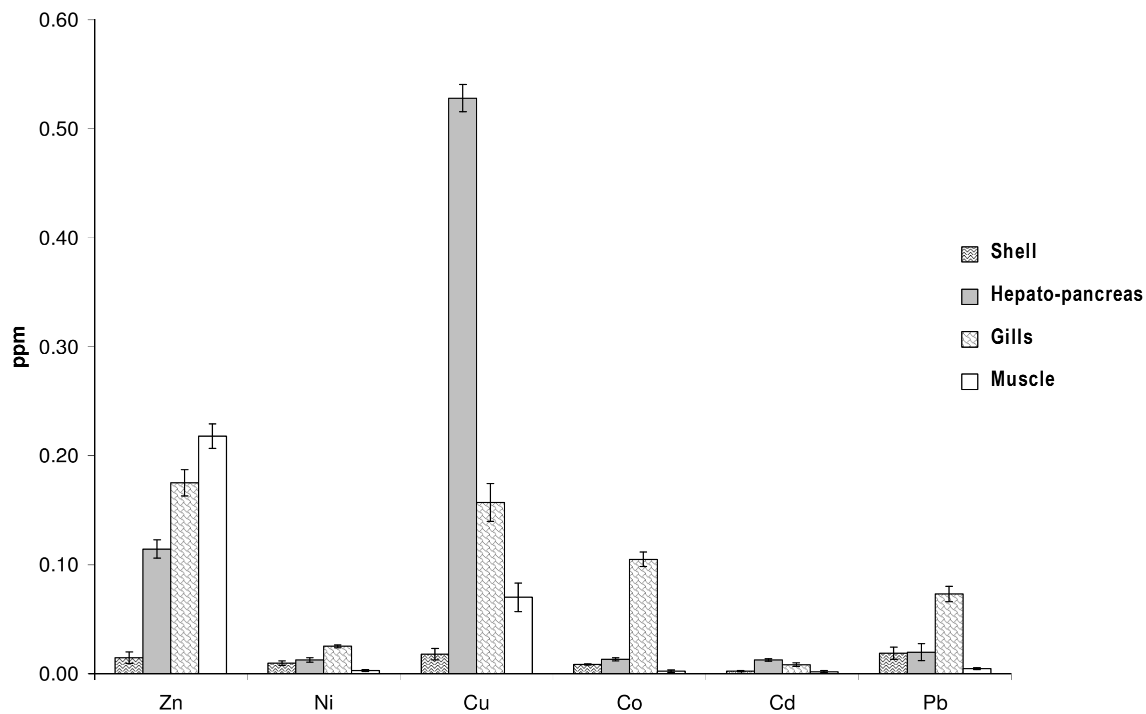

Fig. 3: Distribution of heavy metals in crab, *Scylla serrate*

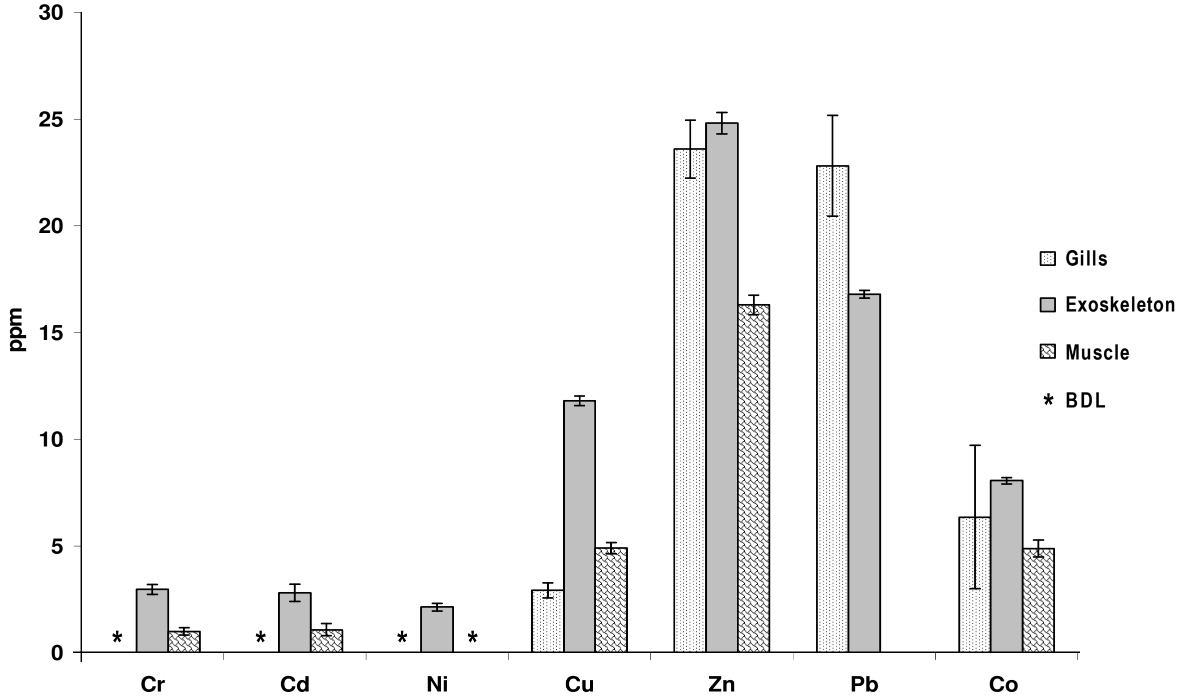

Fig. 4: Distribution of heavy metals in prawn, *Solanocera carcicornis*

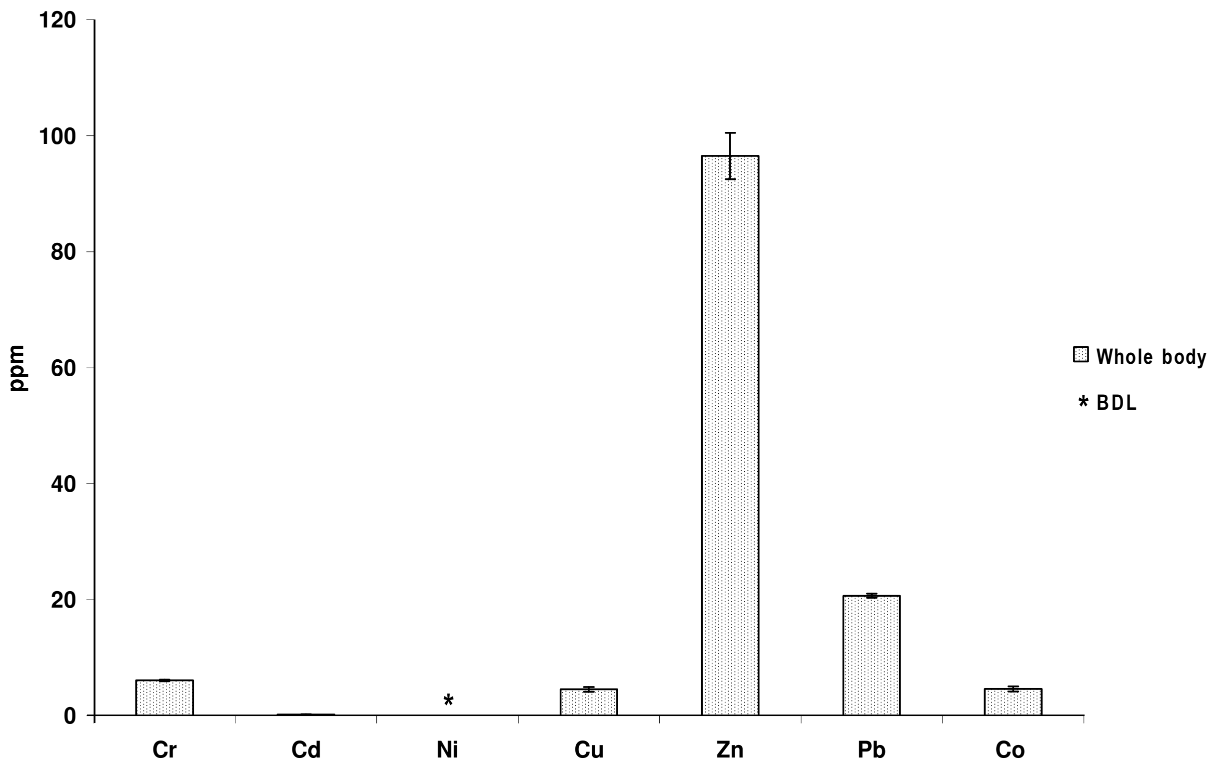

Fig. 5: Distribution of heavy metals in mussel, *Perna viridis*

area. The accumulation of heavy metals in muscles of the fish is in the order as follows, Zn>Pb>Co=Cr>Cu>Ni>Cd the gut and its content is of the following order, Zn>Cr>Pb>Cu>Ni>Co>Cd and that of the gills Zn>Pb>Co>Cr>Cu>Ni>Cd. The above sequences correlated with the studies by Krishnamurthi and Nair (1999), who had the patterns of Zn>Cu>Ni>Pb>Cd. Enriched amounts of Pb in the fish *Carnyx hippos* of the study area may be due to the enrichment of Pb from atmospheric input into the sea surface water (Prabakaramurthy and Satyanarayana, 1999).

