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Distribution and Concentrations of Ni in Tissues of the Gastropod *Nerita lineata* Collected from Intertidal Areas of Peninsular Malaysia

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ABSTRACT

Nickel (Ni) is an essential metal but not a well-studied metal in gastropods. In this study, *Nerita lineata* snails were collected from 20 sites along the western coast of Peninsular Malaysia from December 2005 to December 2010. The concentrations of Ni were determined in the total soft tissues, opercula and shells of the snails. Different patterns of Ni distribution were found in different tissues (shells, opercula and soft tissues) as well as spatial differences and distributions. This finding showed that the distributions of Ni in the shells and total soft tissues of *N. lineata* were significantly different, and this could be due to the different rates of Ni accumulation, excretion and sequestration. Since *N. lineata* can be abundantly found in rocky shores, below jetties and mangrove trees along the intertidal areas of the west coast of Peninsular Malaysia and it can show the ability to accumulate Ni, the snails can therefore act as potential biomonitors of Ni pollution in the western coast of Peninsular Malaysia.

Keywords: Ni, *Nerita lineata*, Peninsular Malaysia, opercula

INTRODUCTION

Aquatic ecosystems may receive anthropogenic pollutants originating from various sources and many pollutants, including heavy metals which are toxic to aquatic organisms and can cause lethal and sublethal deterioration in living organisms (Wang *et al*., 2005). Activities such as fossil fuel burning, emissions from vehicles, disposal of domestic and industrial wastes were some of the sources that contribute to the release of heavy metals (particularly Ni) into the environment (Yusuf *et al*., 2011).

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Therefore, biomonitoring studies remain crucial in the field of ecotoxicology. In past studies, bivalve species were applied as biomonitors for heavy metal pollution in global monitoring programmes (Rainbow *et al*., 2000; Wang *et al*., 2005; Yap *et al*., 2002a; Yap *et al*., 2004; Yap *et al*., 2006). Besides marine mussels, heavy metal reports on other intertidal molluscs such as the gastropods are also available in the literature (Foster & Cravo, 2003; Amin *et al*., 2006). Similarly to marine mussels, gastropods meet many of the recommended criteria as a good biomonitor, and these include wide distribution and high abundance, sedentary lifestyle, of relatively high longevity, as well as easily collected and weighed (Blackmore, 2001; Rainbow, 1995).

Nerita snails are dwellers of rocky shores and mangrove areas along the western coast of the peninsular. *N. lineata* is of the Order Archeaogastropoda and the Family Neritidae. They are herbivorous gastropods that graze on micro-algae growing on rocks, shells or larger plants (Hughes, 1986). They are known by the locals as 'siput timba' (bucket snail).

Prior to 1975, according to Boyle and Robinson (1988), Ni was considered to have no essential biological function but it was later discovered to be significant in a number of plant, animal and bacterial systems, although a well-defined biochemical mechanism for the role of Ni is still obscure. Meanwhile, the uptake and metabolism of Ni are very decisive for certain enzymatic activities, depending on the organisms (Yusuf *et al*., 2011). In general in bivalves, many of the toxic responses to Ni involve interferences with Fe metabolism and Ni, like most metals, bound to protein and nucleic acid (Stokes, 1988). In this paper, the focus was on Ni because this metal had been shown to be relevant for ecotoxicological studies. Based on some recent literature, Ni has been a focused metal such as in sediments (Yap & Wong, 2011), mussels (Yap *et al*., 2006), snails (Yap *et al*., 2008) and plants (Ong *et al*., 2011). Therefore, this study aimed to determine the distribution and concentrations of Ni in three different tissues of *N. lineata* collected from 20 sites along the western coast of Peninsular Malaysia.

