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Original paper

A COMPARATIVE STUDY OF HEAVY METAL CONCENTRATIONS IN *Nerita lineata* FROM THE INTERTIDAL ZONE BETWEEN DUMAI INDONESIA AND JOHOR MALAYSIA

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ABSTRACT

The concentrations of Cd, Cu, Pb, Zn, Ni and Fe were determined in the marine gastropod Nerita lineata collected on May 2005 from the intertidal zone of fourteen stations in Dumai, Indonesia (mean length 21.43 – 24.04 mm) and ten stations in Johor, Peninsular Malaysia (mean length 22.61 – 26.60 mm). The results of the present study showed that metal concentrations in the shell, operculum and soft tissue of N. lineata varied at different sampling stations. The mean concentrations of Cd, Cu, Pb, Zn, Ni and Fe in the samples collected from Dumai were 4.14; 5.90; 44.43; 3.74; 20.73; 24.91 µg/g in shell; 4.16; 7.31; 51.78; 17.63; 23.52; 30.60 µg/g in operculum and 0.71; 15.16; 9.34; 94.69; 5.08; 397.96 µg/g dry weight in the total soft tissue; whilst those collected from Johor were 4.18; 5.06; 59.84; 4.8122; 19.29; 31.60 µg/g in shell; 4.73; 6.51; 60.57; 19.48; 20.68; 34.92 µg/g in operculum and 1.24; 18.02; 19.75; 95.09; 5.57; 473.56 µg/g dry weight in the total soft tissue, respectively. Samples of N. lineata from both Dumai and Johor tend to show similar trend in metal accumulation in which the concentrations of Cd, Pb and Ni decreased in the order: operculum > shell > soft tissue whilst Cu, Zn and Fe in the order of soft tissue > operculum > shell. In general, samples from Johor accumulated higher heavy metal concentrations when compared to samples from Dumai, except for Cu and Ni in the shell and operculum, which exhibited vice versa situation. Higher concentrations of metals were recorded in samples collected from the stations close to the industrial and anthropogenic activities. However, most of the concentrations were still comparable to the previous reported studies from other geographical areas.

Key words: Heavy metals, *Nerita lineata*, Indonesia, Malacca Straits

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INTRODUCTION

The middle-east coast of Sumatera Indonesia and the south-west coast of Peninsular Malaysia are both located at the opposite sides of The Straits of Malacca (Fig. 1). The Straits of Malacca is subjected to a great variety of pollutants due to its strategic location as an international waterway and known as one of the busiest shipping lanes in the world and the concentration of agriculture, industry and urbanization which predominate on the west coast of Peninsular Malaysia including the south-west coast of Peninsular Malaysia (Abdullah *et al*., 1999; Chua *et al*., 2000). Some parts of the east coast of Sumatera Indonesia are also having rapid development in agriculture, industry and urbanization. Hence, the Straits have been becoming a principle repository for industrial, agricultural and domestic wastes originating from land-based and sea-based activities.

Studies of heavy metal pollution in coastal waters often focus on sediment as the matrix samples, however many researchers (Philips, 1980; Philips and Rainbow, 1993; Szefer *et al*., 2002; 2006; Yap *et al*., 2002; 2003; 2004; Usero *et al*., 2005; Sidomou *et al*., 2006) have reported the potential of using biomonitor organisms especially bivalve mollusc for monitoring heavy metal pollution in aquatic ecosystem. Studies have also been carried out to evaluate the coastal marine environmental quality of the Malacca Straits, especially in the Malaysian side, by employing green-lipped mussel *Perna viridis* and sediment (Yap *et al*., 2002; 2003; 2004), oyster (Saed and Ismail, 2002; Ismail and Ramli, 1997). However, there has yet been any report on the concentrations of heavy metals in biomonitors on the Indonesian side.

A lot of studies on gastropods has been reported in the literature from biomonitoring point of view (Peerzada *et al*., 1990; Walsh *et al*., 1994; Leung and Furness, 1999; Kang *et al*., 1999; 2000; de Wolf *et al*., 2000; Blackmore, 2001; Cubadda *et al*., 2001; Gay and Maher, 2003; Conti and Cecchetti, 2003; Foster and Cravo, 2003; Liang *et al*., 2004; Ismail and Safahieh, 2005; Hamed and Emara, 2006). Owing to the gastropods' potential characteristics as biomonitors of heavy metal pollution, this study focused on snail *Nerita lineata*.

The objective of the present study was to determine the heavy metal concentrations of Cd, Cu, Pb, Zn, Ni and Fe in three different parts of *N. lineata* along the intertidal zone of Dumai coastal waters in the middle-east coast of Sumatera Indonesia and Johor coastal waters in the south-west coast of Peninsular Malaysia. It was also aimed at comparing the concentrations of heavy metals at either side of the Malacca Straits as they have different level of resource development in its respective coastal environment.

