Bioaccumulation of Toxic Heavy Metals in the Edible Soft Tissues of Green Mussel (*Perna viridis* L.) of Mahe Region

Project report submitted to the Department of Science, Technology and Environment (DSTE), Government of Pondicherry

By

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Introduction

Human exploitation of world mineral resources and advance in industrialization has resulted in high levels of heavy metals in the environment. The aquatic bodies near the industrial and urban area are more prone to the accumulation of such metals. The presence of heavy metals causes hazardous impact on the flora and fauna of earth. There are number of toxic heavy metals, whose increasing levels in the environment are of serious concern today. They are released in large concentration through effluent discharges from industries, ore and metal processing, paints and pigment production, biocides production, tanning, electroplating, textile dyeing etc. The mobility of toxic metals is related to their solubility in water and once migrated to the environment, these elements get concentrated as they progress through the food chain. The concentrations of toxic metals are more in the bottom dwellers of aquatic environment especially in molluscs and polychaets.

Green Mussel (*Perna viridis* L.)

**Classification.** Kingdom: Animalia  
Phylum: Mollusca  
Class: Bivalvia  
Subclass: Lamellibranchia  
Order: Mytiloida  
Family: Mytilidae  
Genus: *Perna*  
Species: *viridis* (Linnaeus 1758)
**Common Name:** Asian Green Mussel

The bivalve ‘green mussel’ (*Perna viridis* L.) is a native to Asia-Pacific region where it is widely distributed ([Fig-1](#)). It is primarily found in estuarine habitat with salinities ranging from 18-33 ppt and temperatures from 11-32\(^{0}\)C. *Perna viridis* is a large mussel, 80-100 mm in length, occasionally reaching 165 mm (Rajagopal *et al.*, 1998). The shell has a smooth exterior surface characterized by concentric growth lines and slightly concave ventral margin with a bright green colour in young and fading to brown with green edges as it matures.

The sexes of the species are separate and fertilization is external. Spawning generally occurs twice in the year (Chatterji *et al.*, 1984). Fertilized egg develops in to larvae and remains in the water column for two weeks. During this planktonic period, larvae will be widely dispersed by physical processes, but may aggregate periodically at certain depths through a variety of biological processes, most notably vertical migration (Hayes *et al.*, 2005). The larvae completely metamorphose in eight to twelve days of growth. Sexual maturity typically occurs at 2-3 months of age with a length of about 15-30mm (Benson *et al.*, 2001). *Perna viridis* has the greatest growth rate of the mussels studied, which have a life span of about 2-3 years (Shafee, 1979). Maximum growth of the green mussel occurs 2m below the surface because of the increased productivity of the water at that depth and a narrow area of temperature and salinity fluctuation (Sivalingam, 1977).

*Perna viridis* L. (‘kallummekkaya’) is commonly available, popular and most consumed seafood in Mahe region. It is available throughout the year and consumes by making various preparations.
Factors related to the overall toxicity of the chemical elements

The "noncritical" elements include alkali metals, alkaline earths, halogens and a few others. Calling them noncritical is not to say that toxic compounds of these elements do not exist; rather, these are the least problematic in general. Other elements are more or less toxic and more or less accessible in a generic polluted environment. Notice that more toxic metals tend to be in the center of the periodic chart and thus are moderately electronegative. In general it is many of these metals' ability to make covalent or partially covalent bonds with natural Lewis bases found in organisms (O, N and S bearing molecules) that allow them to disrupt biochemical functions and result in adverse effects. Ironically, Lewis acid behavior of some of these metals also can make them essential nutrients at other times (e.g., Co, as in B vitamins).
Table-1 Classification of elements according to toxicity and availability

<table>
<thead>
<tr>
<th></th>
<th>Non-critical</th>
<th>Toxic but very insoluble or very rare</th>
<th>Very toxic and relatively accessible</th>
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<tr>
<td>Na</td>
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<td>Mg</td>
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<td>H</td>
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<tr>
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<td>Br</td>
<td>Si</td>
<td>Ta</td>
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<tr>
<td>N</td>
<td>Re</td>
<td>Ba</td>
<td>Cr</td>
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</table>