The accumulation patterns in the gills of the prawns revealed the following order Zn>Pb>Co>Cu while Cr, Cd, Ni were below the detectable range. In the muscles, the concentration revealed Zn>Cu>Co>Cr>Cd sequence and Ni and Pb were found only below the detectable limits. The exoskeleton of the prawns (*Solenocera crassicornis*) Zn>Cu>Co>Cr>Cd and Ni was also below the detectable limit. Accumulated heavy metals in crab hepatopancreas followed the sequence of Zn>Pb>Cu>Cd>Cr and Ni and Co was below the detectable range. Gills of the crab had a pattern Pb>Zn>Co>Cu>Cd>Cr, while Ni was below the detectable range. Mussels were found to accumulate all the heavy metals in various proportions. The order of accumulation is Zn>Pb>Cr>Co=Cu>Cd and Ni was below the detectable range.

The water analysed showed higher amounts of Co and Ni and Zn was below the detectable range (Table 2). Our study revealed high levels of Zn followed by Pb, Cu, Co and Cr was found in all the marine animals and their organs, while Ni and Cd were found to be in least concentrations.

Bioconcentration factor (BCF): Bioconcentration factor was calculated to estimate the amount heavy metal input from the surrounding environment (Table 1). Bioconcentration is defined as the net result of the absorption, distribution and elimination of a substance in an organism, after an exposure *via* water. The bioconcentration factor is the ratio between the chemical concentration in the organism and the chemical concentration in water, at equilibrium:

$$BCF_{fish} = \frac{C_{fish}}{C_{water}}$$

where C_{fish} is the chemical concentration in fish (test organism) in mg/kg (preferably wet weight), C_{water} is the chemical concentration in water, in mg/l, and BCF_{fish} is the bioconcentration factor for the test organism.

The bioconcentration factors of the muscle analysed is much below the Organisation for Economic Co-operation and Development guidelines (OECD, 1997).

Higher concentration of heavy metals in the gills, gut and exoskeleton suggests that the animal's capability to sequester the heavy metals safely from the body. Jargensen and Pedersen (1994), reported several factors that influence the elimination of metals from the body of marine animals. These include time, temperature, interacting agents, age of the fish, metabolic activity of

Table - 1: Trace metal content in water

	Cr (ppm)	Cd (ppm)	Ni (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)	Co (ppm)
Water	19.45	0.5	45	8.13	ND	18.25	50.75

Table - 2: Bio-concentration factors for the tissues analysed

	Cr	Cd	Ni	Cu	Zn	Pb	Co
Fish							
Gills	0.04	0	0	0.001	0	0.004	0.0004
Gut contents	0.14	0	0	0.001	0	0.002	0.0001
Muscle	0.044	0	0	0.0005	0	0.001	0.0001
Prawn							
Gills	0	0	0	0.0004	0	0.001	0.0001
Exoskeleton	0.01	0.006	0	0.0015	0	0.001	0.0002
Muscle	0.002	0.002	0	0.001	0	0	0.0001
Crab							
Gills	0.02	0.02	0	0.002	0	0.004	0.0006
Hepato-pancreas	0.02	0.03	0	0.005	0	0.004	0
Mussel							
Whole body	0.01	0.0004	0	0.001	0	0.001	0.0001

the animals and biological half-life of metals (Woo *et al.*, 1993). Elimination routes from fish are generally through gills, bile, urine, skin and via mucus (Kargin, 1996; Nielsen and Andersen, 1996).

