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Mercury accumulation in the gills and muscles of six species of shellfish from Pulicat lake, Tamil Nadu, India

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Abstract
Metal bioaccumulation by marine organisms is of serious concern that high levels of metals may have detrimental effects on the marine organisms and may create problems in relation to their suitability as food for humans. In the present study, the bioaccumulation of mercury in the gills and muscles of six species of shellfish *viz*., *Fenneropenaeus indicus, Fenneropenaeus monodon, Fenneropenaeus semisulcatus, Scylla serrata, Meretrix casta* and *Clibanarius longitarsus* from Pulicat lake, Tamil Nadu, India on a monthly basis for a period of two years from January 2011 to December 2012 during four seasons *viz*., postmonsoon, summer, premonsoon and monsoon were analysed. The accumulation of mercury in the gills and muscles of the six shellfish species exhibited seasonal as well as species specific variations. The overall results indicated that the gill tissues of *Fenneropenaeus indicus* accumulated the maximum amount of mercury (5.45µg/g) during monsoon in 2012. In conclusion, it is evident that even though the mercury content in shellfish at Pulicat lake did not exceed the safe limit, continuous consumption of large quantities of shellfish can lead to mercury toxicity.

Keywords: Heavy metals, mercury, pollution, shellfish, Pulicat lake

1. Introduction

Pollution of marine environment by heavy metals has become a national and international problem in recent times [1]. The current alarm about metal pollution in the sea however started with the tragedy of 'Minamata' disease caused by the consumption of mercury contaminated shellfish and finfish taken from Minamata Bay in Japan [2, 3] and then there was 'Itai itai' disease caused by the consumption of seafoods contaminated by cadmium from Niigata in Japan [4]. The term heavy metal is a loose one. It includes transition metals like chromium, cobalt, nickel, copper, zinc, cadmium, mercury, lead, arsenic, antimony and bismuth. Of these, the most toxic metallic pollutants are mercury, lead, zinc and copper [5]. Heavy metals are natural components of the earth's crust and they can enter the water and food cycles through a variety of chemical and geochemical processes [6, 7]. Various activities by man in recent years have increased the quality and distribution of heavy metals in the atmosphere, land and water bodies [8]. All heavy metals are potentially harmful to most organisms at some levels of exposure and absorption. At low concentrations, many heavy metals including mercury, cadmuim, lead, arsenic and copper inhibit photosynthesis and phytoplankton growth [9]. Metal bioaccumulation by marine organisms has been the subject of considerable interest in recent years because of serious concern that high levels of metals may have detrimental effects on the marine organisms and may create problems in relation to their suitability as food for humans. Metal pollution of the sea is less visible and direct than other types of marine pollution but its effects on marine ecosystems and humans are intensive and very extensive [10]. Heavy metals *viz*., mercury, lead, arsenic, cadmium, tin, chromium, zinc and copper are among the most dangerous pollutants in the marine environment [11-13]. Marine invertebrates accumulate trace metals to varying degrees and body concentrations of the same may reach high levels [14, 15].
Biomonitors have been defined as species which accumulate trace contaminants in their tissues, responding to that fraction in the environment which is of direct ecotoxicological relevance, i.e. the bioavailable form [16]. Bivalves are effective biomonitors and have been widely used for heavy metal monitoring purposes worldwide [17-21]. The bioaccumulation of heavy metals by marine molluscs and other marine organisms may reach many orders of

magnitude above background concentrations in certain localities. This phenomenon may demonstrate the potential of these species as a biomonitor of heavy metal pollution [22, 23]. Monitoring programs and research for metals in the environmental samples have become widely established because of concerns over accumulation and toxic effects, particularly in aquatic organisms and to humans consuming these organisms [19]. In light of the above studies, it was decided to estimate the bioaccumulation of mercury in the gills and muscles of six species of shellfish from 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) with an area of 18,440 hectares is the second largest brackish water body of India and is located 40km north of the metropolitan city of Chennai. The length of this lake is about 60km and varies in breadth from 0.2 to 17.5km. Four rivers drain Pulicat lake; the Araniar, Kalangi, Swarnamukhi and the Royyala Kalava apart from many minor seasonal inflows. The Buckingham canal also brings in large volumes of industrial and domestic waste to this lake [24]. The hydrological characters of Pulicat lake is influenced by the neritic waters from the Bay of Bengal. Local climate and riverine inflow also has a profound influence on this lake. Many euryhaline species are present in this lake which act as breeding grounds for many organisms and certain fishes [25]. Large quantities of untreated effluents from local industries and nearby urban areas are considered to be point sources of pollution [24, 26, 27].

