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Mercury Levels in the Green-Lipped Mussel *Perna viridis* (Linnaeus) from the West Coast of Peninsular Malaysia

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In Malaysia, the green-lipped mussel *Perna viridis* (Linnaeus), is a commercial bivalve species although it is not as popular as the cockle *Anadara granosa* among the local people. Over the last ten years (1989-1998), mussel production ranged from 778-1779 (mean: 1135) metric tons and that of cockles ranged from 35932-100276 (mean: 64977) metric tons (Rosly 2002). Marine mussels have been used and proposed as biomonitors for heavy metals since two decades ago (Goldberg 1975). Their potential for biomonitoring purposes is due to their wide geographical distribution, sedentary lifestyle, reasonable abundance and availability throughout the year, easily identified and sampled, bioaccumulative and correlative properties with the average pollutants of the environment, tolerance to natural environmental fluctuations and pollution, and ecological and economical importance (Phillips and Rainbow 1993). Although their capability to accumulate a wide range of chemicals is one of the attributes that led to the use of marine mussels as biomonitors, this is probably not a good point in promoting marine mussels as a seafood delicacy.

P. viridis has been used as a biomonitor for heavy metals in the Southeast Asian waters, Hong Kong and India (Tanabe 2000). In Malaysia, *P. viridis* had been suggested as a potential biomonitoring agent for heavy metals in the west coast of Peninsular Malaysia (Ismail et al. 2000) since its metal concentrations (Cd, Cu and Pb) showed good correlations with those found in its environment (Yap et al. 2002a) and low genetic differentiation was found among its different geographical populations in the west coast of the peninsula (Yap et al. 2002b).

Hg has drawn particular attention since it is prone to be bioaccumulated in the food chain (Watras and Bloom 1992). The phenomenon of Hg bioaccumulation was first recognized in 1953 when Minamata disease was caused by the human consumption of Hg contaminated shellfish living in the sediments of Minamata Bay, Japan (Fujiki and Tajima 1992). Since there is no detailed information on Hg levels in *P. viridis* from Peninsular Malaysia, this paper aimed at providing such baseline information on both natural and aquacultured mussel populations found along the west coast of Peninsular Malaysia.

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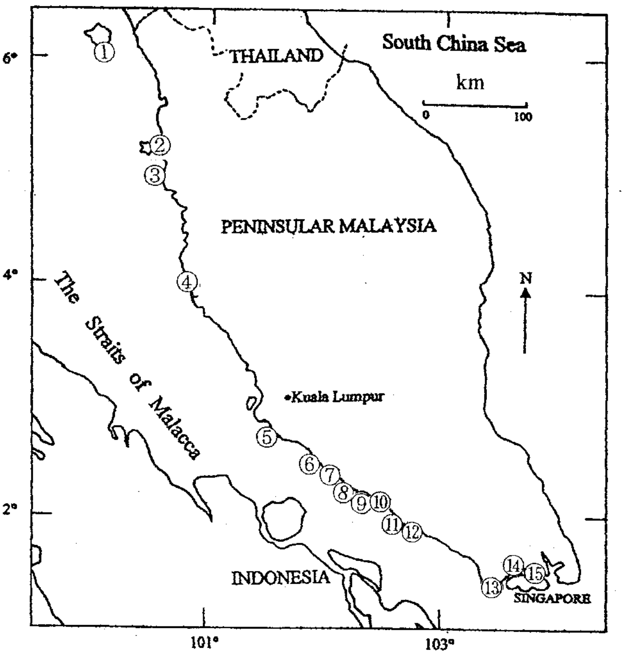

Figure 1. Map showing sampling stations of the green-lipped mussel *Perna viridis* from the west coast of Peninsular Malaysia.

MATERIALS AND METHODS

The 15 sampling sites of *P. viridis*, both from the wild (8) and aquacultured (7) sites, are shown in Figure 1 and Table 1. All the mussels were collected between 1998 and 2000. The samples were brought back to the laboratory and kept at –10°C until analysis. Similar size of mussels were selected and analysed for total Hg (Table 1). Since there is a possibility of metal distribution in different soft tissues of *P. viridis* (Ismail et al. 1999), only the mantle tissue of the mussels was analysed from all populations in order to have a reliable comparison among the different locations. The soft tissue mantle was selected because it is an easily dissectable organ and is one of the soft tissues consumed by humans.

