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Bioaccumulation of nickel in gills and muscles of shellfish species from Pulicat Lake, Tamil Nadu, India

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Abstract
Heavy metal bioaccumulation by marine organisms has been the subject of considerable interest in recent years due to serious concerns that high levels of heavy 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, six species of shellfish, *Fenneropenaeus indicus*, *Fenneropenaeus monodon*, *Fenneropenaeus semisulcatus*, *Scylla serrata*, *Clibanarius longitarsus* and *Meretrix casta* in Pulicat lake, Tamil Nadu, India were analysed for the presence of nickel in its gills and muscles from January 2011 to December 2012. The results showed seasonal variations in the uptake of nickel. Very high accumulation of nickel was found in the gills and muscles of *Fenneropenaeus indicus* during post monsoon, premonsoon and monsoon. The corresponding values of nickel present in the gills of *Fenneropenaeus indicus* were 1.17, 1.56 and 1.86µg/g in 2011 and 1.19, 1.58 and 1.90µg/g in 2012. Whereas for muscles, high accumulation of nickel was observed in post monsoon, summer, premonsoon and monsoon in 2011 only and values were 3.35, 6.65, 7.78 and 0.80µg/g respectively. The results of the present study have shown that the accumulation of nickel found in the gills and muscles were high in *Fenneropenaeus indicus* when compared to other species of shellfish. Thus, the consumption of the shellfish is safe, but does not exclude bioaccumulation risk in their meat. The 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 nickel 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.

Keywords: heavy metals, nickel, pollution, pulicat lake, estuary

1. Introduction
Trace metal contamination of the estuarine area is of environmental concern nationally and internationally. Little attention has been directed towards the trace metal contamination of aquatic environments, such as streams and estuaries [1]. Estuarine environment is the most productive habitat which serves as a primary habitat or as spawning ground for most marine species [2]. The coastal zone constitutes about ten per cent of the oceanic area on the earth surface. It not only accounts for more than half of ocean's biological productivity, besides being the most vulnerable and abused zone [3]. Heavy metals are considered to be hazardous inorganic and organic pollutants in the coastal environment [4-6]. Unlike many contaminants, heavy metals are normal constituents of the marine environment [7]. They are natural components of the earth's crust and can enter the water and food cycles through a variety of chemical and geochemical processes [8,9]. Various activities by man in recent years have increased the quantity and distribution of heavy metals in the atmosphere, land and water bodies. The extent of this wide spread but diffused contamination has raised concern about their hazards on plants, animals and humans [10]. The fates of heavy metals introduced by human activities into aquatic ecosystems have recently become the subject of worldwide concern, since beyond the tolerable limits they become toxic [11,12]. All heavy metals are potentially harmful to most organisms at some levels of exposure and absorption [10]. Metals can enter and contaminate estuarine waters from feeder rivers and from direct discharges, and are trapped and accumulated in sediments [13] or directly captured by living organisms [14]. Heavy metals may enter an aquatic ecosystem from different natural and anthropogenic sources, including industrial or domestic sewage, storm runoff, leaching from landfills, shipping and harbour activities and also from atmospheric deposits [15].

Marine organisms tend to accumulate heavy metals from the environment and are adapted to handle natural fluctuations in intake brought about by minor changes in their availability in water or food. Such a process of accumulation of pollutants by organisms is termed bioconcentration or bioaccumulation [7]. Metal bioaccumulation by marine organisms has been the subject of considerable interest in recent years due to serious concerns 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 [16]. It is learnt that fish, crab and prawn form an important link as possible transfer media of trace metals to human beings [17]. Different animals in the same community at the same trophic level could accumulate pollutants differently due to differences in habitat/niche's physical and chemical properties [18]. Invertebrates appear to have a particularly high capability for concentrating metals along with other foreign materials found in their environment when they filter plankton during feeding [19]. Hence, the objective of the present study was to estimate the concentration of the heavy metal nickel in the gills and

muscles of six species of shellfish present in the estuarine 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 40km north of Chennai. The length of this lake is about 60km and varies in breadth (0.2 to 17.5km). 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 [20]. 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 [21]. Untreated effluents from industries and urban areas are considered to be point sources of pollution [20, 22, 23].

