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Health risk assessments of heavy metal exposure via consumption of marine mussels collected from anthropogenic sites

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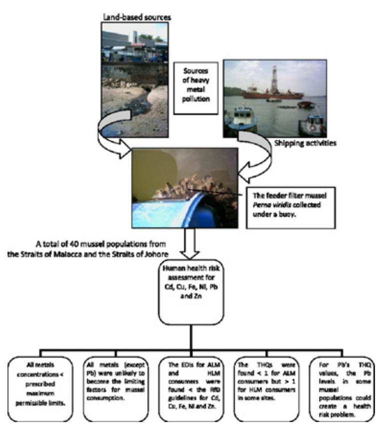
HIGHLIGHTS

- Human health risk assessments of heavy metals in *Perna viridis* were investigated.
- All metals in the mussels were below the established seafood safety guidelines.
- Pb in mussels could easily reach the percentage of prescribed PTWI value of Pb.
- Potential health risk with Pb exposure was found for the mussel consumers.
- Consumption rate of mussels should be limited to minimize the metal health risks.

GRAPHICAL ABSTRACT



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ABSTRACT

A total of 40 marine mussel *Perna viridis* populations collected (2002–2009) from 20 geographical sites located in two busy shipping lanes namely the Straits of Malacca (10 sites; 16 populations) and the Straits of Johore (8 sites; 21 populations) and three populations (2 sites) on the east coast of Peninsular Malaysia, was determined for Cd, Cu, Fe, Ni, Pb and Zn concentrations. In comparison with the maximum permissible limits (MPLs) set by existing food safety guidelines, all metal concentrations found in all the mussel populations were lower than the prescribed MPLs. In terms of the provisional tolerable weekly intake prescribed by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) and oral reference doses (ORDs) by the USEPA, all the studied metals (except for Pb) were unlikely to become the limiting factors or unlikely to pose a risk for the consumption of the mussel populations. The estimated daily intake (EDI) for average level mussel (ALM) and high level mussel (HLM) consumers of mussels was found to be lower than the ORD guidelines for Cd, Cu, Fe, Ni and Zn. Furthermore, the target hazard quotient (THQ) was found to be less than 1 for ALM consumers but higher than 1 for HLM consumers in some sites. Therefore, there were no potential human health risks to the ALM consumers of the mussels. However, for Pb THQ values, the Pb levels in some mussel populations could create a health risk problem. Present results indicate that the consumption amounts of mussels should be limited for minimizing potential health risks of heavy metals to the HLM consumers.

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1. Introduction

The Straits of Malacca (SOM) is one of the busiest shipping lanes in the world while the Straits of Johore (SOJ) is a semi-enclosed ecosystem strait, bordering between southern Peninsular Malaysia (PM) at Johore and Singapore Island. Both Straits have received waste discharges from both land- and sea-based sources, as well as natural and anthropogenic sources (Yap et al., 2003a). They are very sensitive to contamination which primarily comes from the mainland via rivers or canals due to various human activities and shipping activities. These wastes might potentially contain hazardous substances which are harmful to both human health and marine ecosystem. Previous studies showed that contributions of heavy metals (Yap and Pang, 2011; Yap and Wong, 2011) were related with pollution sources in the SOM. Similarly for SOJ, elevation of hazardous substances into the area has also been reported previously (Eugene Ng et al., 2013; Yap et al., 2012a).

Heavy metals are one of the major pollutants firstly proposed by Goldberg (1975) to assess the health of the ocean through a Mussel Watch Programme (MWP). Later, Farrington et al. (1983) strongly supported the MWP proposal by highlighting the bivalves as ideal surveillance tools to monitor coastal pollution. They reasoned that bivalves 1) have a widespread distribution across the world's coastal waters, 2) are sedentary, 3) concentrate pollutants by factors of a thousand to a hundred thousand, 4) appear to be resistant to pollutants, 5) are commercial products and, 6) are consumed extensively in some areas of the world, and hence pose a risk to human health. The essential keyword from the above statement was 'pose a risk to human health' because humans are the eventual benefactor from the consumption of the natural marine resources. As a matter of fact, the use of mussels to monitor coastal pollution is both widely and broadly accepted by many researchers around the world (Liu and Kueh, 2005; Sasikumar et al., 2006; Szefer et al., 2004). The reliability of the mussel *Perna viridis* as a biomonitor of metal contamination has been mainly summarized by Yap (2012) from Malaysia. Considering that *P. viridis* is edible and marketed commercially, the measurement of metal levels in the soft tissues (STs) are of public concern because excessive consumption of metal-contaminated mussels could result in toxicity to consumers (Jovic and Stankovic, 2014).