The third category includes all the toxic heavy metals, which mainly accumulates in the aquatic biotic communities. The major sources of these toxic elements are given in Fig – 2. All these elements reach the ocean floor through estuarine region, which connects fresh water bodies to the marine ecosystem. Though estuarine region are highly productive, dynamic and much diversified regions, the entry of these elements in the biotic system is much easier. From the estuarine biotic communities the bottom dwelling mollusks have a tremendous capacity of bioaccumulation. Since the estuaries are more prone to the accumulation of all toxic elements and chemicals there is a higher chance of accumulation in the body of mollusks. In the dynamic lotic riverine ecosystem deposition and accumulation of such elements are rare because of its fluvial dynamics. But due to the continuous and alternate tidal actions, the retention times for such elements are high in the estuarine region, which results in the better chance for their entry in to the biotic communities. The fast growing and highly edible green mussel in the estuarine region are more susceptible to heavy metal accumulation and act as a route of toxicity to human population.
Figure -2. Route of metals and pollutants in to the environment (Nisbet and Sarofim, 1976)

**Flow of nutrients in the estuarine ecosystem**

The flow of elements through different trophic level through food chain and the role of mollusk in the route are given in **fig –3**. Mollusks are filter feeders, which feed on algae, zooplanktons and excreta of all aquatic vertebrates mainly present in the bottom
Molluscs are the major bottom feeders in the estuarine ecosystem, which also have tremendous capacity to accumulate all the microelements present in their food. Mollusks are considered as the main bioaccumulators of pesticides, heavy metals, toxic chemicals etc. Calcium carbonate are the major constituent present in the calcareous protective shell of mollusks and the rest is edible soft pertinacious tissues, in which the toxic elements accumulates. Heavy metals are the class of highly toxic elements, causing great health problem to human life through bioaccumulation from the edible bivalves (Fig-3). Some major such heavy metals are

**Figure -3.** Food chain model for heavy metals
1. Lead (Pb)

Lead is a highly toxic substance, exposure to which can produce a wide range of adverse health effects. Both adults and children can suffer from the effects of lead poisoning, but childhood lead poisoning is much more frequent. Even today, at minimum more than four hundred thousand children under the age of six who have too much lead in their blood. There are many ways in which humans are exposed to lead: through deteriorating paint, household dust, bare soil, air, drinking water, food, ceramics, home remedies, hair dyes and other cosmetics. Much of this lead is of microscopic size, invisible to the naked eye. More often than not, children with elevated blood lead levels are exposed to lead in their own home. Young children under the age of six are especially vulnerable to lead's harmful health effects, because their brains and central nervous system are still being formed. For them, even very low levels of exposure can result in reduced IQ, learning disabilities, attention deficit disorders, behavioral problems, stunted growth, impaired hearing, and kidney damage. At high levels of exposure, a child may become mentally retarded, fall into a coma, and even die from lead poisoning. In adults, lead can increase blood pressure and cause fertility problems, nerve disorders, muscle and joint pain, irritability, and memory or concentration problems. When a pregnant woman has an elevated blood lead level, that lead can easily be transferred to the fetus, as lead crosses the placenta. In fact, pregnancy itself can cause lead to be released from the bone, where lead is stored—often for decades—after it first enters the blood stream.
2. Cadmium (Cd)

Cadmium is widely distributed in earth’s crust and it is principally used as the stabilizers and pigments in plastics and in electroplating. Molluscs accumulate large concentration of calcium ranging from 1900-2000p.p.m. dry weight (Clark, 1992). Highest concentration in cadmium causes several health problems in human. Cadmium and its compounds along with mercury and some other dangerous metals are, however, included in the blacklist. It is being used routinely in different industrial processes and its potential hazard to life form is predominant. Eating food or drinking water with very high cadmium levels severely irritates the stomach, leading to vomiting and diarrhea, and sometimes death. Eating lower levels of cadmium over a long period of time can lead to a build-up of cadmium in the kidneys. If the levels reach a high enough level, the cadmium in the kidney will cause kidney damage, and also causes bones to become fragile and break easily. As a conservative approach, and based on the limited human data and the studies in rats, the United States Department of Health and Human Services (DHHS, 1999) has determined that cadmium and cadmium compounds may reasonably be anticipated to be carcinogens.

