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Anthropogenic Inputs of Heavy Metals in the East Part of the Johore Straits as Revealed by their Concentrations in the Different Soft Tissues of *Perna viridis* (L.)

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ABSTRACT

Concentrations of Cd, Cu, Ni, Pb and Zn were determined in seven different soft tissues of *Perna viridis* collected in May-November 2006 from the six sites in the Straits of Johore. The metal concentrations in the soft tissues of the samples from the east of the Johore Causeway were generally higher than those of the samples collected from the western partI of it. This indicated that the eastern part of the straits had higher contamination and bioavailabilities of Cd, Cu, Ni, Pb and Zn. Therefore, these results are in agreement with the fact that there are various anthropogenic activities, such as petrochemical plants and port activities, in the eastern part of the Straits of Johore. The findings of this work are useful for future reference, particularly for the semi-enclosed Straits.

Keywords: Heavy metal, green-lipped mussel, *Perna viridis*, Johore Causeway, The Straits of Johore

INTRODUCTION

In 1996, the most interesting issue related to the Johore Causeway was the intention to replace the semi-enclosed Johore Causeway with a bridge. In 2003, the Malaysian government planned to build a "crooked half bridge". On 12 April 2006, however, the Malaysia government scrapped off the plan to build the bridge due to unavoidable circumstances. Among the initial reasons cited for building the bridge were that it would allow free flow of water across both sides of the Straits, whereby the 1909-built causeway artificially divides it into two parts (Yap *et al*., 2006), and that the bridge would help to ease the traffic congestion in Johore Bharu city (Berita Harian, 2006), apart from markedly improving the marine ecology of the Johore Straits, alleviating the stagnation

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and stench, and enhancing the aesthetic value of the marine environment (Berita Harian, 2006). From the ecotoxicological point of view, the demolishment of the Causeway could create substantial impacts on the living organisms on the both parts of the Causeway.

Studies on heavy metals in the green-lipped mussel *Perna viridis* in Malaysia have been widely reported in the literature and its potential use as a biomonitor of heavy metal pollution for the west coast of Peninsular Malaysia has also been well established (Yap *et al*., 2002a, 2002b, 2003, 2004a, 2004b, 2006a). In this study, the Mussel Watch approach was employed for monitoring Cd, Cu, Ni, Pb and Zn. The objective of this study was to compare the heavy metal concentrations in the green-lipped mussel *P. viridis* collected from the west and east parts of the Johore Causeway.

MATERIALS AND METHODS

This study was carried out at the Straits of Johore. The study sites consisted of three sampling sites, namely, each at the western and eastern parts of the Johore Straits which are separated by the Johore Causeway (Table 1 and Figure 1). The samplings were conducted between May - November 2006. After sample collection, the mussels were put into polyethylene bags and kept in a cool box at < 5°C before they were transported to a laboratory at Universiti Putra Malaysia (UPM). Upon arrival at the laboratory, all the samples were placed in a freezer at -10°C until further analysis.

About 30 mussels from each sampling site, with the shell sizes ranging from 60 to 90 mm, were used for metal analyses. The mussels were carefully dissected into seven different soft tissues, namely mantle, muscle, gonad, foot, gills remainder and byssus. Triplicates of each dried category of soft mussel tissues were digested in 5 ml of concentrated HNO_3 (AnalaR grade, BDH 69%). Later, they were placed in a digestion block at 40ºC for 1 hour and then fully digested at 140°C for 3 hours. After cooling, they were diluted to 20 ml with double de-ionized water. The digested samples were then filtered through Whatman No.1 filter paper into acid-washed pill boxes. The samples were determined for their Cd, Cu, Ni, Pb and Zn concentrations by using an air-acetylene flame atomic absorption spectrophotometer (AAS) Perkin–Elmer Model AAnalyst 800. The data are presented in µg/g dry weight basis. To avoid possible contamination, all the glassware and equipment used were acid-washed.