2.2 Collection of specimens

Six shellfish species *viz.*, *Fenneropenaeus indicus*, *Fenneropenaeus monodon*, *Fenneropenaeus semisulcatus*, *Scylla serrata*, *Clibanarius longitarsus* and *Meretrix 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 nickel content. The analysis was carried out using the method suggested by Watling and Emmerson [24]. Analytical grade reagents were used. For analysing nickel, the samples were oven dried at 60°C for 24 hours. The dried sample (0.5g) 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 a hot plate at 120°C until white residues were formed. Finally the residue 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. The solution was then diluted and filtered through a 0.45µm nitrocellulose membrane filter. Determination of nickel in samples was carried out by inductively coupled plasma atomic emission spectroscopy (Optima 2100 DV, Perkin-Elmer, USA).

3. Results

The gills of all the shellfish species studied except *Fenneropenaeus semisulcatus* had a very high accumulation of nickel during premonsoon and monsoon. Moderate accumulation of nickel was observed in the gills of all the shellfish species studied during postmonsoon and low concentrations during summer in both the years except *Fenneropenaeus semisulcatus* which exhibited high accumulation of nickel during summer (Figure 1). *Fenneropenaeus indicus* showed the highest accumulation of nickel in its muscles than the other species during all the four seasons in 2011. *Clibanarius longitarsus* exhibited an accumulation of moderate amount of nickel in its muscle during post monsoon and premonsoon in both the years (Figure 2).