3. Chromium (Cr)

Chromium is the naturally occurring compound found in soil, rocks and plants. It is normally exists in oxidation states ranging from chromium (II) to Chromium (VI). However, two major forms trivalent (III) and hexavalent (VI) forms have biological significance. The major source of chromium emission in to the environment from the chemical manufacturing industry, combustion of fossil fuel, cement producing plants,
waste from electroplating, leather tanning, textile industry and consumer products such as inks, paints, papers, toner powder used in copying machine etc.

Physiologically chromium is considered as a trace element and it is required for the optimum function of insulin in mammalian tissues and the maintenance of normal metabolism of glucose, cholesterol and fat. The normal level of blood chromium concentration in human beings is between 20-30 µg/l. It is found that the intake of chromium is about 50-200 µg/day is regarded to be safe and adequate.

Hexavalent chromium is an extremely toxic metal, which exist as an anion (CrO$_4^{2-}$) and most readily absorbed from the gastrointestinal tract, skin and lungs. Most reports describe the toxicity of chromium (VI) in the form of chromate of dichromate. It can cause chronic ulceration of skin surface, denaturation of tissue proteins, Asthma, kidney failure, discoloration of teeth and inflammation of skin. Acute poisoning results in symptoms such as dizziness, intense thirst, abdominal pain, vomiting and shock and sometimes death may occur due to the presence of urea in blood.

4. Copper (Cu)

The natural input of copper to the marine environment from erosion of mineralized rocks. Anthropogenic inputs of copper are from the production of electrical equipments, as chemical catalysts, as antifouling agents in paints, as algicides, in alloys, and as wood preservatives. Copper dissolved in seawater is chiefly in the form of CuCO$_3$ or in reduced salinity as CuOH$^+$. It also forms complexes with organic molecules. Mollusks have a
tremendous capacity to accumulate copper from contaminated waters. Reports are saying the copper concentration factor for oysters growing in contaminated waters are 7500 and they may accumulate 2000 ppm. of copper in their blood (Clark, 1992).

5. Nickel (Ni)

Nickel is a silver-white metal with siderophilic properties that facilitate the formation of nickel-iron alloys. In contrast to the soluble nickel salts (chloride, nitrate, sulfate), metallic nickel, nickel sulfides, and nickel oxides are poorly water-soluble. Nickel carbonyl is a volatile liquid at room temperature that decomposes rapidly into carbon monoxide and nickel. Drinking water and food are the main sources of exposure for the general population with the average American diet containing about 300 µg Ni/d. Nickel is highly mobile in soil, particularly in acid soils. There is little evidence that nickel compounds accumulate in the food chain. Nickel is not a cumulative toxin in animals or in humans. The initial effects involve irritation of the respiratory tract and nonspecific symptoms. Patients with severe poisoning develop intense pulmonary and gastrointestinal toxicity. Diffuse interstitial pneumonitis and cerebral edema are the main cause of death.

Nickel is a common sensitizing agent with a high prevalence of allergic contact dermatitis. Nickel and nickel compounds are well-recognized carcinogens. However, the identity of the nickel compound or compounds, which cause the increased risk of cancer, remains unclear. Currently, there are little epidemiological data to indicate that exposure to metallic nickel increases the risk of cancer, or that exposure to the carcinogenic forms of nickel causes cancer outside the lung and the nasal cavity.
6. Zinc (Zn)

Zinc is an essential element to human being. Zinc is widely seen in nature. The natural concentration of zinc in soil estimated to be 10-30 mg/kg. Zinc is used in coating of other metals, in alloys and many common goods. Besides this zinc is used for wood preservation, catalyst, ceramic, fertilizers, batteries, paints, explosives household and medical appliances. According to WHO (1996) the dietary requirement of zinc up to 22mg/day, which is equivalent to 0.3mg/kg bw/day.

