Heavy Metal Concentration of Sea Water and Marine Organisms in Ennore Creek, Southeast Coast of India

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**1. Introduction**

Environmental pollution and its hazards are the most important problems of societies and living creatures. On the other hand, increased population with the development of technology and production can cause a lack of attention to environmental safety (Saravi et al., 2009). Industrialization leads to the pollution of ecosystems. Therefore, recognition of pollutants and prevention of their environmental dispersion are one of the necessities in this field. Therefore, we must determine the pollution sources, their marine environmental effects and prevention methods; also, filtration of industrial waste water and education of instructions for environmental protection is vital works to
control and protect against pollutants. Heavy metals are a group of the most important pollutants which cause environmental degradation in coastal areas. Heavy metals are introduced into the aquatic ecosystems in a number of ways. These chemicals accumulate in the tissues of aquatic organisms at concentrations many times higher than concentrations in water and may be biomagnified in the food chain to levels that cause physiological impairment at higher trophic levels and in human consumers (Raposo et al., 2009). Heavy metals are natural constituents of the Earth's crust and are present in varying concentrations in all ecosystems. During the past two decades, high levels of heavy metals and their compounds, both inorganic and organic, have been released to the environment as a result of a variety of anthropogenic activities (Komarnicki, 2005). From an environmental point of view, coastal zones can be considered as the geographic space of interaction between terrestrial and marine ecosystems that is of great importance for the survival of a large variety of plants, animals and marine species (Castro et al., 1999). Coastal pollution has been increasing significantly over the recent years and found expanding environmental problems in many developing countries. Urban and industrial activities in coastal areas introduce significant amount of heavy metals into the marine environment, causing permanent disturbances in marine ecosystems, leading to environmental and ecological degradation and constitute a potential risk to a number of flora and fauna species, including humans, through food chains (Boran et al., 2010). Heavy metals were chosen as suitable pollutants because they are widespread environmental contaminants, from either natural or anthropogenic sources, and are widely believed to be a threat to the health and survival of many marine or aquatic animals, including crustaceans (Lorenzon et al., 2001). The contaminated fish and crustaceans from aquatic environment may become a public health concern. Hence, it is important to determine the concentrations of heavy metals in commercial fish and shrimps in order to evaluate the possible risk of human consumption (Cid et al., 2001). Pollution enters fin and shell fishes through five main routes: via food or non-food particles, gills, oral consumption of water and the skin. The use of fin and shell fishes as bio-indicators of metal pollution of aquatic environments and suitability for human use from toxicological point has been documented (Amin et al., 2011). Apart from that, the sensitivity of crustaceans to heavy metals is well documented and for all these reasons, the importance of marine shrimp for environmental monitoring studies as bio-indicators of heavy metal pollution has been emphasized by several investigators (Yilmaz et al., 2007). The concentration of trace metals by seafood is a potential problem to man. Aquatic organisms accumulate metals to concentrations many times higher than present in water. Hence, estimation of heavy metal accumulation is of utmost importance in this sector of biotic community. Increased circulation of hazardous heavy metals in soil, water and air has raised considerable concern for environmental protection and human health.

The most basic property of heavy metal is that they are bioavailable and are indestructible having toxic effects on living organisms when they exceed a certain concentration limit (Ridgway et al., 2002). Heavy metals may affect organisms by accumulating in their bodies or by transferring to the next trophic level of the food chain. Accumulated heavy metals in the tissues of aquatic animals and may become toxic when accumulation reaches a substantially high level (Yildirim et al., 2009). Aquatic organisms exposed to a higher concentration of heavy metals in water may take up substantial quantities of these metals (Kord et al., 2010). In the environment the metals are accumulated either directly from the surrounding water or by ingestion of food (Kumar et al., 1991). Accumulation of heavy metals in tissues mainly depends upon concentration of metals in water and exposure period; although some other environmental factors such as salinity, pH, hardness and temperature play significant roles in metal accumulation (Blackmore et al., 2003). Mussels and fish are specific indicators of different environmental compartments in relation to their habitat and food web position, and they exhibit different rates of bioaccumulation with respect to xenobiotics (Kord et al., 2010). Comparisons of levels of heavy metal pollution in aquatic environments are undertaken by analysis of water, sediments and members of indigenous biota, i.e. biomonitor (Nwuche et al., 2008). Marine organisms are characterized by a greater spatial ability to accumulate some metals when compared with bottom sediments. Mussels have been considered as a potential biomonitor for metallic contamination in marine ecosystems (Jung et al., 2008). Seasonal variations have a potential to affect metal concentrations in estuarine organisms due to
changes in physiochemical variables and some biological factors (Padmini et al., 2007). Excessive pollution of surface waters can lead to hazards in human health, either through drinking of water and/or consumption of contaminated seafood. Exposure to heavy metals can also affect reproduction efficiency of aquatic biota and can lead to a gradual extinction of their generations in polluted waters (Sridhara et al., 2008). Studies have aimed at examining the bioaccumulation and effects of various toxicants in marine animals due to the reason that, most of the organisms inhabit estuaries (Fialkowski et al., 2009). Fishes are major part of the human diet and it is therefore not surprising that numerous studies have been carried out on metal pollution in different species of edible fish (Karadede et al., 2000; Prudente et al., 1997; Unlu et al., 1996; Erdogrul., 2006). Predominantly, fish toxicological and environmental studies have prompted interest in the determination of toxic elements in seafood (Waqar, 2006).