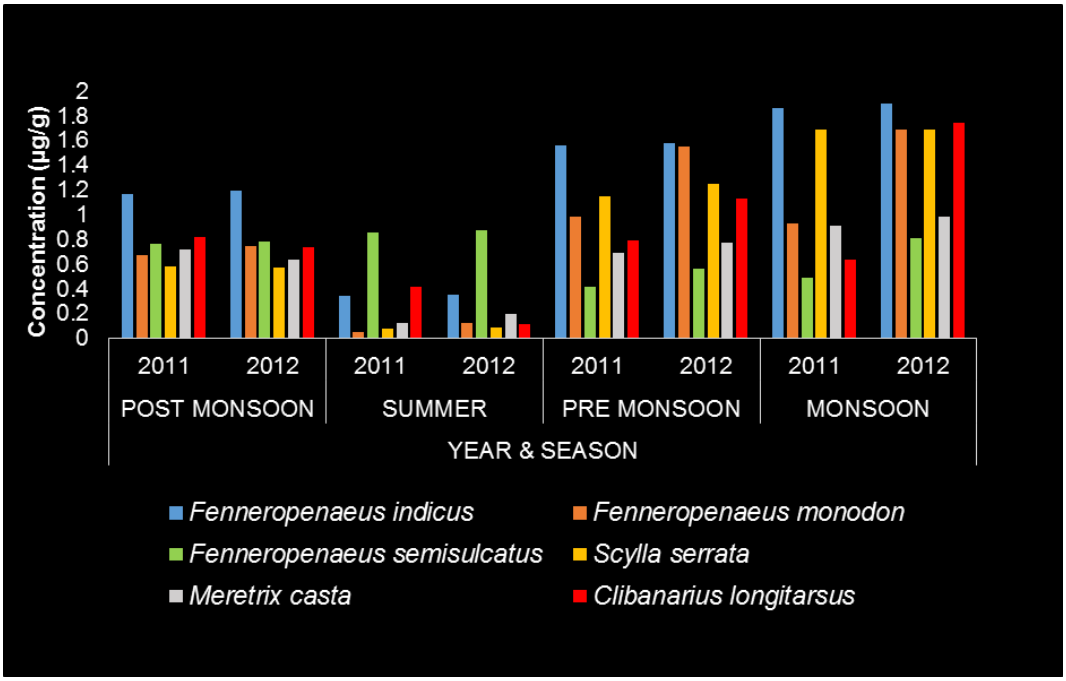

Fig 1: Presence of nickel in gills of shellfish species

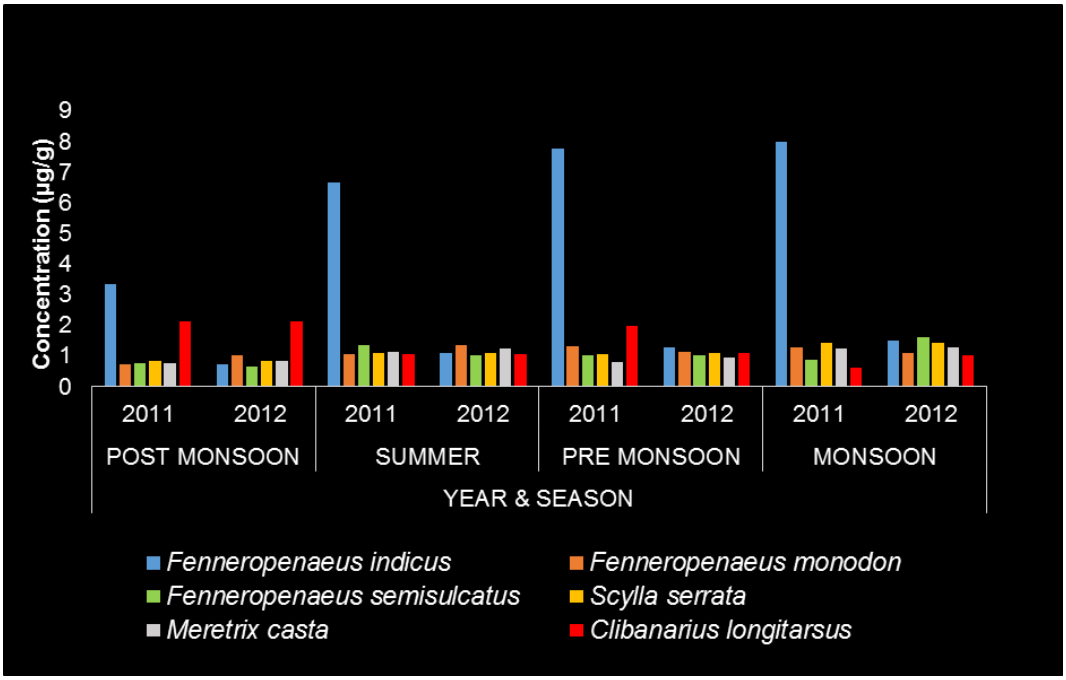

Fig 2: Presence of nickel in muscles of shellfish species

4. Discussion

Aquatic environment accumulate heavy metals from industrial effluents, sewage treatment plants, runoffs from domestic garbage dumps and agricultural fields [25]. The heavy metals present in the ambient water enter the bodies of the organisms by gills, digestive tract and the general body surface. However, it is established that the body surface play a minor part in the uptake of the metals from their environment [26] and of these three regions, gills are considered to directly take up metals from water [27, 28]. Several factors play a key role in heavy metal toxicity to estuarine and marine organisms such as salinity of water, developmental stage of the organism and its size [29]. The tissues of each organ either regulate or accumulate metals which is evident by the total amount of metal accumulated in organs or tissues. The accumulated heavy metals can be transferred by the organism to next trophic level of the food chain [30]. The general reaction of any organism is to show a response of regulation of metal concentration to a certain limit after which bioaccumulation occurs [31]. Bioaccumulation is the process were all organisms concentrate metals in its body from the surrounding medium or food either by absorption or ingestion [32, 33]. Bioconcentration is influenced by factors such as physical and chemical parameters of water, season, developmental stage of the organism and nutrient availability [34, 35]. Several marine organisms have the ability to concentrate heavy metals in several orders of magnitude than those in water and sediment [36]. Nickel is a siderophilic element naturally available from the earth crust's as well as from industries and combustion of fossil fuel [37]. Nickel is present in food and water through environmental contamination mostly due to human influence. Studies have indicated that nickel accumulates in large quantities in the gills, liver and muscles of aquatic organisms than in the hepatopancreas [38]. Organisms suffer from reproductive and developmental changes due to chronic exposure to nickel. The estimated maximum guideline value, proposed by USFDA [39] for nickel is 70-80mg/kg in tissues, however there are currently no maximum levels for nickel in food in the European Union. The major source of nickel contamination for humans is through food than from natural sources [40]. Since seafood is an important source of protein, contamination by metals is of public health interest [41]. The EFSA [42] has set a safe limit known as Tolerable Daily Intake (TDI) of 2.8µg/kg of body weight. They also conclude that high exposure to nickel is of current concern for the general population. Thus, in the present study, the concentration of nickel was a maximum of 8.0µg/g in *Fenneropenaeus indicus* which is a commonly consumed shellfish by carnivorous animals as well as humans. This high level of nickel present in the organism is of serious concern and therefore appropriate steps have to be taken by the authorities to reduce the contamination of Pulicat lake by the heavy metal nickel.

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