Heat vaporization method analysis was conducted on the fresh samples by using a Hg Analyser Model MA-1S. The samples were analysed for total Hg concentration. The analytical method (USEPA method 7473) used two different types of additives (activated alumina and calcium hydroxide) to minimize the effect of measurement interruptive materials. The additive application followed the procedure as described in the instruction manual for Hg/MA-1S (Nippon Instrument Corp). The accuracy of the data was checked by performing recovery tests by using a quality control sample made from Hg standard solution (mercuric nitrate, Wako Pure Chem., Japan) before and after each day of measurement. The recovery for the Hg was between 90-100%.

Table 1. Mean (mm) shell lengths (SL) (n= 5), description of sampling sites of green-lipped mussel *Perna viridis* and their levels of mercury (mean µg/kg wet weight ± SE).

No.	Location	SL (min-max)	Area description	Range (min-max)	Hg level
1w	Sangkar Ikan, Langkawi	69.8 (61.9-91.0)	Town and aquaculture	9.90-21.0	14.9 ± 3.26
2w	Penang Bridge, Penang	86.3 (70.0-96.8)	Port, industry and urban	7.00-16.6	11.0 ± 2.87
3w	Pulau Aman, Penang	91.5 (72.0-113)	Aquaculture	20.7-35.4	26.4 ± 4.56
4c	K. Dinding, Perak	87.1 (67.2-98.8)	Jetty and aquacultural areas	12.8-15.3	14.6 ± 1.60
5c	Bagan Lalang, Selangor	88.9 (73.5-97.1)	Recreational beach and agriculture.	6.29-15.5	10.1 ± 1.26
6c	Pasir Panjang, Negeri Sembilan	8.78 (7.41-10.8)	Recreational beach and aquaculture	3.89- 8.03	5.03 ± 0.90
7c	Kuala Linggi	61.1 (51.8-91.3)	Port, industry and urban	6.80-10.5	8.91 ± 2.30
8w	Pantai Kundor, Malacca	87.8 (80.6-97.7)	Recreational beach	13.8-19.2	16.2 ± 2.50
9c	Anjung Batu, Malacca	92.2 (84.3-106)	Agriculture and aquaculture	5.30-9.23	7.50 ± 0.89
10c	Telok Emas, Malacca	97.7 (78.0-113)	Aquaculture	8.60-11.6	10.1 ± 1.50
11c	Sebatu, Malacca	85.4 (75.2-88.0)	Aquaculture and agriculture	5.65-7.34	6.50 ± 0.49
12w	Muar Estuary, Malacca	84.4 (68.2-99.2)	Agriculture	16.0-19.1	17.6 ± 1.55
13w	Tanjung Kupang, Johore	83.6 (70.0-90.0)	Port and aquaculture	10.7-23.5	16.6 ± 3.73
14w	Pantai Lido, Johore	64.6 (53.4-82.4)	Port, industry and urban	20.2-39.8	32.5 ± 7.30
15w	Kg. Pasir Puteh, Johore	61.1 (51.8-91.3)	Port, industry and urban	19.7-50.0	33.8 ± 5.51

Note: No. follows those found in Fig. 1. w: wild mussels, c: cultured mussels.

RESULTS AND DISCUSSION

The Hg levels found from the 15 sampling sites along the west coast of Peninsular Malaysia ranged from 3.89-50.00 µg/kg wet weight (Table 1). The Hg levels in Kampung (Kg.) Pasir Puteh and Pantai (P.) Lido were higher than other populations. High levels of Cd, Cu, Pb and Zn in *P. viridis* had also been reported by Ismail et al. (2000) at the Kg. Pasir Puteh. Similarly, Moradi et al. (1999) reported an elevation level of polycyclic aromatic hydrocarbons in this mussel species at Kg. Pasir Puteh. Yap et al. (2002a) reported high levels of Cd, Cu, Pb and Zn in the soft tissue of *P. viridis* and sediment at the same site. These levels were most probably due to anthropogenic inputs in the vicinity of the sampling sites. Based on the site description (Table 1) at the Kg. Pasir Puteh, the sampling site was characterized as having received a variety of anthropogenic activities such as domestic wastes, industrial effluents and marina activities.