2. Objective of Research

The main objective of this present study was to determine the heavy metals concentrations (Hg, Cu, Cr, Zn, Ni, Pb, Cd and as) in water and commercially important marine organisms from the Ennore creek, since this marine organisms is an important component of the human diet in this zone. The results obtained from this study would provide information for background levels of heavy metals in the water and marine organisms of the creek, contributing to the effective monitoring of both environmental quality and the health of the organisms inhabiting the marine ecosystem.

3. Materials and Methods

3.1 Study area

Ennore Creek (Fig. 1) located in the north eastern part of Chennai City; Tamil Nadu, India is spread over an area of 4 km along the coast of Bay of Bengal. The creek lies between Chennai City and Pulicat Lagoon which is 40 km North of Chennai city (Latitude 13° 15'N and Longitude 80° 19'E). Ennore Creek is a fresh/brackish water system, which is nearly 800 m wide and elongated in a NE-SW direction. Ennore Creek is complex, the average depth rarely exceeding 5 m in the non-monsoon period, being fed by Kortalaiyar River and the Buckingham Canal; it is also connected to the Pulicat brackish water lake on the northern side. Ennore is one of the major industrial regions of India, having two thermal power plants - North Chennai Thermal Power Station and Ennore Thermal Power Station both of them drawing coolant water from the creek. Manali industrial complex and the recently built Ennore satellite port are located in the northern section of the creek. The Buckingham Canal stretches as the Ennore creek in the north to Cooum River in the south and further southwards from there on. Several discharges enter this stretch of the Buckingham Canal from industrial sites such as Madras Refineries Ltd., (MRL) and Indian Oil Corporation etc. Municipal discharges also enter Ennore creek through a number of drains from the north Chennai area.

3.2 Sample collection

The surface sea water samples were collected from the Ennore creek (January to December 2011) and were kept in clean polyethylene bottles. Metal concentration in water samples were determined based on the ammonium pyrrolidine dithiocarbamateisobutyl methyl ketone (APDC-MIBK) extraction procedure (Grasshoff, 1976). The post-larvae of Penaeus monodon, (length 3.33±0.17cm and weight 1.90±0.10g) juvenile bivalves of Perna viridis (length 4.52±0.29cm and weight 6.33±0.11g) and Crossostrea madrasensis (length 5.46±0.24cm and weight 6.95±0.47g), the fingerlings of Mugil cephalus (length 5.34±0.21cm and weight 3.33±0.27g) and Terapon jarbua (length 4.22±0.35cm and weight 2.29±0.16g) was collected from the Ennore creek (January to December 2011). The metal content of the tissue samples was based on dry weight. The organisms collected from the field were sacrificed in the field and was stored to -4 °C and then transported to the laboratory and stored at -20 °C in the deep freezer until analysis.