Gastrointestinal absorption of zinc varied substantially from 8-80%. The absorption decreases after ingestion with calcium and phosphorus. This is due to the precipitation of zinc in the intestine. Dermal absorption of zinc also noticed. There is little information about the toxicity of zinc exposure. Chronic exposure of zinc leads to anemia.
Objectives

The proposed project work envisages a detailed study of

1. Continuous evaluation of the concentration of various heavy metals at different stages of life in the soft tissues of *Perna viridis* L.

   a. to understand the quantity of lead in the edible part of the green mussel.

   b. to know how much cadmium is accumulated in the mussel.

   c. to ascertain the strength of chromium in the soft tissues of the mussel for explaining the probable health hazards related with if any.

   d. to explain the amount of copper and its probable impacts associated with.

2. To ascertain the ratio of different heavy metals concentration if any in the soft body of the green mussel.
Materials and methods

Sampling
Three different locations in the Mahe estuarine regions were selected for the sample collection. Specimens were collected from the rocks at every month during low tide from all the different sites using chisel. The collected specimens were analyzed for various heavy metals.

Test for heavy metals

Entire soft edible tissues of animal wee homogenized and the tissue homogenate were tested using gravimetric and spectrophotometric methods for various heavy metals like lead, cadmium, chromium, and copper. All the tests were done in triplicate and results were compared with control.

a. Analysis of Lead

Lead in the sample is estimated gravimetrically as lead sulphate (PbSO$_4$). The tissue homogenate is treated with nitric acid to dissolve the same. Lead present in the sample is precipitated as lead sulphate (PbSO$_4$) using concentrated sulphuric acid (Arthur I. Vogel, 1969).

b. Analysis of Cadmium

Cadmium present in the tissue homogenate of *Perna viridis* (L.) also estimated gravimetrically after precipitating it with 2-(o-hydroxyphenyl)-benzoxazole complex (Arthur I. Vogel, 1969).
c. Analysis of Chromium

The concentration of chromium in a solution is determined spectrophotometrically at 540nm, using 2,5 –Diphenyl carbazide as complexing agent. To about 10 ml of the tissue homogenate, 0.83 ml of 3M H$_2$SO$_4$ was added followed by 1ml of 2.5 –Diphenyl carbazide solution (A 0.25% (w/v) solution was prepared in 50% (v/v) distilled acetone). After 10 minutes, the concentration of pink colour solution was analyzed for Cr (VI) ions (Eaton et al., 1995).

d. Analysis of Copper, Zinc and Nickel

The quantity of copper, zinc and nickel were estimated with the help of VA trace analyzer (M/s Orion, Japan, from CSIR Trivandrum, Kerala) after acid hydrolysis (with 50% HNO$_3$) of the edible part of the soft tissues of green mussel (Eaton et al., 1995).

Results and Discussion

1. Growth rate

Studies shows that *Perna viridis* L. traditionally called ‘kallummekkaya’ in the region have steady growth from the second moth onwards. The estuarine region of Mahe represents high nutrient rich area with comparatively high tidal and wave action. Blackmore and Wang (2003) have reported that the growth of green mussel influenced by nutrient level of the habitat and physicochemical factors, especially water current through tidal and wave action. The fully grown mussel reach a length group 10-13 cm with one
Heavy metal accumulation studies

year (fig-4). Initially the mussel have comparatively lesser growth and which attain steady after a month.