MATERIALS AND METHODS

Samples of *N. lineata* were collected in May 2005 from fourteen stations along the intertidal zone of Dumai waters in the middle-east coast of Sumatera Indonesia and from ten stations along the intertidal zone of Johor waters in the south-west coast of Peninsular Malaysia **(Fig. 1).** In each station, sample collection was carried out over a distance of meters to establish an appropriate sampling site. The samples were randomly taken from bedrock or gravel substrates and mangrove trees at the mean high tide level of the intertidal zone. Collected samples were rinsed with sea water and kept in plastic bag for at least twelve hours for defecation before they were put in the fridge at -10 ºC until analysis in the laboratory. Between twenty two to seventy five individuals for each station were pooled and homogenized to produce nine replicates for metal analysis. In laboratory, samples were washed with distilled water and each individual was separated into shell, operculum and soft tissue, and were later put onto separate aluminium foil tray and they were then dried up in the oven until constant weight at 80º C following the procedure of Cravo *et al*. (2002; 2004).

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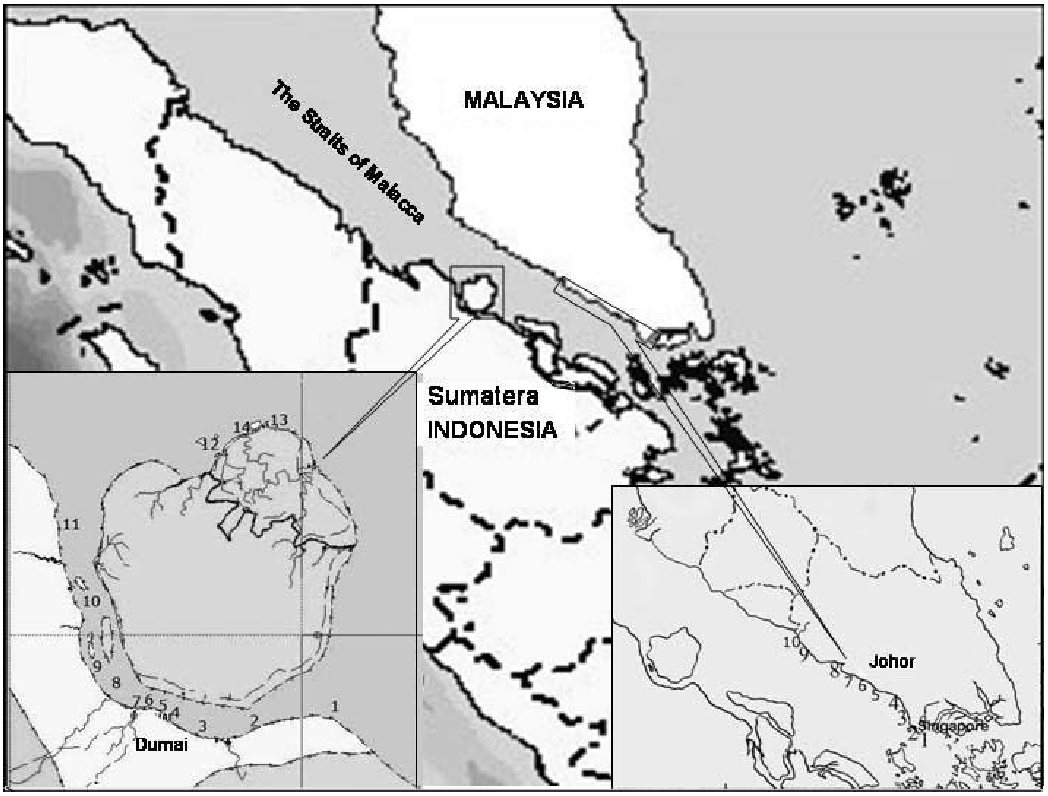

Fig. 1. Map of the study area and sampling station in Dumai Indonesia and Johor Malaysia

The detailed processes for metal analysis were conducted by following the procedures outlined by Yap *et al*. (2003). The dried samples were digested in concentrated nitric acid (AnalaR grade, R&M Chemicals 65%). They were placed in a hot-block digester at low temperature (40°C) for 1 hour and were then fully digested at high temperature (140°C) for at least 3 hours. The digested samples were then diluted to a certain volume with milli-Q water (18.2Ω). After filtration, heavy metals were determined for Cd, Cu, Pb, Zn, Ni and Fe by using an air-acetylene flame atomic absorption spectrophotometer (AAS) Perkin-Elmer Model AAnalyst 800 series. The data were presented in μg/g dry weight.

All glassware and equipment used were acid-washed with 10% HCl and then rinsed with double distilled water to avoid possible contamination. Multiple level calibration standards were analyzed to generate calibration curves against which sample concentrations were calculated. The percentages (%) of recoveries for heavy metal analysis were between 96 - 103%. Procedural blanks and quality control samples were made from the standard solutions for Cd, Cu, Pb, Zn, Ni and Fe. They were prepared from 1000 mg/l stock solution (BDH SpectrosoL) of each metal, and they were analyzed for every five to ten samples in order to check for sample accuracy.