Figure 1: Map showing sampling location of study area.
3.3 Sample analysis

After arrival in the laboratory, the collected samples were measured for their length and weight individually. Fish samples were gutted, viscera removed, beheaded, washed and filleted before frozen. Shellfish samples were also prepared by removing inedible parts, washed and frozen. All samples were kept at -75°C without any prior treatment. Before analysis, composite sample of each species was prepared by mixing and grinding homogenously the prepared samples using food processor. All composite samples were packed into polyethylene (PE) covered cup, stored in freezer at -20°C and analyzed within a week. Before digestion process, samples were dried for 72 hours at 60-70°C using air oven and grinded using mortar. The dry samples were weighed and crushed or homogenized using a porcelain mortar and stored in an air tight container. Ten grams of the dried, homogenized samples were weighed into 250 ml conical flask. Twenty ml of Perchloric acid (HClO₄) and twenty ml of Nitric acid (HNO₃) in a ratio of 1:1 were then added to the sample. The content was heated in a burner (digester) until the volume decreased to 5 ml with temperature not exceeding 160°C. The residue was energized with 5 ml 20% Hydrochloric acid (HCl) and filtered using Whatman no.1 filter paper into 100 ml volumetric flask and made up to the 100 ml mark with deionized water (APHA, 1989; O’Leary and Breen 1997). The filtered sample solutions were directly introduced into atomic absorption spectrometry (Perkin Elmer 800) for estimation of the heavy metals. The blanks were carried out in parallel with all analysis and the blank values were lower than 0.5% of the sample signals. Analysis of standards (MERCK, GERMANY) was done for every fifth sample to maintain the accuracy of analysis. International Reference Standards DORM-3 was run concurrently along with the samples and the obtained values are reported in Table 1.

4. Results

4.1 Heavy metals in water samples

The concentration of Hg in the water samples ranged from 1.45 to 2.13µg g⁻¹ with mean concentration of 1.78±0.20µg g⁻¹. The values of Cu were ranged from 45.29 to 51.02µg g⁻¹ with mean values of 47.27±1.17µg g⁻¹. The concentration of Cr was ranged between 11.60 to 15.75µg g⁻¹ with mean concentration of 14.13±1.44µg g⁻¹. The concentration of Zn ranged from 8.85 to 11.90µg g⁻¹ with mean concentration of 10.26±1.15µg g⁻¹. The concentration of Ni was varied from 12.01 to 15.69µg g⁻¹ with mean concentration of 13.98±1.12µg g⁻¹. The concentration of Pb was ranged between 4.10 to 6.20µg g⁻¹ with mean concentration of 4.93±0.77µg g⁻¹. The concentration of Cd was ranged between 8.15 to 24.18µg g⁻¹ with mean concentration of 14.55±4.42µg g⁻¹. The concentration of As was ranged between 2.12 to 3.05µg g⁻¹ with mean concentration of 2.57±0.29 µg g⁻¹. Heavy metal concentrations in the Ennore creek water decreased in the sequence of Cu > Cd > Cr > Zn > Pb > As > Hg.

Table 1: Recovery of trace elements in certified reference material (DORM-3) Dogfish liver certified reference material for trace metals (mg/kg)

<table>
<thead>
<tr>
<th>Reference materials</th>
<th>Certified values</th>
<th>Observed values</th>
<th>% of recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hg</td>
<td>4.64±0.26</td>
<td>4.51±0.11</td>
<td>97.20</td>
</tr>
<tr>
<td>Cu</td>
<td>2.34±0.16</td>
<td>2.20±0.07</td>
<td>94.36</td>
</tr>
<tr>
<td>Cr</td>
<td>34.7±5.5</td>
<td>34.22±0.18</td>
<td>98.62</td>
</tr>
<tr>
<td>Zn</td>
<td>25.6±2.3</td>
<td>24.91±0.2</td>
<td>97.33</td>
</tr>
<tr>
<td>Ni</td>
<td>19.4±3.1</td>
<td>18.90±0.3</td>
<td>96.93</td>
</tr>
<tr>
<td>Pb</td>
<td>0.065±0.007</td>
<td>0.0628±0.00</td>
<td>96.62</td>
</tr>
<tr>
<td>Cd</td>
<td>0.043±0.008</td>
<td>0.0412±0.00</td>
<td>95.81</td>
</tr>
<tr>
<td>As</td>
<td>18.02±1.1</td>
<td>17.33±0.2</td>
<td>96.19</td>
</tr>
</tbody>
</table>

Figure 2: Bioaccumulation of Heavy metals in Ennore creek (a) Penaeus monodon (b) Perna viridis (c) Crossostrea madrasensis (d) Mugil cephalus (e) Terapon jarbua
4.2 Heavy metals in marine organisms

The mean bioaccumulation of heavy metals in the marine organisms samples are given in Table 2. Heavy metal concentrations presents in the sequence for the *Peneaus monodon* as Cu > Cd > Zn > Ni > Pb > As > Hg > Cr, *Perna viridis* as Cu > Cd > Ni > Zn > Cr > Pb > As > Hg, for the *Crossosstrea madrasensis* as Cu > Zn > Ni > Cd > Pb > Cr > As > Hg, for the *Terapon jarbua* as Cu > Cd > Zn > Ni > Pb > Cr > As > Hg, and for the *Mugil cephalus* as Zn > Cd > Ni > Cu > Pb > Cr > As > Hg.