The Hg levels of *P. viridis* recorded from the present study were considered low when compared to those reported from this region. Hutagalung (1987) reported that the Hg levels in *P. viridis* were as high as 848 μg/kg wet weight from Jakarta Bay while Senthilnathan et al. (1998) reported the levels in the mussels from Indian waters as being between 19 and 495 μg/kg dry weight. Samples from Thailand's Chao Phraya River had a wider range of Hg levels (10-290 μg/kg dry weight) (Menasveta and Cheevaparanapiwat 1981). The Hg levels in *P. viridis* collected from Victoria harbor in Hong Kong and Putai coast in Taiwan were reported to be 110-140 μg/kg dry weight and 210 μg/kg dry weight, respectively.

The reported Hg concentrations in intertidal molluscs including *P. viridis* were also limited. In Malaysia, Liong (1986) reported Hg levels as being between 20 and 70 μg/kg wet weight in *P. viridis* found from the northern part of Peninsular Malaysia. In comparison with other bivalve species in Malaysia, the Hg level in *P. viridis* from the west coast of Peninsular Malaysia was much lower than those reported in cockle *Anadara granosa* (1443 μg/kg wet weight) (Sivalingam and Ahzura 1980).

When compared with other biological samples, the Hg level in *P. viridis* was comparable to those reported in fish species, squids, prawns and crabs from the Straits of Singapore and the Straits of Malacca (Chai and Wong 1976) and some freshwater molluscs species from the Sarawak River (Lau et al. 1998). Chai and Wong (1976) reported that Hg levels of six species of fishes from the Straits of Singapore ranged from 5 to 90 μg/kg wet weight which were also comparable to the present Hg levels. The overall results in the present study were lower than the Hg levels (20-260 μg/kg wet weight) in some fish species collected from the coastal waters off Perlis, Kedah, Penang, Selangor and Terengganu (Babji et al. 1986) and much lower than that (1200-1288 μg/kg wet weight) found in the cockle *A. granosa* from Jakarta Bay (Hutagalung 1987). Earlier, Babji et al. (1979) reported that the Hg levels in six species of coastal fishes caught from Peninsular Malaysia ranged from 80 to 110 μg/kg wet weight. Only Law and Singh (1988) reported that some fishes caught from the Klang Estuary had a high Hg level (510 μg/kg wet weight). Similarly, the Hg levels of some fish species of other countries were much higher than those in *P. viridis* from the present work such as fishes from the waters of Colombia (6-334 μg/kg wet weight) (Alonso et al. 2000) and Brazil (68-311 μg/kg wet weight) (Moraes et al. 1997). In addition, the range of Hg level was also lower than that reported in clams (180 μg/kg wet weight) and oysters (180 μg/kg wet weight) from the coastal waters off Taiwan (Han et al. 1998).

Many studies on Hg in fish and shellfish (Alonso et al. 2000) showed that Hg contamination was related to anthropogenic activities. Since an elevated level of Hg in *P. viridis* was not found, the Hg status in the west coast of Peninsular Malaysia using *P. viridis* as the biomonitor is considered as the background level.

From the public health point of view, it was found that the Hg levels (3.89-50.0 μg/kg wet weight) found in the mussels collected from the west coast of Peninsular Malaysia were about 10 times lower than the maximum permissible limit set by the Malaysian Food Regulation (1985) (500 μg/kg wet weight). The present range of Hg found was also below the maximum permissible limits for fish products set by USEPA (600 μg/kg wet weight) (Fairey et al. 1997), Chinese national EPA (300 μg/kg wet weight) (Luo et al. 1988) and health standards in Canada (500 μg/kg wet weight) (Health Canada 1992). Therefore, the consumption of *P. viridis* from the west coast of Peninsular Malaysia is not a health hazard as far as contamination by Hg is concerned although this could depend also on the amount of mussels being consumed.