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RESULTS AND DISCUSSION

Results

The average size of *N. lineata* from Dumai waters used in the present study ranges from 21.42 – 24.13 mm (shell length) and 3.01 – 4.71 g (weight) with water content between 70.59 – 76.59%. The mean concentrations of metals in samples from fourteen stations in the intertidal zone of Dumai range from 3.74 – 4.49, 5.32 – 6.43, 38.55 – 53.35, 3.38 – 3.94, 19.60 – 22.72 and 9.27 – 53.58 µg/g in the shell; 3.65 – 5.81, 6.74 – 8.55, 49.12 – 58.18, 12.42 – 27.30, 18.07 – 27.40 and 18.68 – 46.60 µg/g in the operculum; 0.42 – 1.50, 10.78 – 20.60, 4.79 – 14.55, 88.28 – 101.97, 2.23 – 8.47 and 237.13 – 806.34 µg/g dry weight in the soft tissue for Cd, Cu, Pb, Zn, Ni and Fe, respectively (Table 1).

Table 2 showed the mean concentrations of metals in the shell, operculum and soft tissue of *N. lineata* from ten stations in the intertidal zone of Johor in the south-west coast of Peninsular Malaysia ranging from Tanjung Piai to Muar. Samples from these stations range between 22.61 – 26.60 mm (shell length) and 3.21 – 6.37 g (weight) with water content of the samples between 70.45 – 72.97%. The concentrations of metals in samples from Johor waters were 3.26 – 5.10, 4.65 – 5.68, 50.39 – 80.17, 3.80 – 5.37, 17.63 – 20.44 and 17.10 – 40.47 µg/g in the shell; 3.67 – 5.99, 5.84 – 7.86, 49.48 – 94.36, 13.71 – 29.05, 18.10 – 28.95 and 21.90 – 66.43 µg/g in the operculum; 0.72 – 1.71, 11.59 – 27.63, 3.81 – 48.33, 86.04 – 101.32, 3.90 – 10.63 and 217.98 – 810.57 µg/g dry weight in the soft tissue for Cd, Cu, Pb, Zn, Ni and Fe, respectively.

The mean concentrations of each metal varied for the shell, operculum and soft tissue of *N. lineata* from Dumai and Johor **(Fig. 2).** Concentrations of Cd, Pb and Ni were found to be highest in operculum, followed by shell and the lowest in soft tissue; whilst Cu, Zn and Fe were recorded to be the highest in soft tissue followed by operculum and the lowest in shell as seen in **Table 3** for samples from Dumai Indonesia and Johor Malaysia. Higher concentrations of Cd, Pb and Ni in operculum might be due to the volume ratio of operculum as compared to the shell which follow their growth rate. Smaller size of operculum was assumed to concentrates more metal from its surrounding. This calcified tissue might also consist of protein as suggested by Hunt (1970) in other gastrtopod species of *Buccinum undatum*.

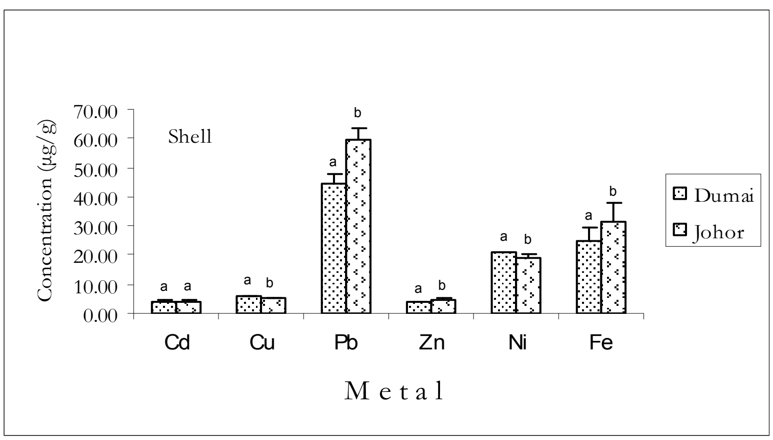

Fig. 2. Mean metal concentrations in shell of *N. lineata* from Dumai and Johor waters (Note: Bars with different letter denote significantly different ($p< 0.01$)

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Table 1. Mean metal concentrations in the shell, operculum and soft tissue of *N. lineata* from intertidal zone of Dumai waters