Metal elimination routes are more than uptake routes, however metal accumulation is more rapid than metal elimination probably due to the presence of metal binding proteins in tissues (Kendrick *et al.*, 1992). The accumulation of the metals in liver could be based on the greater tendency of the elements to react with the oxygen, carboxylate, amino group, nitrogen or sulphur of the mercapto group in the metallothionein protein, which was at highest concentration in the liver (Kendrick *et al.*, 1992). These complexes are slowly redistributed to the renal cortex. Liver has also an important role in contaminant storage, redistribution, detoxification or transformation and also serve as an active site of pathological effects induced by contaminants (El-Shahawi, 1996). Zn seemed to accumulate up to a certain level and then remains constant in tissues due to several biochemical mechanisms (Evans *et al.*, 1993).

The interdependency of the uptake and diminution rates when sufficient levels of the essential elements for metabolism are sequestered in the body, equilibrium is established between the body burden of Zn and the environmental concentration (Evans *et al.*, 1993). The fish muscle is not considered to be specific physiological site for Cu (Marcovecchio and Moreno, 1993).

The concentration levels of the elements found in this study do not constitute a risk factor for human health and appear to be below the permissible limits set by the UNEP (1993). Higher amounts of Zn and Pb in gills suggest that metals are excreted more rapidly and reduce the body burden of these metals and suggest that Zn and Pb are not accumulated. The fish of Carangidae family are carnivores and feed on small fish and zooplanktons. The high concentration of Zn, Pb, Co and Cu is due to the process of biomagnifications in these species.

Molluscs, as filter feeder organisms, are most frequently used to monitor the pollution of coastal water by metals (Zia and Khan, 1989). Lying in the second trophic level in the aquatic ecosystem, mollusks have long been known to accumulate both essential and non-essential trace elements in aquatic ecosystems (Phillips, 1977). The presence of Zn, Cu, Pb and Co in higher amounts is due to their richness in the surrounding niche.

The common mud crab is one of the few species found in all the seasons. The routes of metal absorption in decapod crustaceans are from the food in the digestive tract and the heavy metals also cross the permeable gill membranes (Dallinger, 1993). Heavy metals such as Cu and Zn are essential for normal growth and development in crustaceans, whereas metals such as Cd and Pb are non-essential (Rainbow, 1988). Non-essential metals are often regulated, detoxified and stored in an inert form, or may accumulate and cause toxic effects (Rainbow, 1988). When metals are bioavailable, the crabs are able to effectively depurate metals through normal physiological processes or store them in other tissues (*i.e.*, hepatopancreas). Red king crabs (*Paralithodes camtschaticus*) purge Ni through the exoskeleton during ecdysis (Rusanowski *et al.*, 1989). This supports our data of low concentration of Ni in the crabs. Anderson and Brewer (1978) observed high concentration of Zn in gills regardless of treatment, the same was observed in the present study. In crabs, hepatopancreas showed higher concentration of all metals, this might be due to the fact that hepatopancreas plays a prime role in binding the metals and act as primary route of excretion.

Bryan (1984) concluded that for crustaceans, metal uptake via the food is of great significance. Metals such as Fe, Cu, Zn and Mn, are essential metals since they play an important role in biological systems, where as Hg, Pb and Cd are non-essential, as they are toxic even in traces. The essential metals can also produce toxic effects when they accumulate and their level is excessively elevated. Presence of detectable amounts of cadmium in the exoskeleton of prawns revealed that the animals were continuously exposed to Cd probably through food web, water column and sediments and as a result of which they accumulated in the exoskeleton. Cd has the tendency to replace calcium due to the common site for which they both compete.

Green mussels like *Perna viridis* have been effectively used as an indicator for marine pollution especially with reference to Cd (Sze and Lee, 1995). It appears to regulate metals in its tissues to greater degrees than oysters, by means of mucus secretion (Chidambaram, 1996) and metalloprotein production (Yang and Thompson, 1996). Their sedentary way of life and ability to accumulate a wide range of pollutants in proportion to the degree of environmental contamination (Ruangwises and Ruangwises, 1998) is one of the main causes for high concentration of heavy metals. In the present study the Cd concentration in *Perna viridis* is comparatively higher indicating Cd contamination.

Acknowledgments

The authors are grateful to The National Institute of Ocean Technology (NIOT), Chennai, for providing the Coastal Research Vessel 'Sagar Paschimi' for collecting marine animals for this work. The authors thank The Head, Department of Geology, Anna University for providing necessary facilities. This work is produced under the UGC-DRS Phase-I programme with financial assistance to the Department of Geology, Anna University, Chennai and UGC funded project F.No 30-278/2004(SR).

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