Procedural blanks and quality control samples made from the standard solutions of Cd, Cu, Ni, Pb, and Zn were analyzed after every five samples to check for sample accuracy. The percentages of recoveries for the heavy metal analyses were between 80 and 110%. In addition, the quality of the analytical method was checked using the Certified Reference Material for Dogfish (DOLT-3, National Research Council Canada) and the metal recoveries were shown to be satisfactory (80–100%).

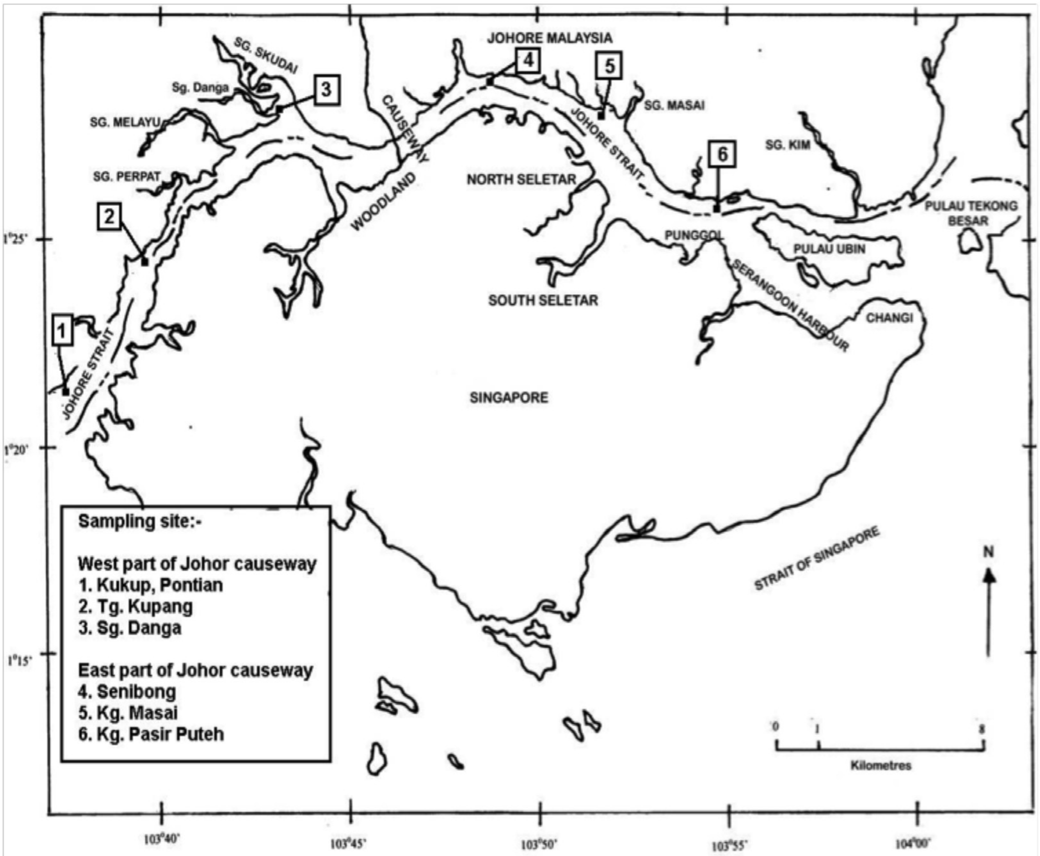

Fig.1: Map showing the sampling sites of *Perna viridis* in the Johore Straits.

For the statistical analyses, independent T-tests were performed to determine the significance levels of any two variables. The statistical analyses were conducted using SPSS Version 13.0 for Windows Release software.

RESULTS AND DISCUSSION

A comparison of the heavy metal concentrations in the different tissues of *P. viridis,* collected from the eastern and western parts of the Straits of Johore which is separated by the Johore Causeway, is given in Table 2. Generally, the eastern part of the Straits recorded higher (although not significantly higher, $p > 0.05$) bioavailabilities and contaminations of Cd, Cu, Ni and Pb and Zn than the western part, as indicated by the metal concentrations in the tissues of the mussels.