Figure -4. Growth rate (shell length) of Perna viridis L. in a year

2. Weight gain

The mussels have a maximum weight gain of about 140g with 13 month of age. The weight gain of the mussel is linear up to 10\textsuperscript{th} month and a sudden increase in the weight was observed during the period between 10\textsuperscript{th} and 12\textsuperscript{th} month (Fig-5). In the initial period the weight gain of the animal is so negligible and which attain a steady increase from the second month onwards. However, the weight gain of edible soft tissues reported to have a steady increase from 2\textsuperscript{nd} month onwards and reaches a value of 68g. with a period of 12 month of growth.
The edible soft parts have reported with about 80-85% of moisture content (Fig-6). The moisture seems reduce after 12 months of age. This weight lose may be due to salinity change due to the large influx of fresh water during the monsoon season from June to August.

**Figure -5.** Weight gain of green mussel (with shell) in a year

**Figure -6.** Weight of edible soft tissues of green mussel
Heavy metal accumulation

The toxicity of heavy metals has been reported to follow the general order of Zn < Pb < Ag < Cd < Cu < Hg, which may vary depending on environmental conditions and species (Rai et al., 1981). Heavy metals are among the major environmental hazards due to their affinity for metal sensitive groups, such as thiol groups. Heavy metals block functional groups of proteins, displace and/or substitute essential metals, induce conformational changes, denature enzymes and disrupt cells and organelle integrity (Hall, 2002).

Toxic heavy metals accumulations in green mussel are of great economic importance. Their presences in higher concentrations in the edible soft tissues are of great health concern. Higher concentrations of heavy metals like Pb, Cd, Cr and Cu in the green mussel _Perna viridis_ L. were reported by Shin _et al._ (2002); Blackmore and Wang (2003); Wnag and Wong (2003); Yap _et al._ (2003); Yap _et al._ (2004); Pan and Wand (2004); Liuand and Kueh (2005); Yap _et al._ (2006). Fung _et al._ (2004) reported that due to industrial activity the heavy metal concentration such as As, Cd, Cr, Ni, Pb, Se, Zn, Cu, Fe and Hg were increased in the body of _Perna viridis_ and _Mytilus edulis_ in the east coast of China.

**Copper (Cu)**

The copper concentration in the edible soft tissues of _Perna viridis_ of Mahe estuary ranges from 0.05 to 22.64 µg/g dry wt. in the different age group (Table-2). Copper is the abundant metal present in the body fluid of mollusks. According to WHO (1996) daily
Heavy metal accumulation studies

Copper intake 1-5 mg/L is needed for adult. This is equal to daily requirement of 80 µg/g bw/day. It is reported that copper concentration factor for oysters growing in contaminated waters are 7500 and they may accumulate 2000 ppm. of copper in their blood (Clark, 1992).

**Table-2.** Copper concentration in the edible tissues of *Perna viridis* L. in Mahe estuary

<table>
<thead>
<tr>
<th>Age (in months)</th>
<th>Site-1 (µg/g dry wt.)</th>
<th>Site-2 (µg/g dry wt.)</th>
<th>Site-3 (µg/g dry wt.)</th>
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<tr>
<td>1</td>
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<tr>
<td>3</td>
<td>0.05</td>
<td>0.08</td>
<td>0.09</td>
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<tr>
<td>5</td>
<td>5.06</td>
<td>5.95</td>
<td>5.81</td>
</tr>
<tr>
<td>8</td>
<td>12.01</td>
<td>13.33</td>
<td>11.97</td>
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<tr>
<td>10</td>
<td>16.40</td>
<td>18.21</td>
<td>15.20</td>
</tr>
<tr>
<td>12</td>
<td>21.44</td>
<td>22.64</td>
<td>22.08</td>
</tr>
</tbody>
</table>

**Cadmium (Cd)**

The cadmium concentration in the edible tissues of *Perna viridis* L. in Mahe estuary ranges from 0.085 to 1.67 µg/g dry wt. (Table-3). It is observed that the cadmium concentration increasing with growth and aging of the animal. There is slightly higher level of cadmium is reported in the region. The acceptable range of cadmium in food specified by Food and Drug Administration (USA) is at 7 g/kg body weight/week. The reported concentration in Mahe is not so alarming to human health. However continuous intake of *Perna viridis* L. as food may causes health concern. The reported concentration of cadmium in the tissues of *Perna viridis* L. in Peninsular Malaysia were 0.68-1.25 µg/g.
Heavy metal accumulation studies

Dry wt. (Yap et al., 2004), 1.20 mg kg⁻¹ dry weight in the gulf of Thailand (Ruangwises and Ruangwises, 1998) and 5.31 µg/g dry wt. in the east coast of China (Fung et al., 2004). However, Blackmore and Wang (2003) have reported that the factors like salinity, temperature and planktonic diversity and richness influenced the uptake of lead in bivalves.

