Journal of Coastal Life Medicine

journal homepage: www.jclmm.com

Original article https://doi.org/10.12980/jclm.5.2017J6-210

Bioaccumulation of cadmium in gills and muscles of shellfish from Pulicat lake, Tamil Nadu, India

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ARTICLE INFO

Article history:
Received 8 Oct 2016
Received in revised form 17 Oct, 2nd revised form 21 Oct 2016
Accepted 2 Nov 2016
Available online 25 Nov 2016

Keywords:
Heavy metals
Pollution
Estuary
Pulicat lake

ABSTRACT

Objective: To evaluate the presence of heavy metal cadmium in six species of shellfish at Pulicat Lake, Tamil Nadu, India.

Methods: Six species of shellfish, *Fenneropenaeus indicus*, *Fenneropenaeus monodon*, *Fenneropenaeus semisulcatus*, *Scylla serrata*, *Clibanarius longitarsus* and *Meretrix casta* (*M. casta*) in Pulicat lake, Tamil Nadu, India were analysed for the presence of cadmium in the gills and muscles from January 2011 to December 2012.

Results: The results showed seasonal variations in the uptake of cadmium. Very high accumulation of cadmium was found in the gills and muscles of *M. casta* during post monsoon, summer, premonsoon and monsoon. The corresponding values of cadmium present in the gills of *M. casta* were 1.59, 1.56, 1.48 and 1.46 µg/g in 2011 and 1.16, 1.25, 1.15 and 1.14 µg/g in 2012. Whereas for muscles, they were 1.14, 0.11, 0.96 and 0.80 µg/g in 2011 and 0.49, 0.34, 1.05 and 1.20 µg/g in 2012.

Conclusion: The results of the present study has shown that the accumulation of cadmium found in the gills and muscles were high in *M. casta* when compared to other species of shellfish. Thus, the consumption of the shellfish is safe, but does not exclude bioaccumulation risk in their meat. This present study has highlighted the need for estuarine biomonitoring to avoid possible contamination of shellfish and its consumers. The overall scenario of the shellfish accumulating high levels of cadmium indicates that the Pulicat lake is polluted with undesirable elements and the risk of consuming the meat of shellfish by man and other carnivores may lead to their toxicity. Stringent control measures are necessary to control the pollution of this precious lake to reduce the bioaccumulation of toxic metals in organisms.

1. Introduction

The estuaries are considered to be essential components of the marine ecosystem and estuary is a zone which is transitional between the riverine and marine environments. Estuaries effectively trap nutrients to provide resources to aquatic organisms and to humans for commercial and entertainment activities. Oysters and clams prefer this area for their settlement whereas other fin fishes and shell fishes also prefer estuaries to act as their nursery grounds[1].

Heavy metals are present in marine environments due to natural developments and man-made causes[2,3]. The pollution of natural water bodies by trace elements affects the aquatic organisms and creates environmental and human health hazards[4,6]. Heavy metals such as arsenic, cadmium, chromium, copper, lead, mercury, tin and zinc are among the most dangerous pollutants in the marine environment[7-9]. Heavy metal accumulation in water bodies surrounding urban and industrial areas are mainly due to effluents that are discharged from a number of factories involved in the production of biocides, pigments and paints, ore processing, electroplating, tanning and textile dyeing[10]. Heavy metals are one of the most serious pollutants in the environment due to their toxicity, persistence and ability to concentrate along the food chain[11]. Rapid growth in human population, intensive agriculture and industrial activities have eventually led to increased amount of pollutants especially heavy metals that threaten the estuarine environment[12]. Most organisms require minute quantities of essential heavy metals *viz.*, copper, iron, manganese and zinc for essential processes especially for growth[12,13]. When certain limits are exceeded, it becomes toxic to the organisms[11]. Certain metals such as cadmium, chromium and lead are non-essential and exhibit toxicity even at low concentrations[14]. The sediment dwelling biota are exposed to heavy metals due to their ingestion of surrounding waters, sediments and through the food chain[15]. High levels of

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The journal implements double-blind peer review practiced by specially invited international editorial board members.

heavy metals in sediments indicate anthropogenic pollution than due to natural causes[16,17]. Certain marine invertebrates are considered as bioindicators to indicate the presence of heavy metals as the contamination in these organisms depicts a direct relationship to that of the environment[18]. Consumption of bivalves can be severely limited due to the presence of heavy metals since they cause injurious effects to human health[19]. A precise estimation of heavy metals in the environment and in the biota will provide the degree of metal contamination in that particular place[20]. Availability of cadmium may vary due to natural and anthropogenic causes in different habitats[21,22]. In view of the aforementioned factors, the current study was undertaken to evaluate the variation of the trace metal cadmium in the gill and muscle tissues of six species of shellfish *viz.*, *Fenneropenaeus indicus* (*F. indicus*), *Fenneropenaeus monodon* (*F. monodon*), *Fenneropenaeus semisulcatus* (*F. semisulcatus*), *Scylla serrata* (*S. serrata*), *Clibanarius longitarsus* (*C. longitarsus*) and *Meretrix casta* (*M. casta*) present in Pulicat lake, Tamil Nadu, India.