The Hg levels found in *P. viridis* collected from the west coast of Peninsular Malaysia can be used for future reference. By using the biomonitor *P. viridis*, anthropogenic Hg contamination in the waters of the west coast of Peninsular Malaysia was found not to be serious and this will give confidence to the expansion of mussel aquacultural operations along the west coast of the peninsula. An important point to be emphasized here is that although the present Hg levels were low in *P. viridis*, future monitoring is still much needed since the accumulation of Hg can be affected by age of mussels, season, reproductive cycles and other intrinsic factors (Lobel, 1989). Besides, any future increased input of Hg will be of great concern and *P. viridis* is recommended as a suitable biomonitoring agent for this metal in the waters off the west coast of Peninsular Malaysia.

REFERENCES

Alonso D, Pineda P, Olivero J, Gonzalez H, Campos N (2000) Mercury levels in muscle of two fish species and sediments from the Cartagena Bay and the Cienaga Grande de Santa Marta, Colombia. Environ Pollut 109:157-163

Babji AS, Awang Z, Embong MS (1986) Monitoring of heavy metals contents of coastal water fishes in Peninsular Malaysia. In: Chan HH, Ang KJ, Law AT, Mohamed MI, Omar I (eds) Development and Management of Tropical Living Aquatic Resources. The Proceedings of an International Conference Held at UPM, Serdang, Selangor, Malaysia From 2nd-5th August, 1983. Serdang, Penerbit UPM, pp. 219-224

Babji AS, Embong MS, Woon WW (1979) Heavy metals contents in coastal water fishes of West Malaysia. Bull Environ Contam Toxicol 23:830-836

Chai SB, Wong MK (1976) Heavy metals in marine biota from coastal waters around Singapore. J Singapore Nat Acad Sci 5:47-52

Fairey R, Taberski K, Lamerdin S, Johnson E, Clark RP, Downing JW, Newman J, Petreas M (1997) Organochlorines and other environmental contaminants in muscle tissue of spotfish collected from San Francisco Bay. Mar Pollut Bull 34:1058-1071

Fujiki M, Tajima S (1992) The pollution of Minamata Bay by mercury. Wat Sci Tech 25:133-140

Goldberg ED (1975) The Mussel Watch - a first step in global marine monitoring. Mar Pollut Bull 6:111

Han BC, Jeng WL, Chen RY, Fang GT, Hung TC, Tseng RJ (1998) Estimation of target hazard quotients and potential health risks for metals by consumption of seafood in Taiwan. Arch Environ Contam Toxicol 35:711-720

Health Canada (1992) Health Canada Protection Branch, Bureau of Chemical Safety, Chemical Health Hazard Assessments Division, Ottawa, Canada

Hutagalung HP (1987) Mercury content in the water and marine organisms in Angke Estuary, Jakarta Bay. Bull Environ Contam Toxicol 39:406-411

Ismail A, Yap CK, Tanabe S (1999) Distribution of heavy metals in the tissues of green-lipped mussel *Perna viridis* (Linnaeus). In: Saadon MN, Abdullah SA, Sheriff SM, Ariffin NA (eds) Proceedings of the Tenth JSPS/VCC Joint Seminar on Marine and Fishery Sciences, College Universiti Terengganu, Malaysia, pp. 367-375

Ismail A, Yap CK, Zakaria MP, Tanabe S, Takada H, Ismail AR (2000) Green-lipped mussel *Perna viridis* (L.) as a biomonitoring agent for heavy metals in the west coast of Peninsular Malaysia. In: Shariff M, Yusoff FM, Gopinath N, Ibrahim HM, Nik Mustapha A (eds) Towards Sustainable Management of the Straits of Malacca, Technical and Financial Options. Malacca Straits Research and Development Centre, Universiti Putra Malaysia, pp. 553-559