Table-3. Cadmium concentration in the edible tissues of *Perna viridis* L. in Mahe estuary

<table>
<thead>
<tr>
<th>Age in months</th>
<th>Site-1 (µg/g dry wt.)</th>
<th>Site-2 (µg/g dry wt.)</th>
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<td>0.085</td>
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<td>0.33</td>
<td>0.60</td>
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<tr>
<td>12</td>
<td>1.02</td>
<td>1.59</td>
<td>1.67</td>
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</table>

Cadmium is a cumulative toxicant and the human exposure route of most concern is long-term exposure to elevated levels of cadmium in the diet. In the body, cadmium is primarily bound to metallothionein and these complexes are filtered in the kidney so that cadmium accumulates in the renal cortex. Signs of renal dysfunction are the first indications of chronic cadmium toxicity. Cadmium affects the reabsorption capabilities of the proximal tubules and protein in the urine is the first effect to be detected. Later signs include amino acids and glucose in urine, and decreased ability to concentrate urine. There are also abnormalities in the handling of uric acid, calcium and phosphorus, which can lead to kidney stones and osteomalacia.
It is widely accepted that an accumulation of more than 200 g/g (wet weight) in the renal cortex leads to renal toxicity. Renal cortical levels exceeding 200 g/g cause tubular damage kidney, although the health impact of early kidney damage is difficult to assess. Based on this and with assumptions about absorption and excretion rates, the WHO/FAO Joint Expert Committee on Food Additives and Contaminants set the PTWI for cadmium at 7 g/kg body weight/week.

**Lead (Pb)**

Lead concentration in the edible soft tissues of *Perna viridis* L. in Mahe estuaries ranges from 1.01 to 6.27 µg/g dry wt. (Table-4) in the animals of different age groups. It is also observed that the concentration of lead is increasing with age and growth of the animal. However, the values are slightly upper than the permissible limit to human beings. Overall, the findings demonstrated that the bivalves are safe for human consumption and that the ecosystems where they were harvested do not pose any hazard to man or to marine life. However, caution should be taken if these bivalves are to be considered for feeding children. For example, the FAO/WHO recommendation for lead is 5 µg/kg body weight/day for adults. However, children have about five times the gastrointestinal absorption rate of adults and consumption of these bivalves by children may predispose them to lead exposure. Similar results of lead concentration ranging from Pb and 75.1 to 129 µg/g dry wt. west coast of Peninsular Malaysia (Yap, 2003, 2004), 2.02 to 4.36 µg/g dry wt. in Hong Kong (Wong, 2000) in the edible tissues of *Perna viridis* L were reported.
Blackmore and Wang (2003) have reported that the factors like salinity, temperature and planktonic diversity and richness influenced the uptake of lead in bivalves.

There are many different health effects associated with elevated blood lead levels. Young children below six years are especially vulnerable to lead's harmful health effects, because their brains and central nervous system are still being formed. For them, even very low levels of exposure can result in reduced IQ, learning disabilities, attention deficit disorders, behavioral problems, stunted growth, impaired hearing, and kidney damage. At high levels of exposure, a child may become mentally retarded, fall into a coma, and even die from lead poisoning. Lead poisoning has also been associated with juvenile delinquency and criminal behavior (Schaumberg et al., 2004).