Station	Length (mm)	Weight (g)	Body part	Metal concentration (µg/g) Cd	Cu	Pb	Zn	Ni	Fe
1. Pelintung	24.13	4.04	Shell	4.49	5.33	50.16	3.94	22.72	26.32
n = 38			Operculum	5.81	8.55	49.25	27.31	27.40	46.60
			Soft tissue	1.50	11.83	10.65	98.07	7.04	363.34
2. Guntung	23.53	4.15	Shell	4.35	6.43	43.39	3.92	21.56	36.83
n = 25			Operculum	3.76	6.79	52.23	12.42	24.27	35.54
			Soft tissue	0.43	10.78	14.55	90.55	2.23	780.20
3. Mundam	22.70	3.32	Shell	4.21	6.16	43.73	3.80	20.69	32.85
n = 34			Operculum	4.17	6.80	53.58	13.33	24.70	39.20
			Soft tissue	0.42	14.93	11.78	93.23	4.77	806.34
4. Pertamina	23.72	4.72	Shell	3.95	5.98	53.35	3.85	20.84	23.80
n = 22			Operculum	4.78	7.11	58.18	17.81	20.44	21.02
			Soft tissue	0.83	13.73	10.62	97.08	3.47	237.13
5. Pelabuhan	24.04	4.14	Shell	4.27	5.98	44.33	3.38	19.61	53.58
n = 36			Operculum	4.34	7.72	51.25	17.59	25.64	42.36
			Soft tissue	0.92	15.10	10.12	93.64	7.75	619.76
6. Sg. Dumai	21.43	3.01	Shell	4.40	5.77	44.03	3.87	19.80	21.12
n = 38			Operculum	4.05	6.74	49.12	15.23	24.50	29.12
			Soft tissue	0.69	18.47	7.81	91.93	5.99	303.10
7. Purnama	23.49	3.85	Shell	4.37	5.79	46.71	3.83	20.58	22.86
n = 48			Operculum	3.83	7.09	51.11	12.52	24.14	32.69
			Soft tissue	0.50	20.60	9.31	93.58	8.47	318.94
8. Sg. Mesjid	23.64	4.23	Shell	4.44	5.74	50.32	3.72	20.71	20.44
n = 42			Operculum	3.65	6.90	49.95	17.83	26.61	30.75
			Soft tissue	0.52	12.47	9.46	91.35	5.17	282.70
9. Lubuk Gaung	23.58	4.09	Shell	3.94	6.01	46.15	3.68	20.72	23.46
n = 33			Operculum	4.16	7.65	51.76	18.49	26.80	31.99
			Soft tissue	0.57	18.66	9.84	93.75	5.16	360.89
10. Basilam Baru	21.51	3.32	Shell	4.11	5.67	39.95	3.57	20.33	19.39
n = 26			Operculum	3.82	7.62	53.55	22.64	19.57	24.51
			Soft tissue	0.56	14.25	6.36	101.97	3.60	252.65
11. Penyembal	23.28	3.47	Shell	3.95	5.79	38.55	3.61	19.62	18.64
n = 50			Operculum	3.72	7.25	52.84	19.91	18.07	25.29
			Soft tissue	0.75	14.06	8.96	99.68	4.27	318.75
12. Pulau Babi	23.97	4.01	Shell	3.74	5.88	40.54	3.87	20.62	18.55
n = 31			Operculum	3.82	7.16	49.26	17.33	26.20	29.63
			Soft tissue	0.66	17.04	9.03	94.62	5.75	315.44
13. Tj. Medang luar	22.98	3.59	Shell	3.92	5.78	40.91	3.70	21.04	21.59
n = 44			Operculum	4.06	7.35	51.84	16.46	18.93	21.08
			Soft tissue	0.67	13.78	7.56	97.98	3.02	306.33
14. Tj. Medang dalam	22.93	3.53	Shell	3.83	6.35	39.91	3.59	21.33	9.27
n = 40			Operculum	4.22	7.67	51.01	17.91	21.98	18.68
			Soft tissue	0.91	16.55	4.79	88.28	4.47	305.95

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Table 2. Mean metal concentrations in the shell, operculum and soft tissue of *N. lineata* from intertidal zone of Johor waters

Station	Length (mm)	Weight (g)	Body part	Metal concentration (µg/g) Cd	Cu	Pb	Zn	Ni	Fe
1. Tj. Piai	23.27	3.64	Shell	3.99	5.26	59.48	3.80	19.77	17.10
n = 75			Operculum	4.77	6.80	70.18	25.54	19.73	23.11
			Soft tissue	1.30	19.65	30.27	95.96	7.19	460.65
2. Kukup	23.37	3.52	Shell	4.57	5.68	59.41	5.37	19.71	31.31
n = 60			Operculum	4.34	7.86	62.31	29.05	21.62	32.64
			Soft tissue	1.03	27.63	36.39	101.32	5.86	504.95
3. Pontian	22.63	6.37	Shell	5.10	5.19	52.88	4.99	17.90	27.26
n = 66			Operculum	5.99	6.49	51.30	17.70	18.10	37.29
			Soft tissue	1.71	20.48	14.12	99.93	5.04	287.01
4. Benut	22.66	3.35	Shell	4.01	4.66	60.29	5.06	19.57	38.44
n = 39			Operculum	5.58	5.86	52.06	15.60	20.65	24.63
			Soft tissue	1.43	19.04	3.81	98.19	5.18	564.41
5. Rengit	22.75	3.21	Shell	4.11	5.00	55.75	4.51	19.85	40.47
n = 50			Operculum	4.34	6.59	56.74	17.76	19.79	66.43
			Soft tissue	1.54	11.59	16.21	88.94	5.27	810.57
6. Sg. Ayam	23.82	4.20	Shell	4.07	5.07	80.17	4.60	20.44	37.30
n = 70			Operculum	4.82	7.05	94.36	23.03	28.95	42.55
			Soft tissue	1.04	15.97	48.33	97.72	10.62	355.57
7. Tj. Laboh	22.61	3.38	Shell	3.51	4.89	58.54	4.53	19.06	23.14
n = 51			Operculum	3.67	5.84	58.67	13.71	18.56	22.24
			Soft tissue	0.98	15.81	16.51	86.04	4.51	217.98
8. Parit Simen	23.24	3.68	Shell	4.73	4.95	50.39	5.10	19.31	37.43
n = 53			Operculum	5.27	5.90	49.48	15.97	20.14	39.64
			Soft tissue	1.06	13.18	9.88	94.33	4.18	436.01
9. Parit Jawa	26.60	5.25	Shell	3.26	5.10	64.06	4.93	17.63	34.47
n = 30			Operculum	3.76	6.83	58.85	19.74	18.19	38.82
			Soft tissue	0.72	20.26	11.47	95.05	3.96	778.30
10. Muar	23.67	3.68	Shell	4.46	4.83	57.45	5.23	19.63	29.06
n = 31			Operculum	4.81	5.88	51.74	16.72	21.10	21.90
			Soft tissue	1.63	16.56	10.52	93.42	3.90	320.13