5. Discussion

The classification of the habitat was based on the living habitat (Majid, 2004). Knowledge on the living habitat is very important as it may represent the basis for accumulation of mercury and others heavy metals in fishes (Hajeb et al., 2009). Furthermore, many previous literatures stated that the occurrence of heavy metals including mercury and others were also related to length, weight and age of fish (Agusa et al., 2005; Demarco et al., 2006). This clearly indicates the influence of aquatic environments as well as surrounding human activities at specific point of time may contribute to accumulation of heavy metals in fishery products (Zhang et al., 2007). Accumulation of heavy metals in the aquatic environments have been associated with urban runoff, sewage treatment plants, industrial effluents and wastes, mining operations, boating activities, domestic garbage dumps and agricultural fungicide runoff (Alemdaroglu et al., 2003).

Table 2: Bioaccumulation of heavy metals (Mean ± SD) of Ennore creek (µg g⁻¹ in dry wt)

<table>
<thead>
<tr>
<th>Heavy metal</th>
<th><em>Peneaus monodon</em></th>
<th><em>Perna viridis</em></th>
<th><em>Crossosstrea madrasensis</em></th>
<th><em>Mugil cephalus</em></th>
<th><em>Terapon jarbua</em></th>
<th>Sea water</th>
<th>FAO/WHO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hg</td>
<td>0.90±0.11</td>
<td>0.85±0.16</td>
<td>0.43±0.07</td>
<td>0.41±0.07</td>
<td>0.68±0.10</td>
<td>1.78±0.20</td>
<td>5</td>
</tr>
<tr>
<td>Cu</td>
<td>9.30±2.96</td>
<td>22.35±2.42</td>
<td>30.84±0.89</td>
<td>2.75±0.53</td>
<td>14.56±0.66</td>
<td>14.72±1.71</td>
<td>10-100</td>
</tr>
<tr>
<td>Cr</td>
<td>0.51±0.27</td>
<td>4.93±1.02</td>
<td>3.30±0.23</td>
<td>1.77±0.67</td>
<td>2.32±0.38</td>
<td>14.13±1.44</td>
<td>50</td>
</tr>
<tr>
<td>Zn</td>
<td>15.86±0.67</td>
<td>8.32±0.74</td>
<td>7.57±0.55</td>
<td>9.78±1.02</td>
<td>5.00±0.53</td>
<td>10.26±1.15</td>
<td>30-100</td>
</tr>
<tr>
<td>Ni</td>
<td>3.62±1.37</td>
<td>9.14±1.45</td>
<td>7.42±0.46</td>
<td>4.34±0.66</td>
<td>4.53±0.46</td>
<td>13.98±1.12</td>
<td>10</td>
</tr>
<tr>
<td>Pb</td>
<td>4.37±0.33</td>
<td>3.42±0.29</td>
<td>4.00±0.29</td>
<td>2.59±0.31</td>
<td>3.42±0.29</td>
<td>4.93±0.77</td>
<td>0.05-6</td>
</tr>
<tr>
<td>Cd</td>
<td>19.25±0.53</td>
<td>11.26±1.14</td>
<td>6.20±0.40</td>
<td>6.58±0.61</td>
<td>5.81±0.46</td>
<td>14.55±4.42</td>
<td>0.05-5.5</td>
</tr>
<tr>
<td>As</td>
<td>1.82±0.58</td>
<td>2.05±0.23</td>
<td>1.37±0.20</td>
<td>1.54±0.40</td>
<td>1.75±0.39</td>
<td>2.57±0.29</td>
<td>86</td>
</tr>
</tbody>
</table>