2.2 Collection of specimens

Six species of shellfish *viz.*, *Fenneropenaeus indicus*, *Fenneropenaeus monodon*, *Fenneropenaeus semisulcatus*, *Scylla serrata*, *Meretrix casta* and *Clibanarius longitarsus* were collected from Pulicat lake, Tamil Nadu, India for a period of two years from January 2011 to December 2012 on a monthly basis during postmonsoon, summer, premonsoon and monsoon seasons. The organisms that were collected were brought to the laboratory in an ice box and stored at 4°C until further analyses. The entire organisms were thoroughly washed with running tap water to eliminate mud, debris and other detritus then subsequently rinsed with distilled water. Stainless steel kit was used to dissect the animal to prevent rust contamination. Care was taken to avoid external contamination of the samples.

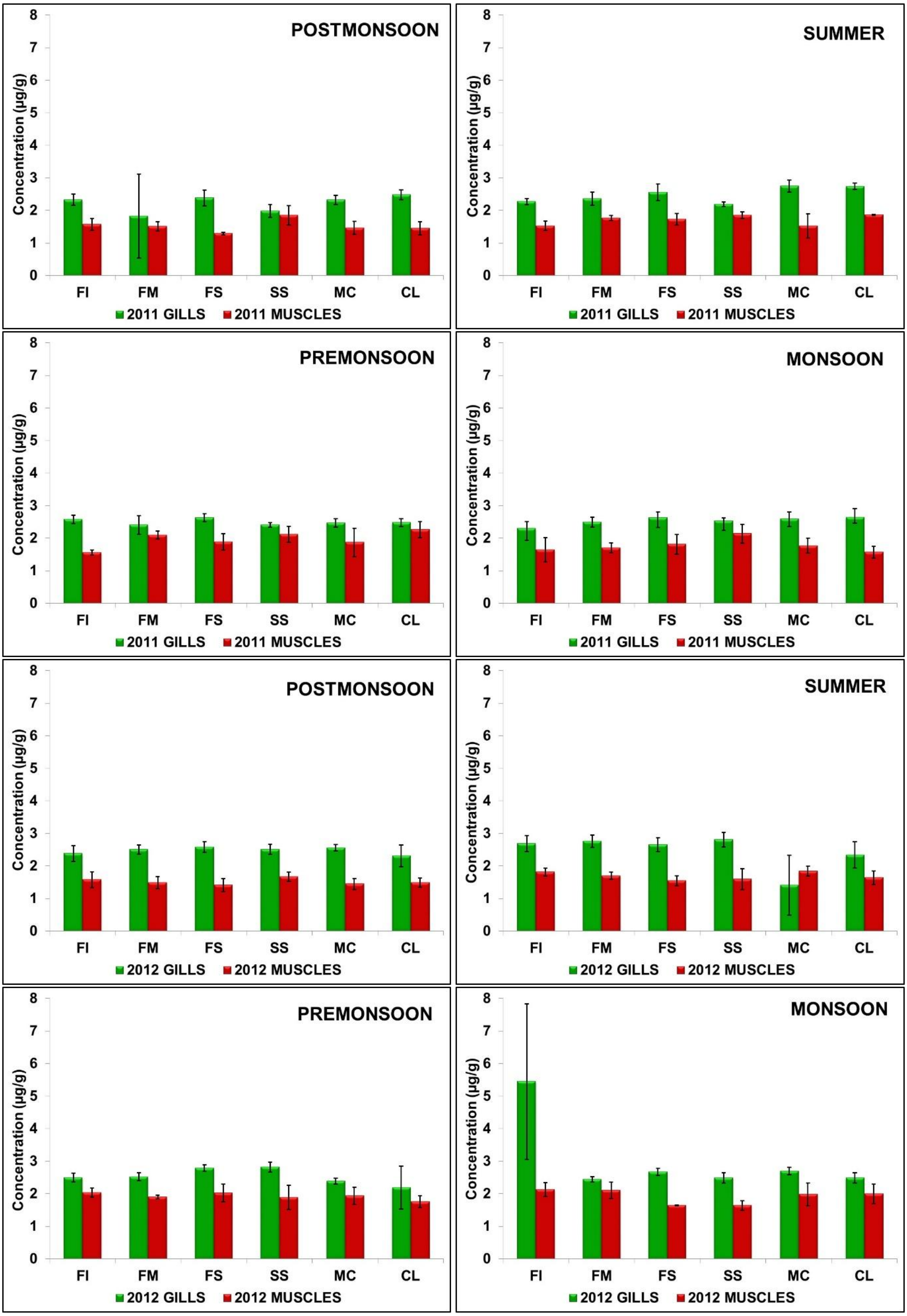
2.3 Determination of metals in animals

Gill and muscle tissues were analysed to estimate the amount of mercury present in them. The analysis was carried out as per the protocol suggested by Watling and Emmerson [28]. Analytical grade reagents were used for analysis. The samples were oven dried at 60°C for 24 hours and 0.5g of this sample was taken and ground with a mortar and pestle. The ground samples were digested using nitric and perchloric acid in the ratio 3:1. After adding the acids, the samples were kept in a hot plate at 120°C until white residues were formed which was dissolved in 10mL of distilled water and then filtered. The filtered sample was aspirated into the atomic absorption spectrophotometer and the reading was recorded. Determination of mercury in samples was carried out by inductively coupled plasma atomic emission spectroscopy (Optima 2100 DV, Perkin-Elmer, USA).

3. Results