2. Materials and methods

2.1. Study area

Pulicat lake (13°24'–13°47' N, 80°03'–80°18' E) is the second largest brackish water body of India with an area of 18 440 hectares and is located 40 km north of Chennai. The length of this lake is about 60 km and varies in breadth (0.2 to 17.5 km). Pulicat lake is drained by four rivers, the Swarnamukhi, the Kalangi, the Araniar and the Royyala Kalava apart from many minor inflows. Industrial and domestic waste are brought into this lake by the Buckingham canal and finally to the Bay of Bengal[23]. Local climate, riverine inflow and the neritic waters from the Bay of Bengal influence the hydrological characters of Pulicat lake. Many euryhaline species are present in this lake which act as breeding grounds for many organisms and certain fishes[24]. Untreated effluents from industries and urban areas are considered to be point sources of pollution[23,25,26].

2.2. Collection of specimens

Six shellfish species *viz.*, *F. indicus*, *F. monodon*, *F. semisulcatus*, *S. serrata*, *C. longitarsus* and *M. casta* were collected from Pulicat lake, Tamil Nadu, India on a monthly basis for a period of two years from January 2011 to December 2012. The collected organisms were brought to the laboratory in an ice box and were stored at 4 °C until analyses. The organisms were thoroughly washed with running tap water to eliminate mud and other debris and were subsequently rinsed with double-distilled water. Rust free stainless steel kit was used to dissect the animal. Care was taken to avoid external contamination of the samples.

2.3. Determination of metals in animals

The gills and muscles were used to estimate cadmium content. The analysis was carried out using the method suggested by Watting[27]. Analytical grade reagents were used. For analysing cadmium, the samples were oven dried at 60 °C for 24 h. The dried sample (0.5 g) was taken and ground with a mortar and pestle. Using nitric and perchloric acid (3:1), the ground samples were digested. After adding the acids, the samples were kept in the hot plate at 120 °C until white residues were formed. Finally the residue was dissolved in 10 mL of distilled water and then filtered. The filtered sample was aspirated into the atomic absorption spectrophotometer and the reading was recorded. The solution was then diluted and filtered through a 0.45 µm nitrocellulose membrane filter. Determination of cadmium in samples was carried out by inductively coupled plasma atomic emission spectroscopy (Optima 2100 DV, Perkin-Elmer, USA).

3. Results

Bioaccumulation is the net uptake of chemicals through probable routes such as diet and respiration, thereby resulting in cytotoxicity. Most studies on bioaccumulation of trace metals in the marine environment have focused on animals nearer to the lower end of the food web, since these animals could be directly utilized for consumption by both human and livestock, and can serve to transfer heavy metals to carnivores[28].

Industrialization and exploitation of mineral resources around the globe has caused heavy accumulation of toxic trace metals in the environs. Increasing levels of numerous toxic heavy metals in the environment has evoked serious concern among the masses. The transfer of heavy metals through the food chain is attributed to the migration, concentration and solubility in marine waters. Bottom dwellers such as polychaetes and molluscs are more prone to accumulation of high concentrations of heavy metals[10]. Trace metal accumulation in the various tissues of aquatic organisms depends on the route of entry which may be from the water medium or from other chemical sources. Therefore, accumulation of trace metals in the tissues of such aquatic fauna is due to their presence in water. The gills function as the major pathway for intake of heavy metals from the aquatic medium by the external mucous membrane and also due to specific characters of the cell wall[29-31].

The accumulations of cadmium in the gills of shellfish are exhibited as seasonal as well as species specific variations. During post monsoon, the gills and muscles tend to accumulate a high amount of cadmium in *M. casta* whereas for other organisms it is highly reduced in both the years. During summer, there is moderate uptake of cadmium by all the shellfish species except *F. monodon* and *C. longitarsus* in both the years. Premonsoon exhibits a rise in the accumulation of cadmium in all the six organisms for both years, especially *M. casta* which shows a very high build-up of cadmium in both gills and muscles. Similarly in monsoon, there is an overall increase in the cadmium accumulation in the gills and muscles for both the years. Among the six shellfish species studied, *M. casta* had accumulated the highest amount of cadmium (Figures 1 and 2).