**Table-4.** Lead concentration in the edible tissues of *Perna viridis* L. in Mahe estuary

<table>
<thead>
<tr>
<th>Age in months</th>
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<td>5.99</td>
<td>6.11</td>
<td>6.27</td>
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Chromium (Cr)

The chromium concentration in the edible soft tissues of *Perna viridis* L. in Mahe estuaries ranges from 1.06 to 2.93 µg/g dry wt. (Table-5) in the animals of different age groups. The reported values are slightly above the range of the permissible limit. The FDA has determined that the chromium concentration in bottled drinking water/food should not exceed 0.1 mg/L. The normal level of blood chromium concentration in human beings is between 20-30 µg/L. It is found that the intake of chromium is about 50-200 µg/day is regarded to be safe and adequate. The reported concentration of chromium in the tissues of *Perna viridis* L. in Peninsular Malaysia were 0.82-4.89 µg/g dry wt. (Yap et al., 2004), 15.72 mg kg⁻¹ dry weight in the gulf of Thailand (Ruangwises and Ruangwises, 1998) and 5.31 µg/g dry wt. in the east coast of China (Fung et al., 2004).

Hexavalent chromium is an extremely toxic metal, which exist as an anion (CrO₄²⁻) and most readily absorbed from the gastrointestinal tract, skin and lungs. Most reports describe the toxicity of chromium (VI) in the form of chromate of dichromate. It can cause chronic ulceration of skin surface, denaturation of tissue proteins, Asthma, kidney failure, discoloration of teeth and inflammation of skin. Acute poisoning results in symptoms such as dizziness, intense thirst, abdominal pain, vomiting and shock and sometimes death may occur due to the presence of urea in blood.
Table-5. Chromium concentration in the edible tissues of *Perna viridis* L. in Mahe estuary

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</table>

Zinc (Zn)

The zinc concentration studies in the edible soft tissues of different age group samples of *Perna viridis* L. in Mahe estuary shows that it ranges from 9.38 to 122.30 µg/g dry wt. (Table-6). Zinc is an essential element to human being. Zinc is widely seen in nature. The natural concentration of zinc in soil estimated to be 10-30 mg/kg. According to WHO (1996) the dietary requirement of zinc up to 22mg/day, which is equivalent to 0.3mg/kg bw/day. There is little information about the toxicity of zinc exposure. The results suggests that *Perna viridis* L. is rich source of zinc which is good for human health. The reported values of zinc in the tissues of *Perna viridis* L. in Peninsular Malaysia were 90-135 µg/g dry wt. (Yap et al., 2004), 94.48 mg kg⁻¹ dry weight in the gulf of Thailand (Ruangwises and Ruangwises, 1998) and 7.4 µg/g dry wt. in the east coast of China (Fung et al., 2004).
Table-6. Zinc concentration in the edible tissues of *Perna viridis* L. in Mahe estuary

<table>
<thead>
<tr>
<th>Age in months</th>
<th>Site-1 (µg/g dry wt.)</th>
<th>Site-2 (µg/g dry wt.)</th>
<th>Site-3 (µg/g dry wt.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.26</td>
<td>9.38</td>
<td>9.67</td>
</tr>
<tr>
<td>3</td>
<td>25.43</td>
<td>24.68</td>
<td>26.01</td>
</tr>
<tr>
<td>5</td>
<td>42.38</td>
<td>41.30</td>
<td>41.98</td>
</tr>
<tr>
<td>8</td>
<td>78.64</td>
<td>76.76</td>
<td>72.30</td>
</tr>
<tr>
<td>10</td>
<td>107.00</td>
<td>90.68</td>
<td>93.50</td>
</tr>
<tr>
<td>12</td>
<td>122.30</td>
<td>121.72</td>
<td>118.33</td>
</tr>
</tbody>
</table>

Nickel (Ni)