Lau S, Mohamed M, Tan ACY, Su'ut S (1998) Accumulation of heavy metals in freshwater molluscs. Sci Total Environ 214:113-121

Law AT, Singh A (1988) Heavy metals in fishes in the Kelang Estuary, Malaysia. Malay Nature J 41:505-513

Liong PC (1986) Heavy metals in shellfish from the Northern Part of Malacca Straits. In: Chan HH, Ang KJ, Law AT, Mohamed MI, Omar I (eds) Development and Management of Tropical Living Aquatic Resources. The Proceedings of an International Conference Held at Universiti Putra Malaysia, from 2nd-5th August 1983, UPM Publisher, Universiti Putra Malaysia, pp. 225- 229

Lobel PB, Belkhode SP, Jackson SE, Longerich HP (1989) A universal method for quantifying and comparing the residual variability of element concentrations in biological tissues using 25 elements in the mussel *Mytilus edulis* as a model. Mar Biol 102:513-523

Luo C, Guo N, Zhang G, Wu J, Qin J (1988) An investigation on water quality standard in the area of cultivating fish with municipal sewage. Environ Sci 9:52-55 (In Chinese)

Malaysian Food Regulation (1985) Malaysian law on food and drugs. Malaysian Law Publishers.

Menasveta P, Cheevaparanapiwat V (1981) Heavy metals, organochlorine, pesticides and PCBs in green mussels, mullets and sediments of river mouth in Thailand. Mar Pollut Bull 12:19-25

Moradi AM, Zakaria MP, Ali J, Yusoff FM (1999) Temporal and spatial fluctuation of polycyclic aromatic hydrocarbons in mussels from Peninsular Malaysia. In: Saadon MS, Adullah SA, Sheriff SM, Ariffin NA (eds) Proceeding the 10th JSPS/VCC Joint Seminar on Marine and Fisheries Science, Kolej Universiti Terengganu, Malaysia, pp. 206-216.

Moraes LAP, Lenzi E, Luchese EB (1997) Mercury in two fish species from the Parana River floodplain, Parana, Brazil. Environ Pollut 98:123-127

Phillips DJH, Rainbow PS (1993) Biomonitoring of trace aquatic contaminants. Elsevier Science, London.

Rosly H (2002) Future challenges of sustainable mariculture in the Straits of Malacca. In: Yusoff FM, Shariff M, Ibrahim HM, Tan SG, Tai SY (eds) Tropical Marine Environment: Charting Strategies for the Millenium. Malacca Straits Research and Development Centre, Universiti Putra Malaysia, pp. 175-187

Senthilnathan S, Balasubramanian T, Venugopalan VK (1998) Metal concentration in mussel *Perna viridis* (Bivalvia/Anisomyaria) and oyster *Crassostrea madrasensis* (Bivalvia/Anisomyaria) from some parts in southeast coast of India. Indian J Mar Sci 27:206-210

Sivalingam PM, Ahzura S (1980) Mercury content in hair from fishing communities of the State of Penang, Malaysia. Mar Pollut Bull 11:188-191

Tanabe S (2000) Asia-Pacific Mussel Watch progress report. Mar Pollut Bull 40:651

Watras CJ, Bloom NS (1992) Mercury and methylmercury to individual zooplankton: implications for bioaccumulation. Limnol Oceanogr 37:1313-1318

Yap CK, Ismail A, Tan SG, Omar H (2002a) Correlations between speciation of Cd, Cu, Pb and Zn in sediment and their concentrations in total soft tissue of green-lipped mussel *Perna viridis* from the west coast of Peninsular Malaysia. Environ Int 28:117-126

Yap CK, Ismail A, Tan SG, Omar H (2002b) Genetic structures of populations of the green-lipped mussel *Perna viridis* (Linnaeus): a biomonitoring agent for the Straits of Malacca. In: Fatimah FM, Shariff M, Ibrahim HM, Tan SG, Tan SY (eds) Tropical Marine Environment: Charting Strategies for the Millennium. Malacca Straits Research and Development Centre, Universiti Putra Malaysia, pp. 641-650