(Celik et al., 2005) studied fourteen demersal, thirteen benthopelagic and nine pelagic species from Izmir Outer bay and the highest zinc concentration in the edible part of a demersal species was analysed in leaping grey mullet, *Liza saliens* with 692 µg g⁻¹, in a benthopelagic species in Mediterranean shad, *Alosa fallax* with 973 µg g⁻¹, and in a pelagic species in sardine, *Sardina pilchardus* with 944 µg g⁻¹. In the present study zinc levels were less concentration when compared with the above cited values, due to difference in age, size and varying ecological suits. Cadmium levels in the present study were higher to cadmium values reported from Tolo harbor (Hong-Kong) sampled from Tolo harbor (Hong-Kong) was due to the decrease in temperature and salinity due to precipitation. In the present studies showed that in the sequence order in *P. viridis* Cu> Cd> Zn>Pb, it may be environmental condition or release the more effluent from the industries.

The clam, *Sunetta scripta* tends to accumulate more metal during monsoon season and in smaller individuals against relatively higher load of metals from that of the larger ones (Pillai et., 1995). Bioaccumulation of zinc and copper were much higher in *Nemipterus japonicus*, cadmium in *S. scripta* and lead in *Metapenaeus dobsoni*. Inshore areas of Cochin containing trace metals in tissue and sediment showed the order of metal levels as Zn> Cu>Pb>Cd (Kaladharan et al., 2005). In the Ennore estuary, the concentrations of metals were significantly higher during summer than during the monsoon (Padmini et al., 2007). Metal accumulation could increase in the presence of dissolved organic carbon (Chandrasekhar et al., 2004). Pb is found to
be higher in locations that were located near industrial areas (Praveena et al., 2008). Generally, crustaceans accumulate some metals in direct proportion to the increase in the bioavailability from water and food chains (Rainbow et al., 1990). The level concentrations of heavy metals (essential and nonessential) were measured in different marine biota including cephalopoda, bivalve, crustacean and fish. The results reveal that these organisms show more or less the same order of distribution for each of the metals studied. The average concentrations of heavy metals exhibited the following decreasing order: cephalopoda>bivalve>crustacean>fish reported by (Ahdy et al., 2007). In the present study the bivalves accumulated higher proportions of Cu, Cr, Ni, As in Ennore creek than P. monodon and Hg, Cu, Cr, Ni, Pb, Cd, As in M. cephalus and T. jarbua. The order of highest heavy metal concentrations is as follows bivalves>crustaceans>fish. (Uluturhan et al., 2007) found lower results (0.07-0.21 µg g⁻¹ wet weight) for copper in Pagellus erythrinus caught from Eastern Aegean Sea. The values of copper in fish samples obtained in the present study were also higher with those reported by (Turkmen et al., 2006) (0.74 – 2.24 µg g⁻¹) for M. cephalus sampled from three stations in Iskenderun bay, Southeastern Turkey. These copper levels were within the permissible concentrations of (FAO, 1983) limit of 10-100 µg g⁻¹. Mean zinc concentrations in our study lower than (FAO, 1983) limit (30-100 µg g⁻¹). (Nammalwar, 1992) reported that the concentrations of copper, cadmium, lead and zinc in various tissues of Liza macrolepis inhabiting the Ennore estuary were found to be above the permissible safe levels. (Rajathy et al., 1996) reported that the levels of copper in water and sediment samples showed seasonal fluctuations in the Ennore estuary. Measurement of trace metals in M. cephalus at contaminated sites shows that this fish accumulates metals in response to contamination (Sahoo et al., 2005). It has been reported that M. cephalus surviving in the polluted Ennore estuary are subjected to severe oxidative stress potentially leading to cell death (Padmini et al., 2005).

The concentration of mercury in muscle tissues of different fish species from Ennore coast varied from 0.41 to 0.90 µg g⁻¹ (Table 2). The highest concentration was observed in Penaeus monodon (0.90 µg g⁻¹) and lowest was in Mugil cephalus (0.41 µg g⁻¹). The concentrations of Hg in fin fishes and shell fishes from Ennore coast were comparable with fishes from Malaysia (Hajeb et al., 2009), Mosa Bay, Persian Gulf (Mortazavi et al., 2011), Bangladesh (Sharif et al., 2008) and Thailand (Agusa et al., 2007). However, concentrations were lower than those reports on Gulf of Cambay (Reddy et al., 2007), west coast of India (Mukerjee et al., 2011) and higher than Saudi Arabia (Nawal Al-Bader, 2008; Waqar, 2004). In the present study different species of marine organisms from Ennore coast accumulated mercury in the order of: P. monodon>P. viridis>T. jarbua>C. madrasensis>M. The toxic kinetics of mercury is associated with its chemical form: elemental, inorganic and organic. The organic form, usually methyl mercury is more hazardous than both other forms. The liver and kidneys of stock animals, fish and shellfish tend to concentrate environmental mercury. Marine organisms possess a remarkable capacity to turn inorganic mercury into organic compounds, thus rendering mercury more easily transferable throughout the aquatic food chain. As a result, marine organisms contain mercury in levels up to 5 mg/kg (Dudka et al., 1999). Earlier studies have shown that fish consumption may constitute an important source of mercury exposure for health (Fakour et al., 2010; Díez et al., 2008).