The Nickel concentration studies in the edible soft tissues of different age group samples of *Perna viridis* L. in Mahe estuary shows that it ranges from 9.38 to 122.30 µg/g dry wt. (Table-7). Nickel is not a cumulative toxin in animals or in humans. The nickel metabolism depends on the presence of other metals; presence of other metals like magnesium and manganese strongly antagonize the binding of nickel to phosphate. Soluble nickel is excreted through urine, small amount of nickel excretes through feces. Hair is also excretory tissue for nickel. Information about oral poisoning of nickel is not lethal. It is reported that the concentration of nickel in the tissues of *Perna viridis* L. in Peninsular Malaysia were 3.25-6.87 µg/g dry wt. (Yap et al., 2004), 1.54 mg kg-1 dry weight in the gulf of Thailand (Ruangwises and Ruangwises, 1998) and 4.78 µg/g dry wt. in the east coast of China (Fung et al., 2004).
Table-7. Nickel concentration in the edible tissues of *Perna viridis* L. in Mahe estuary

<table>
<thead>
<tr>
<th>Age in months</th>
<th>Site-1 (µg/g dry wt.)</th>
<th>Site-2 (µg/g dry wt.)</th>
<th>Site-3 (µg/g dry wt.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>0.03</td>
<td>0.09</td>
</tr>
<tr>
<td>5</td>
<td>0.31</td>
<td>0.44</td>
<td>0.89</td>
</tr>
<tr>
<td>8</td>
<td>1.60</td>
<td>1.80</td>
<td>2.01</td>
</tr>
<tr>
<td>10</td>
<td>3.01</td>
<td>3.06</td>
<td>3.81</td>
</tr>
<tr>
<td>12</td>
<td>4.89</td>
<td>5.07</td>
<td>5.21</td>
</tr>
</tbody>
</table>

In the graph showing the average concentration of toxic heavy metals in the edible part of the green mussel reveals that the accumulation rate was almost linear with the growth of the animal (Fig-7&8). However, exponential rate of chromium accumulation starts from eighth month onwards (Fig-7). The accumulation of lead and copper is in straight line from the second month of its growth. Among the estimated heavy metals zinc and copper concentration is more and least value represented by cadmium. However, the toxic potential of cadmium is very high and its concentration in the mussel is in the upper range of permissible level. Lead is the other metal along with cadmium occupies an upper range in concentration.
Figure -7. Average concentration of bioaccumulated heavy metals in the edible soft tissues of *Perna viridis* L. of different age group in Mahe estuary.

![Graph showing concentration of heavy metals over age in months](image1)

Figure -8. Average concentration of bioaccumulated heavy metals in the edible soft tissues of *Perna viridis* L. of different age group in Mahe estuary

![Graph showing concentration of copper and zinc over age in months](image2)
Conclusion

The edible soft tissues of *Perna viridis* L. available in Mahe estuary were analyzed from September 2007 to August 2008 for heavy metals like cadmium (Cd), lead (Pb), chromium (Cr), zink (Zn), nickel (Ni) and copper (Cu). The metal concentration of mussel collected in the study sites were Cd (0.085-1.67 µg/g dry wt.), Pb (1.71 to 6.27 µg/g dry wt.), Cr (0.13 to 2.93 µg/g dry wt.), Zn (41.3 to 121.72 µg/g dry wt.), Ni (0.31 to 5.21 µg/g dry wt.) and Cu (5.06 to 22.64 µg/g dry wt.). It was noted that the concentration of metals increases with the age and growth. But, from the study site too little mussel were collected with more than one year of age because almost all the animals were harvested every year for consumption or due to large influx of fresh water during the monsoon season (June to August) the coastline rocky bivalves were totally eradicated because of very low salinity in the study area. The animal found to have a steady growth from 2\textsuperscript{nd} month to 12\textsuperscript{th} month. The weight gain studies also revealed that maximum weight gain achieved by the animal simultaneous to the growth. All the studied metals are in the acceptable range of concentration. However, concentration of lead and cadmium were reported slightly in the upper range of acceptable concentration. Overall, the findings demonstrated that the bivalves are safe for human consumption and that the ecosystems where they were harvested do not pose any hazard to man in terms of health risk. However, caution should be taken if the bivalves are continuously used; especially children have about five times more gastrointestinal absorption rate of adults.
Acknowledgement

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References


Heavy metal accumulation studies


**Dr. K.M. Gopinathan**