Table 3. Concentrations of heavy metals in decreasing order according to body part of *N. lineata*

Metal	Location	Concentrations in decreasing order
Cd, Pb, Ni	Dumai and Johor	Operculum > Shell > Soft tissue
Cu, Zn, Fe	Dumai and Johor	Soft tissue > Operculum > Shell

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Concentrations of heavy metals in the shell, operculum and soft tissue of *N. lineata* from Dumai waters showed different pattern. Highest concentrations of Pb were recorded in the shell and operculum, whilst Fe in the soft tissue. Cd concentrations were lowest in the soft tissue and operculum whilst shell exhibited the lowest concentration of Zn. Distribution pattern of metals in each analyzed body part of *N. lineata* from Johor were almost similar with samples from Dumai waters. However, the lowest concentration of Cd in samples from Johor was found in the shell instead of Zn in samples from Dumai waters (Table 4).

Table 4. Concentrations of heavy metals in *N. lineata* from Dumai and Johor waters in decreasing order

Body part	Location	Metals in decreasing order
Shell	Dumai	Pb > Fe > Ni > Cu > Cd > Zn
	Johor	Pb > Fe > Ni > Cu > Zn > Cd
Operculum	Dumai	Pb > Fe > Ni > Zn > Cu > Cd
	Johor	Pb > Fe > Ni > Zn > Cu > Cd
Soft tissue	Dumai	Fe > Zn > Cu > Pb > Ni > Cd
	Johor	Fe > Zn > Pb > Cu > Ni > Cd

Concentrations of heavy metals in samples from Johor Malaysia also varied between sampling stations. The highest concentrations of Pb and Ni were recorded in the shell, operculum and soft tissue of samples from Sungai Ayam; Cu and Zn in Kukup, Cd in Pontian and Fe in samples from Rengit. Highest concentration of Pb were observed in the in the shell (80.17 µg/g), operculum (99.26 µg/g) and soft tissue (48.33 µg/g) of samples from Sg. Ayam, indicating that this station was more contaminated by Pb when compared to others. Apart from general sources of pollutants in the west coast of Peninsular Malaysia, Sg. Ayam is one of the fishing areas where many boats are berthed in this area. The sediment in this area was also visually darker than others, indicating some organic inputs from the surroundings.

Discussion

The results of the study showed that shell, operculum and soft tissue of *N. lineata* from Dumai and Johor intertidal zones were able to accumulate metals from their environment. Shell and operculum recorded higher concentrations of Pb, Cd and Ni, whilst soft tissue recorded higher concentrations of Cu, Zn and Fe. The soft tissues of marine molluscs are generally recognized as more efficient accumulators of metals than shells (Rainbow, 1990; Brown and Depledge, 1998). However, the shells are also useful in studying metal accumulation since they can be used as a record of environmental pollution. The composition of the mollusc's shell is strongly related to the chemical mineralogy which includes metal accumulated from the environment, and therefore metal concentrations in the shell

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follow the metal concentrations in their environments (Carell *et al*., 1987). Shells also have some practical advantages over the use of soft tissue as they can reveal less variability, integrate metal concentrations over the life of the organisms, able to give an idea on the metal levels in the past and offer considerable advantages in easy preservation and storage (Bourgoin, 1990; Al-Dabbas *et al*., 1984; Cravo *et al*., 2002; Yap *et al*., 2003).

The concentrations of Cd, Pb and Ni in the shells were 5.83, 4.76 and 4.08 and in the operculum were 5.86, 5.54 and 4.63 times, respectively, higher than those of the soft tissue of *N. lineata* from Dumai. The concentrations of Cu, Zn and Fe in the shells were, however, lower than that in the soft tissues (ratios of shell/soft tissue: 0.39, 0.04 and 0.06 for shell and operculum/soft tissue: 0.48, 0.19 and 0.08, respectively). Samples from Johor also showed similar pattern in the metal accumulation, where in the shell: 3.73, 3.03 and 3.46 and in the operculum were 3.81, 3.07 and 3.71 higher than in the soft tissue. The concentrations of Cu, Zn and Fe in the shell were also lower than that in the soft tissues (ratios of shell/soft tissue: 0.28, 0.05 and 0.07 and operculum/soft tissue: 0.36, 0.20 and 0.07, respectively). These results indicated that the shell and operculum had higher affinities for Cd, Pb and Ni than the soft tissues. Walsh *et al*. (1995) also found that marine gastropod *Austrocochlea constricta* recorded higher concentration of Cd in the shell as compared to the soft tissue. The high concentrations of Pb found in the shell could probably be due to the fact that the crystalline structures of the shell matrix have a higher capacity for incorporation of these metals than the soft tissues (Al-Dabbas *et al*., 1984; Koide *et al*., 1982). The incorporation of Cd, Pb and Ni in the shell matrices might take place at a faster rate than that for Cu, Zn and Fe. These metals (Cd, Pb and Ni) are assumed not being affected by the physiological conditions of the *Nerita* snail and stored almost permanently in their hard tissues.