The high levels of metal concentrations in the mussels from the eastern part were found in the gill, foot, mantle, gonad, remainder and byssus, indicating the higher metal bioavailabilities and contaminations in this part of the Straits. However, for the concentrations of Cd, Cu and Zn in the gonads, Cd and Pb in the muscles, as well

TABLE 1
Sampling dates, shell lengths (cm) of *Perna viridis* analyzed and descriptions of the sampling sites

No.	Sampling sites	Sampling dates	Shell lengths [mean ± SD]	Description of the sampling sites
1.	Kukup, Pontian	12 May 2006	7.82 - 8.93 [8.25 ± 0.50]	Boat repairing platform, fishing jetty, and an aquacultural area.
2.	Tg. Kupang	24 June 2006	7.5 - 7.89 [7.60 ± 0.20]	Boat repairing platform, fishing jetty, aquacultural area, seaport activities, shipping activities in the surrounding area and coal-powered power plant.
3.	Sg. Danga	23 November 2006	8.53 - 9.00 [8.71 ± 0.20]	Receiving municipal wastes.
4.	Senibong	27 August 2006	9.52 - 10.31 [9.90 ± 0.30]	Port activities and municipal wastes.
5.	Kg. Masai	27 August 2006	6.06 - 7.3 [6.71 ± 0.60]	Port activities and municipal wastes.
6.	Kg. Pasir Puteh	10 June 2006	7.82 - 8.63 [8.19 ± 0.40]	Receiving industrial (petrochemicals) and municipal wastes. Port activities, shipping in the surrounding and a marina site.

as Pb in the byssus, higher concentrations of the metals were found in the samples from the western part compared to those taken from the eastern part. In certain circumstances, the metal concentrations in gonads may be influenced by physiological conditions such as the spawning period of the mussels (Yap *et al*., 2006b). Therefore, the metal concentrations found in the gonads undertaken in this study could not be accurately used as a reflection of the metal contaminations and bioavailabilities of the sites. On the other hand, the big standard deviation (SD) values of the metal concentrations found in every tissue indicated the wide variations in the contents of the Cd, Cu, Ni and Zn. In the mean time, a wider variation of the SD values of metal concentrations observed in the tissues of the mussels from the eastern than the western part could be due to a known metal-contaminated site in Kg. Pasir Puteh (Yap *et al*., 2006b).

The high metal contaminations and bioavailabilities in the eastern part could be due to the discharge of effluents from the domestic and industrial sources nearby. Besides, Kg. Pasir Puteh is also located next to the Pasir Gudang Industrial Estate, where some petrochemical plants and a seaport (Port Pasir Gudang) are located. Moreover, Cu leachate from the antifouling paints of boats and the semi-enclosed topography of the area may further aggravate the pollution problem (Yap *et al*., 2003, 2004, 2006a). The other possible reasons for the high levels of metals found in the mussels from the eastern part could be the riverine inputs from the Tebrau, Skudai, and Segget rivers, which all empty into the waters off Pasir Gudang (Yap *et al*., 2006a). These inputs would carry larger quantities of heavy

TABLE 2
Mean concentrations (mean ± standard error, µg/g dry weight) of the heavy metals in the different soft tissues of *Perna viridis* collected from the western (three sites) and eastern (three sites) parts of the Straits of Johore