The accumulation of mercury in the gills and muscles of the six shellfish species are exhibited as seasonal as well as species specific variations. The order of maximum accumulation of mercury in the gills of the shellfish species in 2011 were as follows: *Meretrix casta* (2.75µg/g) and *Clibanarius longitarsus* (2.74µg/g) during summer; *Fenneropenaeus semisulcatus* (2.63µg/g), *Fenneropenaeus indicus* (2.58µg/g), *Fenneropenaeus monodon* (2.41µg/g) and *Scylla serrata* (2.41µg/g) during premonsoon. For muscles it was, *Clibanarius longitarsus* (2.26µg/g) during premonsoon; *Scylla serrata* (2.14µg/g) during monsoon; *Fenneropenaeus monodon* (2.10µg/g), *Fenneropenaeus semisulcatus* (1.89µg/g) and *Meretrix casta* (1.87µg/g) during premonsoon; and *Fenneropenaeus indicus* (1.64µg/g) during monsoon. Whereas, for the year 2012, the order of maximum accumulation of mercury in the gills were, *Fenneropenaeus indicus* (5.45µg/g) during monsoon; *Scylla serrata* (2.82µg/g) and *Fenneropenaeus semisulcatus* (2.79µg/g) during premonsoon; *Fenneropennaeus monodon* (2.76µg/g) during summer; *Meretrix casta* (2.70µg/g) and *Clibanarius longitarsus* (2.49µg/g) during monsoon. For muscles, it was, *Fenneropenaeus indicus* (2.13µg/g) and *Fenneropennaeus monodon* (2.11µg/g) during monsoon; *Fenneropenaeus semisulcatus* (2.02µg/g) during premonsoon; *Clibanarius longitarsus* (2.00µg/g) and *Meretrix casta* (1.98µg/g) during monsoon; and *Scylla serrata* (1.89µg/g) during premonsoon. The overall results indicate the gill tissues of *Fenneropenaeus indicus* to accumulate the maximum amount of mercury (5.45µg/g) during monsoon in 2012 (Figure 1).

Fig 1: Accumulation of mercury in the gills and muscles of shellfish species in Pulicat lake



FI: ***Fenneropenaeus indicus***
FM: ***Fenneropenaeus monodon***
FS: ***Fenneropenaeus semisulcatus***
SS: ***Scylla serrata***
MC: ***Meretrix casta***
CL: ***Clibanarius longitarsus***