There was considerable variation of arsenic levels among the marine organisms from the Ennore coast. The concentration of Arsenic was in range of 1.37 to 2.05 µg g⁻¹ (Table 2). Comparatively higher concentration range was observed in P. viridis and P. monodon. The observed concentrations of arsenic in muscle tissue were lower than those reported from Gulf of Cambay in North West coast of India (Reddy et al., 2007), higher than west coast of India (Mukerjee et al., 2011); Fangauta Lagoon, Tonga (Morrison et al., 2003); Pahang estuary, Thailand (Rattanachongkiat et al., 2004) and American Samoa, south pacific ocean (Peter et al., 2007), but higher levels than our observations were observed in fishes from west coast of India (Mukerjee et al., 2011), Gresik coastal waters of Indonesia (Agoes et al., 2007).

(Ahmed et al., 2009b) studied the heavy metal concentration in fish from the Shitalakhya River, Bangladesh and found the seasonal variation of Cd (0.52-0.8 mg kg⁻¹), Cr (9.38-19.65 mg kg⁻¹), Pb (7.03-12.18 mg kg⁻¹), Cu (7.55-11.50 mg kg⁻¹) and Ni (9.55-13.35 mg kg⁻¹). The present study shows slightly higher concentration of Cu, Cd and slightly lower concentration of Cr, Ni Pb than the above author. (Ashraf, 2006) studied 57 samples of...
canned tuna fish and found the concentration of Pb, Cr, Cd, Cu, Ni, and Hg ranged between 0.14 and 0.82, 0.10 and 0.57, 0.08 and 0.66, 0.02 and 0.33, 0.09 and 0.48 and 0.18 and 0.86 mg/kg respectively, which are much lower than the present findings. (Burgera et al., 2005) found As, Cd, Pb, Mn and Hg ranged from 0.23 to 3.3, 0.0001 to 0.01, 0.04 to 0.12, 0.1 to 1.0 and 0.05 to 0.6 ppm, respectively in the flounder, bluefish, yellow fin tuna, Chilean sea bass, cod, croaker, porgie, red snapper, whiting, shrimp (large and small), and scallops of New Jersey, USA, which are also less than the current studies. They found inter-specific differences in levels of metals for all metals. However, the same metals in fish did not have the highest values for more than two metals. They suggested that the differences were due to geography, trophic level, size, foraging method/location, and propensity of metals to undergo bio-magnification in the food chain. (Haque et al., 2006) studied the seasonal variation of heavy metal concentrations in Gudusia chapra inhabiting the Sundarban mangrove forest and found the concentration of Cu, Zn, Cd, Cr and Ni seasonally varied from 0.527 to 3.99, 5.34 to 25.9, 0.038 to 0.221, 0 to 3.396 and 0.176 to 89.5 µg g⁻¹ dry weight basis, respectively. The concentrations of Zn, Ni well high and Cu, Cd, Cr very low compare to the present analysis.

Conclusion

In view of the importance of finfish and shell fish to diet of human, it is necessary that biological monitoring of the water and fish meant for consumption should be done regularly to ensure continuous safety of the seafood. Safe disposal of domestic sewage and industrial effluents should be practiced and where possible, recycled to avoid these metals and other contaminants from going into the marine environment. Laws enacted to protect our marine environment should be enforced. The activities at the upper-course of the Ennore creek should be kept under strict surveillance as they are capable of increasing the heavy metals discharge into the creek, especially as population is bound to increase. The values reported in this study can serve as baseline data to monitor future anthropogenic activities along the coast. The study showed a need for continuous pollution assessment study of aquatic organisms in the marine environment.

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