With the increasing trend of the incidence rate of cancers among human populations in the world, more efforts and costs for prevention and control of the cancerous diseases shall be paid (Zheng et al., 2015). The main source of human exposure to different essential metals is through the food chain by seafood consumption and it can contribute to achieving the recommended levels of daily intake of trace metals. Therefore, human health risk assessment (HHRA) of exposure to heavy metal risks is of paramount importance (Bilandzic et al., 2014; Jovic and Stankovic, 2014). From the literature, there have been no reports on the HHRA of heavy metal exposure in *P. viridis* from the SOM and SOJ. Therefore, the objectives of this study were to evaluate the HHRA of Cd, Cu, Fe, Ni, Pb and Zn, associated with the consumption of wild and farmed *P. viridis* collected from SOM and SOJ.

2. Materials and methods

2.1. Sampling and sample preparation

A total of 40 *P. viridis* populations were collected, between 2002 and 2009, from 20 geographical sites located in two busy shipping lanes (SOM with 16 populations and SOJ with 21 populations) and three populations (two sites) on the east coast of PM (Fig. 1; Table 1). All the mussels collected were roughly rinsed with seawater from a corresponding sampling site of each population in order to remove attached particles and mud and sediments during the collection. In order to obtain a representative sample at the each location more than 3 kg of mussels of similar shell lengths were collected, placed in plastic bags into an ice compartment at the corresponding sampling sites and transported to the laboratory of Universiti Putra Malaysia. In the laboratory, at least 20 individuals with relatively similar shell lengths from each population were selected, cleaned, and rinsed with distilled water and dissected fresh. Mussel ST was rinsed with double distilled water to remove any remaining sand and/or other particles. The ST of mussels from each location were pooled and dried in an oven (60 °C; 48 h) to a constant dry weight (dw). Afterwards, they were ground to produce homogeneity.

2.2. Metal analysis

Wet digestions were performed in triplicate in each population by weighing approximately 0.50 g of the dried mussel tissues with 10 mL HNO_3 (65% Merck, Suprapur) in a hot block digestor (Szefer et al., 2004). The digested mussel samples were diluted to 40 mL with double distilled water and stored in polyethylene bottles. A blank digest was performed in the same way. The concentrations of Cd, Cu, Fe, Ni, Pb and Zn in the samples were determined using an air-acetylene flame Atomic Absorption Spectrophotometer (Perkin Elmer, AAnalyst 800). The accuracy of the applied analytical procedure for the determination of heavy metals in mussels was tested using Standard Reference Materials (SRM) for mussel tissue (SRM 2976, National Institute of Standards and Technology) and dogfish liver (DOLT-3, National Research Council Canada). The recovery ranges for the mussel tissue were 69.5–107.2% for all metals except for Ni (not available), while for the dogfish liver were 78.8–103.5% for the 6 metals (Table 2).

2.3. Data treatment for human health risk assessment (HHRA)

For HHRA, the six metal data in dw basis were converted into wet weight (ww) ones by using a conversion factor of 0.17 (Yap et al., 2003b). In this study, two levels of mussel consumption values were considered namely 0.125 kg/week (one meal of mussels every week for average level mussel (ALM) consumers or 17.86 g/day) and 0.250 kg/week (high level mussel (HLM) consumers or 35.71 g/day) (Jovic and Stankovic, 2014). To estimate the HHRA derived from ingesting the mussels, six assessments were made namely:

a) direct comparisons with seafood safety guidelines based on established maximum permissible limits (MPLs) set by the EC European Commission (2006), the USFDA for molluscan shellfish (FDA Guidance Document) (USFDA/CFSAN, 2007), and MFR (1985), although other agencies were also included for comparisons;
b) the amount of mussels that would need to be consumed per week by a 60-kg adult to reach the provisional tolerable weekly intake (PTWI) established by the Joint FAO/WHO Expert Committee on Food Additives (JECFA);
c) mean weekly intake (MWI) of metals for ALM and HLM consumers and the percentages of prescribed PTWI values;

PTWI is established by the JECFA. The risk to human health as a result of mussel consumption was evaluated by calculating the weekly metal exposures and comparing the values with the respective prescribed PTWI values. The PTWI is defined as the estimated amount of a substance in food or drinking water, expressed on a body weight (bw) basis (mg/kg bw), that can be ingested weekly over a lifetime without appreciable health risk (WHO, 1993). Therefore, calculations were performed in order to determine the amount of mussels from this study that exceed the PTWI limits. JECFA (2010) established PTWIs for Cd, Cu, Fe, Ni, and Zn as 0.007, 3.50, 5.60, 0.035, and 7.00 mg/week/kg bw, respectively. Thus, the PTWIs for a 60 kg adult are equivalent to 0.42, 210, 336, 2.10, and 420 mg/week for Cd, Cu, Fe, Ni, and Zn, respectively.