4. Discussion

Environmental scientists and ecotoxicologists use the term “heavy metals” to refer to metals that have caused environmental problems [29]. They classify heavy metals as essential, non-essential and borderline of which mercury is absolutely non-essential [30, 31]. Some metals that have received more attention are mercury, cadmium and lead because of their highly toxic properties and effects on the environment and living organisms of which mercury is considered to be an important and dangerous heavy metal pollutant arising from anthropogenic activities [32]. The extent of accumulation of trace metals by organisms in different tissues is dependent on the route of entry, i.e., either from the surrounding medium, or in the form of food or chemical form of material available in the media [33, 34]. Metals are taken up by crustaceans from food and water, distributed throughout crustacean body by blood and eventually accumulated in target organs [35]. Filter feeding bivalves like mussels and oysters may exhibit distinct capacities for trace metals accumulation, metabolism and excretion [36]. This is possibly related to their capacity to select, or filter, the particle size and the composition of the ingested food they assimilate, and also reflects the greater ability of the mussels to concentrate and excrete methylmercury in their tissues. Probably, the high total mercury and methymercury contents in mussels' soft tissues are related to their capacity to ingest food from higher trophic levels than oysters [37]. Hosseini *et al*. [35] observed that there was a positive correlation between mercury concentration in shrimp species with sex and size of its food items. They also investigated the levels of mercury in tissues of *Penaeus merguiensis* from Musa estuary, northwest of the Persian Gulf, where the relationship between mercury levels in hepatopancreas, gills and muscles with sex, size and season was assessed. The order of mercury concentrations in tissues of the shrimp *Penaeus merguiensis* was as follows: hepatopancreas > gills > muscles. Hepatopancreas are considered as target organs for mercury accumulation [38]. The results of Hosseini *et al*. [35] revealed that among the tissues of *Penaeus merguiensis*, hepatopancreas accumulated the highest level of mercury. Very low levels of mercury in the gills and muscles of shrimp in comparison to their hepatopancreas may be related to the content of metallothionein protein in hepatopancreas tissue. Metallothionein protein that plays a significant role in the regulation and detoxification of mercury is produced in high levels in hepatopancreas tissue [39]. Gills usually reflect the concentrations of metals in surrounding water. This organ is directly in contact with water and suspended materials and thus, could absorb different substances from the surrounding environment. They also serve a variety of physiological functions like osmoregulation and gas exchange [40]. Due to these functions, gills have remarkable influences on the exchange of toxic metals between organism and its environment [41]. However, the muscle tended to accumulate less mercury in comparison to the liver and gills. This finding may reflect the low concentration of metallothioneins in the muscle tissue [40]. A similar observation was recorded in the present study. However, according to previous studies, muscle can be of the main target organs for metal accumulation. For muscles, this is possibly attributed to the tendency of metals to react with the sulfhydryl groups of methionine and cysteine proteins that are at high levels in the muscle [42]. Larger organisms generally exhibit higher contaminant level in their bodies [43], and shrimps that are higher on the food chain also accumulate more contaminants when compared to shrimp that eat a range of different foods or eat smaller organisms. Larger species are also more dependent to sediment (benthic) and less to surface (pelagic) in comparison to smaller species and thus are present longer in polluted sediment [44, 45]. These findings are in tune with the observations made by the present study with regard to shellfish at Pulicat lake especially with crustaceans.

Crustaceans are the highly consumed shellfish by the general population hence the risk of transfer of mercury to humans is of great concern. Mercury is generated naturally in the environment from degassing the earth's crust and from volcanic emissions. It exists in three forms: *viz*., elemental, organic and inorganic mercury. Mining operations, chloralkali plants, and paper industries are significant producers of mercury [46]. The other sources of mercury are adhesives, algicides, battery manufacturing, broken thermometers, burning newspapers, building materials, dental amalgams, fungicides, germicides, pesticides, insecticides, industrial waste, manufacture of paper and chlorine, paints, polluted water, sewage disposal, tanning leather and seafood. Inorganic and organic mercury is toxic to the human body in different ways, effecting different organs in different ways. Inorganic mercury can cause neurological and psychological symptoms, involving tremor, changes in personality, restlessness, anxiety, sleep disturbance and depression. Other symptoms are memory loss, shortfall in attention and Alzheimer’s disease like dementia [47]. Hock *et al*. [48] conducted a study on whether environmental factors may influence the risk of getting Alzheimer’s disease and found that Alzheimer’s disease patients had a two-fold higher blood-mercury level than the control group and that early onset of Alzheimer’s disease patients, the blood-mercury levels where three-fold times higher than the control group. Exposure of human foetus to mercury can also cause late development of speech, late walking, memory shortfall in attention and autism [47].

Human population is primarily exposed to mercury via food, where fish is the major source of mercury exposure [49]. Atmospheric mercury is dispersed across the globe by wind and returns to the earth in rainfall, accumulating in aquatic food chains and lake fish [50]. Mercury has caused more problems to the consumers of fish than any other inorganic contaminant. In extreme cases, consumption of mercury-tainted fish has led to the onset of a serious neurological disease, termed ‘Minamata disease’ [2,3]. Victims of this disease are diagnosed as having degeneration in their nervous systems. Symptoms include numbness in limbs and lips, slurred speech and constrict vision. Some people have serious brain damage, while others lapse into unconsciousness or suffer from involuntary movements. Furthermore, some victims are thought to be crazy when they begin to shout uncontrollably. In other cases, entire fisheries have been either restricted or significantly curtailed because of mercury contamination [51].

5. Conclusion

In conclusion, it is evident that even though the mercury content in shellfish at Pulicat lake did not exceed the safe limit, continuous consumption of large quantities of shellfish can lead to mercury toxicity. Apart from this, the lake has to be monitored continuously to prevent the influx of mercury and other heavy metals resulting in the degradation of this precious water body along with mercury toxicity to the resident flora and fauna as well as to the primary and secondary consumers especially man.

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