As for samples from Dumai, metal concentrations in the shell and operculum in samples from Johor also higher than that in the soft tissue. Ismail and Jazlina (2003) found that shell of *N. lineata* from Selangor coastline accumulated higher concentrations of Cd and Pb as compared to Zn. Yap *et al*. (2003) also reported that Pb and Cd concentrations in the shell of *P. viridis* from west coast of Peninsular Malaysia were higher than Zn, whilst in soft tissue Zn was higher than Pb and Cd.

The shell and operculum of *N. lineata* might also be a site for the biodeposition of the excess assimilated Cd, Pb and Ni. Marigomez and Ireland (1990) reported that shell of winkle, *Littorina littorea*, was a good indicator of the average environmental concentration of cadmium. Several previous studies also showed the fact that some trace metals are incorporated into the shells of molluscs and barnacles through substitution of the calcium ion in the crystalline phase of the shell or are associated with the organic matrix of the shell (Al-Dabbas *et al*., 1984; Carriker *et al.,* 1980; 1982; 1991; Koide *et al*., 1982; Watson *et al*., 1995). Shell may act as a safe storage matrix for toxic contaminants resistant to soft tissue detoxification mechanisms (Walsh *et al*., 1995) and not continually exposed to metabolic processes and therefore have longer biological half-lives (Lee and Koide, 1987).

The soft tissues of *N. lineata* from Dumai and Johor accumulated more Cu, Zn and Fe than the shells. This could be due to these metals being needed for metabolism in the soft tissues of *N. lineata*. The higher concentration of these metals found in the soft tissues than in the shell was in agreement with the results reported by Cravo *et al*. (2004) who found that Fe and Zn concentrations were consistently lower in the shell than in the soft tissue of gastropod *Patella aspera* from the south coast of Portugal. The same results were also reported for bivalve mollusc *Mytilus edulis* (Bertine and Goldberg, 1972; Giusti *et al*., 1999; Koide *et al*., 1982; Segar *et al*., 1971) and *Mytilus galloprovincialis* (Puente *et al*., 1996).

Metal concentrations in *N. lineata* varied along the sampling station in Dumai. The highest or lowest concentrations also varied for each different metal. In general, higher metal concentrations were found in samples from the vicinity of industrial complexes and urbanized area which lied between Pelintung and Sungai Mesjid. The shell and operculum showed similar pattern in the accumulation of heavy metals analyzed and the operculum always had higher concentration than the shell. There was no clear pattern of lowest concentration distribution among the stations and analyzed body parts of the gastropod *N. lineata*. However, within the fourteen stations, only Cd was recorded to have highest concentration in all body parts (shell, operculum and soft tissue) at the same sampling station (Pelintung).

The high concentrations of Cd in Pelintung and other metals in stations from Pelintung to Sungai Mesjid were assumed to be related to the human activities along the coastal waters of these stations. Two large rivers are draining their load to these waters, one of which is passing the densely populated area in the Dumai city center. Oil palm and petroleum refineries, some small scale metal and various industries, heavy traffic of tankers and commercial and fishermen boats activities are all in their operation in these areas. However, the industrial and anthropogenic activities in Dumai are still much less when compared to those in the southwest coast of Peninsular Malaysia, especially in Johor.

Concentrations of heavy metals in *N. lineata* from Johor, in general, were significantly higher than that in samples from Dumai ($p<0.01$) as seen in **Fig. 2**,**3**,**4**. Only Cu and Ni concentrations in shell and operculum in samples from Dumai were significantly higher ($p<0.01$) than samples from Johor. For Cd in shell as well as Zn and Fe, although their concentrations were also higher in samples from Johor, statistically they were not significantly different ($p>0.05$). Concentrations of metals in soft tissue of samples from Johor were higher than that of samples from Dumai, but only Cd, Cu and Pb were statistically significant different ($p<0.01$). Higher concentrations of metals in samples from Johor Malaysia, in general, might be related to the more anthropogenic activities in this area. Yap *et al*. (2002; 2004) reported that the west coast of Peninsular Malaysia is more developed than the east coast. Many activities such as petrochemical plants, land reclamation, urbanization, shipping and other industrial activities and some major ports are concentrated in this location.