Part	Heavy metal	West	East	p
	Cd	0.800 ± 0.200	**1.50 ± 0.700**	0.188
	Cu	11.1 ± 0.900	**12.1 ± 1.90**	0.218
Gill	Zn	95.8 ± 35.8	**123 ± 52.0**	0.377
	Pb	4.50 ± 0.900	**14.2 ± 11.9**	0.452
	Ni	6.80 ± 6.40	**44.1 ± 6.27**	0.485
	Cd	0.300 ± 0.200	**0.800 ± 0.400**	0.395
	Cu	6.20 ± 1.20	**10.6 ± 4.00**	0.349
Foot	Zn	52.5 ± 5.20	**67.1 ± 2.38**	0.349
	Pb	3.80 ± 0.800	**11.4 ± 1.49**	0.390
	Ni	2.30 ± 1.00	**26.8 ± 3.78**	0.427
	Cd	0.600 ± 0.400	**1.50 ± 0.500**	0.282
	Cu	11.0 ± 2.30	**11.9 ± 4.50**	0.080
Mantle	Zn	63.3 ± 8.70	**71.9 ± 3.20**	0.213
	Pb	6.20 ± 1.80	**19.1 ± 2.16**	0.227
	Ni	2.90 ± 1.10	**44.1 ± 6.52**	0.421
	Cd	1.20 ± 0.800	1.10 ± 0.500	0.037
	Cu	10.8 ± 1.20	10.6 ± 1.50	0.049
Gonad	Zn	84.0 ± 5.00	77.3 ± 2.91	0.219
	Pb	7.90 ± 1.90	**13.0 ± 1.12**	0.166
	Ni	3.10 ± 1.60	**31.5 ± 4.33**	0.356
	Cd	1.20 ± 0.800	0.800 ± 0.500	0.050
	Cu	5.20 ± 1.60	**8.40 ± 2.50**	0.245
Muscle	Zn	65.9 ± 15.7	**81.4 ± 16.1**	0.430
	Pb	14.0 ± 4.60	11.0 ± 4.20	0.190
	Ni	2.60 ± 1.20	**31.8 ± 4.36**	0.450
	Cd	1.40 ± 0.600	**2.10 ± 0.600**	0.054
	Cu	22.6 ± 5.50	**26.4 ± 13.8**	0.205
Byssus	Zn	104 ± 16.5	**174 ± 91.3**	0.340
	Pb	16.6 ± 5.70	15.5 ± 5.80	0.102
	Ni	22.8 ± 15.7	**67.2 ± 9.28**	0.427
	Cd	1.20 ± 0.600	**2.20 ± 0.600**	0.096
	Cu	12.0 ± 0.800	**15.6 ± 2.00**	0.180
Remainder	Zn	113 ± 32.9	**101 ± 47.6**	0.163
	Pb	9.60 ± 3.70	**19.3 ± 1.59**	0.274
	Ni	8.80 ± 6.60	**49.7 ± 7.03**	0.427

Note: Values in bold indicate higher concentrations of heavy metals.

metals which could put the local marine ecosystem at risk. Based on the sediment studies by Wood *et al*. (1997), higher metal concentrations were found in the eastern side of the Causeway as compared the western side of the causeway. This reflected the generally greater industrial development on the eastern side of the Causeway which would certainly aggravate the environmental degradation of the fragile semi-enclosed Straits, considering the limited tidal flushing of anthropogenic pollutants. In addition, the neighbouring country, Singapore, also contributed to the high heavy metal contamination of the Johore Straits, as evidenced by the Murray-North Report (The News Straits Times, 2006) which reported that the discharges into the Johore Straits came from the Kranji sewage plant and warm-water discharges from the Senoko plant.

CONCLUSION

Based on the metal concentrations in the different soft tissues of *P. viridis*, the eastern part of the 99-year-old Johore Causeway apparently received environmental impacts from various industrial and shipping activities. Meanwhile, the use of the Mussel watch approach was shown to be useful in identifying the higher metal bioavailability and contamination at the eastern part of the Straits. This finding is very important for future reference, should the Johore Causeway be demolished in the future. In particular, the findings of this study should contribute to the understanding of the present status of pollution in the Straits of Johore. The present data are useful to prompt further ecotoxicological and biochemical studies when the contaminated sites located on the eastern part of the Johore Straits are taken into account.

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