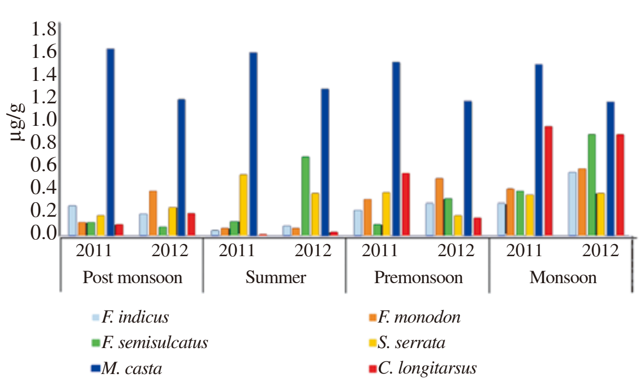

Figure 1. The presence of cadmium in gills of shellfish species.

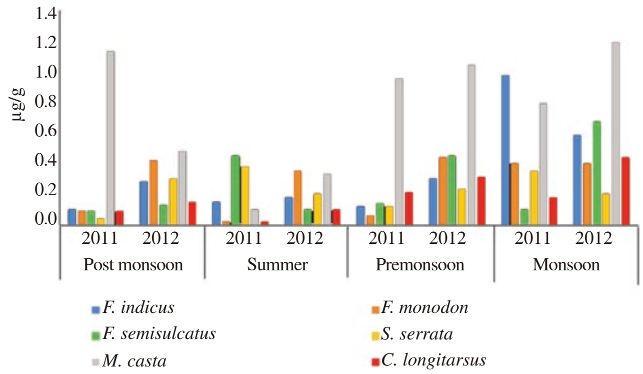

Figure 2. The presence of cadmium in muscles of shellfish species.

4. Discussion

Cadmium is present in the coastal and estuarine environments and does not have any biological functions in organisms. It gets accumulated in marine invertebrates especially crustaceans in the detoxified form[32-35]. However, its toxicity is very high to the aquatic animals and can affect their physiology even at low levels[36-40] .

Besides, scanty reports are present to illustrate the accumulation of cadmium in the penaeid decapods which are of economic and ecological importance in the tropics and subtropics[41-43]. Marine bivalves which are exposed to different concentrations of cadmium tend to concentrate this heavy metal in their tissues acquired from sediments and water to a very high magnitude above their exposure concentrations[44-46]. However, high cadmium concentrations result in acute toxicity, whereas cellular and physiological processes are affected even at low, environmentally realistic concentrations[39,40,47-49].

Cadmium is widely distributed in the earth's crust. Its main sources are from cadmium rich soils from which there is run-off to the river, leaching of rocks and deposition of diatoms in the sediments[21,45]. It is mainly used as pigments in plastics, as stabilizers and in electroplating. Smelting and mining of lead and zinc produce cadmium as a byproduct. Cadmium is also used in the manufacture of nickel-cadmium batteries. Use of commercial fertilizers, insecticides and fungicides containing cadmium increases its concentration in the soil. Exposure to alloys used in dentistry, motor oil and automobile exhausts are lesser known sources of cadmium which generally affect the kidneys, liver, lungs, brain, bones and the placenta[50]. High concentration of cadmium leads to severe health hazards to humans and is a potential toxin along with mercury. Consumption of food or intake of water with high cadmium levels leads to vomiting, irritation of the stomach, diarrhoea and sometimes even death. Ingesting low amounts of cadmium during an extended time can result in its accumulation in the kidneys, thereby causing kidney damage and also fragile bones. Studies on human and rats have pointed out that cadmium and its compounds may be potential carcinogens[10].

In conclusion, the result of the present study has shown that the accumulations of cadmium found in the gills and muscles were high in *M. casta* when compared to other species of shellfish. Thus, the consumption of the shellfish is safe, but do not exclude bioaccumulation risk in crustacean meat. This present study has highlighted the need for estuarine biomonitoring to avoid possible contamination of shellfish and its consumers. The overall scenario of the shellfish accumulating high levels of cadmium indicates that the Pulicat lake is polluted with undesirable elements and the risk of consuming the meat of shellfish by man and other carnivores may lead to their toxicity. Stringent control measures are necessary to control the pollution of this precious lake to reduce the bioaccumulation of toxic metals in organisms.

Conflict of interest statement

We declare that we have no conflict of interest.

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