The results of the present study were still comparable to those previous reported studies in *Nerita* and other gastropods from several geographical regions as presented in Table 5. Concentrations of Cd and Pb in samples from Dumai and Johor were higher in shell than in soft tissue, whereas Cu and Zn were higher in soft tissue than that in shell. This was in agreement with other previous study in *Nerita* by Ismail and Jazlina (2003); Foster *et al*. (1997); Foster and Cravo (2003) and in other gastropods (Cravo, 2004 and Walsh *et al*., 1995). Concentrations of Cu were slighly higher, whilst Fe and Zn in shells comparable to other species of *Nerita* in the previous studies (Foster *et al*., 1997; Foster and Cravo, 2003; Cravo *et al*., 2004). The concentrations of Fe and Zn in soft tissue, however, lower than other gastropod species like *Littorina littorea* (De Wolf, 2000) and *Patella aspera* (Cravo *et al*., 2004). These differences in metal concentrations are believed being attributed to the geographical factor and its environmental sources of contaminants. No available data on heavy metal concentrations in the operculum of *Nerita* or other gastropod species to be compared with the present study.

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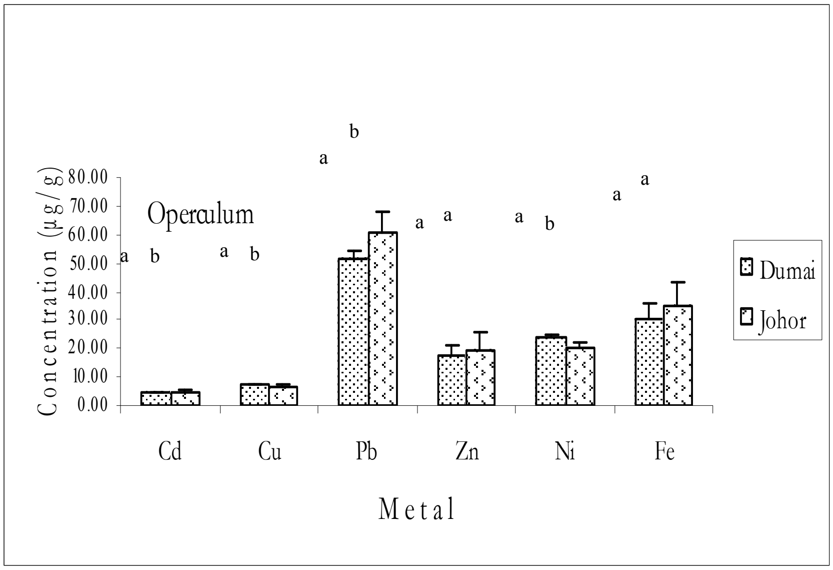

Fig. 3. Mean metal concentrations in operculum of *N. lineata* from Dumai and Johor waters (Note: Bars with different letter denote significantly different (p< 0.01)

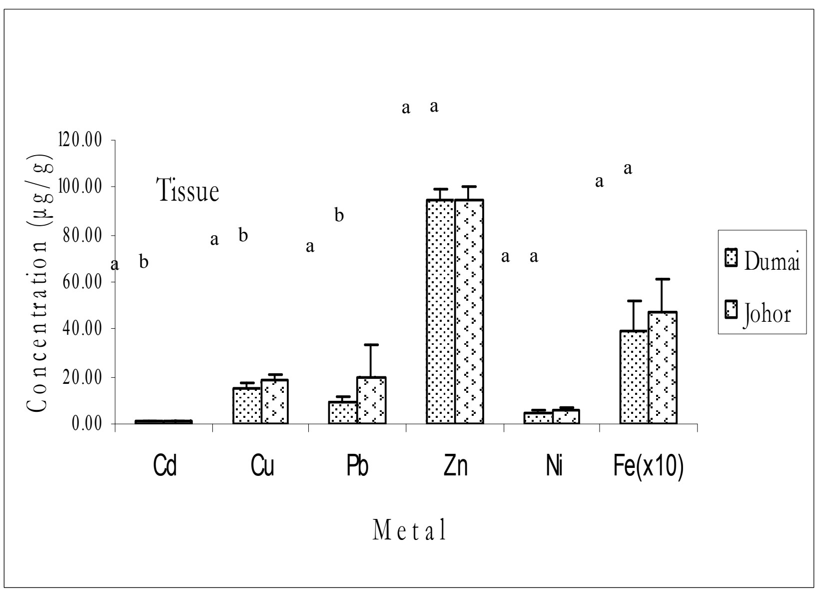

Fig. 4. Mean metal concentrations in soft tissue of *N. lineata* from Dumai and Johor waters (Note: Bars with different letter denote significantly different (p < 0.01)

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Table 5. Metal concentrations (μg/g) in *N. lineata* determined in the present study in comparison with *Nerita* sp and gastropods from other studies

Gastropod species	Location	Body part	Cd	Cu	Pb	Zn	Ni	Fe	Reference
Nerita albicilla	Thailand	Shell	-	-	-	5.8	-	30.8	Foster *et al*., 1997
Nerita polita	...,,...	Shell	-	-	-	4.1	-	20.8	…….,,……..
Nerita costata	...,,...	Shell	-	-	-	5.2	-	21.5	…….,,……..
Nerita undata	...,,...	Shell	-	-	-	4.6	-	32.6	…….,,……..
Nerita polita	East Africa	Shell	-	2.9	-	4.2	-	18.6	Foster and Cravo, 2003
Nerita undata	...,,...	Shell	-	3.1	-	4.7	-	25.2	…….,,……..
Nerita costata	...,,...	Shell	-	3.7	-	5.1	-	18.9	…….,,……..
Nerita plicata	...,,...	Shell	-	2.8	-	6.2	-	20.3	…….,,……..
Nerita albicilla	...,,...	Shell	-	4.1	-	7.2	-	26.4	…….,,……..
Nerita textilis	...,,...	Shell	-	3.8	-	5.8	-	21.3	…….,,……..
Nerita lineata	Malaysia	Soft tissue	1.44-2.80	0.41-11.03	16.26-22.31	23.52-25.01	-	-	Ismail and Jazlina, 2003
Nerita lineata	Singapore	Soft tissue	0.02-0.03	7.5-8.8	0.49-1.1	31-680	2.7-10	-	Cuong *et al.*, 2005
	...,,...	Shell	3.22-4.87	0.40-2.58	45.07-48.42	11.99-16.37	-	-	…….,,……..
Nerita albicilla	Hongkong	Soft tissue	1.78-2.87	33-189	-	105-130	-	-	Blackmore, 2001
Patella aspera	Portugal	Shell	-	-	-	5.6	-	26.7-44.9	Cravo *et al*., 2004
	...,,...	Soft tissue	1.6-6.0	6.1-8.1	-	62.3-128.8	4.4-5.8	1022-1466	…….,,……..
Patelle caerulea	Gulf of Suez	Soft tissue	0.63-2.13	1.6-12.17	6.23-70.91	56.47-191.40	3.06-9.88	1.24-2.94	Hamed and Emera, 2006
Patelle caerulea	Mediterranean	Soft tissue	3.5-8.8	1.27-2.02	0.10-1.42	3.9-18.2	-	-	Cubadda *et al*., 2001
Patelle lusitanica	...,,...	Soft tissue	2.1-4.9	2.08-2.80	0.14-0.71	8.40-17.60	-	-	…….,,……..
Nerita articulata	India	Soft tissue	-	19.74-21.30	5.05-6.03	63.90-81.75	-	238.42-303.65	Mitra and Choudhury, 1993
Littorina undulata	...,,...	Soft tissue	-	15.65-17.89	3.65-7.54	46.20-53.84	-	178.52-219.46	…….,,……..
Littorina brevicula	Korea	Soft tissue	4.5	217	7.53	136	-	-	Kang *et al*., 1999
Littorina littorea	Holland	Soft tissue	0.92-5.23	68.22-176	0.86-1.67	59.65-106	3.43-7.43	337-1214	De Wolf *et al*., 2000
Bembicium nanum	Australia	Soft tissue	0.67-3.47	37-379	-	63-127	-	-	Gay and Maher, 2003
Austrocochlea costata	Australia	Shell	0.21-2.28	0.12-2.81	-	1.28-18.51	-	-	Walsh *et al*., 1995
	...,,...	Soft tissue	0.23-3.07	0.46-5.03	nd-0 .71	3.12-23.06	-	-	…….,,……..
Telescopium telescopium	Malaysia	Soft tissue	-	47.4-60.3	-	37.7-58.4	-	-	Ismail and Safehieh, 2004
	Singapore	Soft tissue	0.05-0.12	85.0-140.0	0.48-1.40	100-340	7.6-10.0	-	Cuong *et al.*, 2005
	Australia	Soft tissue	nd-2.06	0.7-72.0	nd-8.99	9.6-199	nd-2.89	-	Peerzada et al., 1990
Nerita lineata	Indonesia	Shell	4.14	5.90	44.43	3.74	20.73	24.91	Present study
	...,,...	Operculum	4.16	7.31	51.78	17.63	23.52	30.60	Present study
	...,,...	Soft tissue	0.71	15.16	9.35	94.69	5.08	397.97	Present study
Nerita lineata	Malaysia	Shell	4.18	5.06	59.84	4.81	19.29	31.60	Present study
	...,,...	Operculum	4.73	6.51	60.57	19.48	20.68	34.92	Present study
	...,,...	Soft tissue	1.24	18.02	19.75	95.09	5.57	473.56	Present study

CONCLUSION

The present study indicated that more industrial and anthropogenic activities in Johor Malaysia as compared to Dumai Indonesia was reflected in higher concentrations of metals accumulated in the *N. lineata* collected from Johor. Metal concentrations were also recorded to be higher in *N. lineata* collected from the stations closed to the industries and anthropogenic activities in both Dumai and Johor area. Since *N. lineata* can be abundantly found in the intertidal area of both Malaysia and Indonesia, they could be considered as potential biomonitors of heavy metal pollution. It is also proposed that the operculum and shell of *N. lineata* could be potential biomonitoring materials for heavy metals, especially for Cd, Pb and Ni, whilst the soft tissue could be good biomonitoring organ for Cu, Zn and Fe.

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