MATERIALS AND METHODS

Surveys and samplings were done from the northern part to the southern part of Peninsular Malaysia (Fig.1). Out of the 25 surveyed sites, snail samples (*N. lineata*) were collected from 20 sites while sediments were collected from 17 sites along the western coast of Peninsular Malaysia from December 2005 until December 2010 (Table 4). The samples were placed in a cooler box with ice cubes (<10 ºC) during transportation to the laboratory. In this study, the *N. lineata* was not depurated of the contents of their alimentary canal since depuration might lead to contamination (Rainbow & Blackmore, 2001). Most importantly, it was found that there was no significant difference (P>0.05) between metal levels before and after depuration based on our preliminary study.

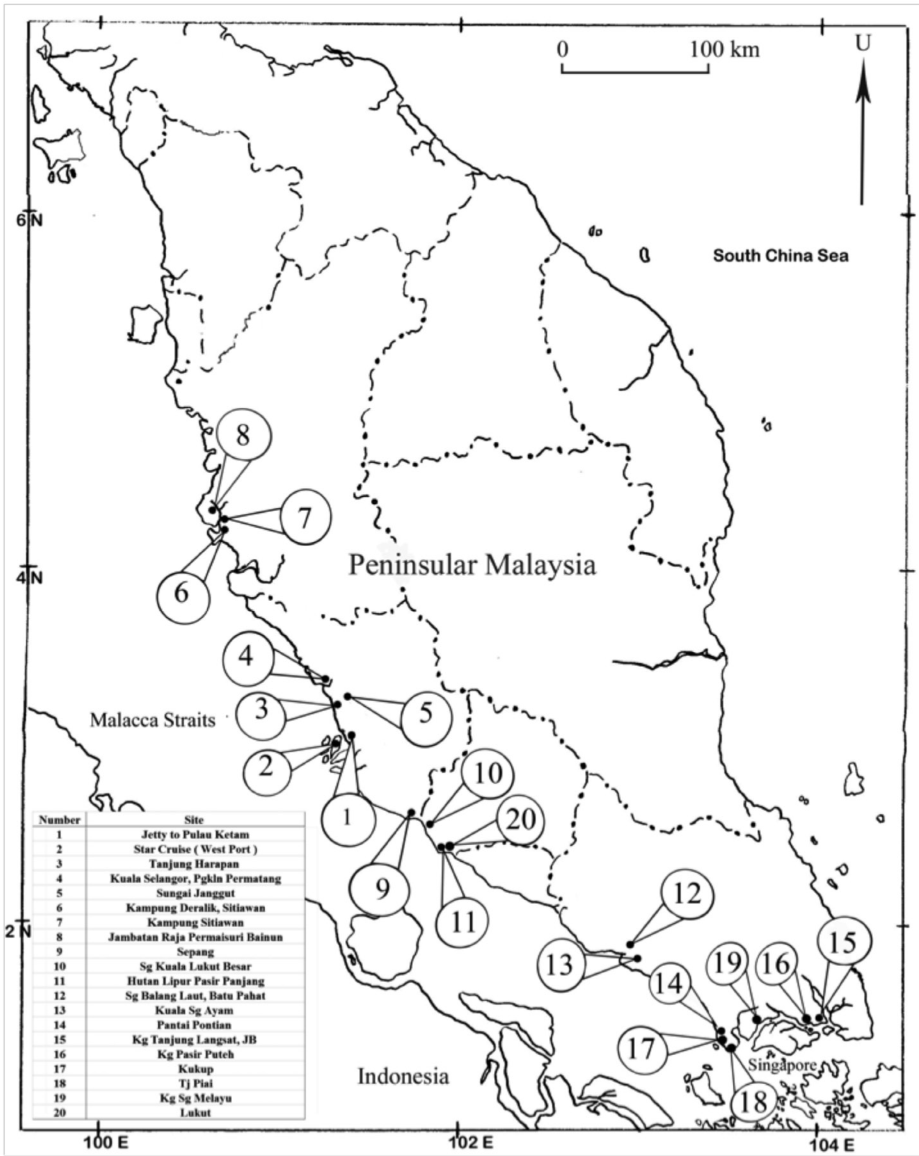

Fig.1: A map showing sampling sites of *Nerita lineata* on the western coast of Peninsular Malaysia

A total of 15 snails with relatively similar sizes were collected from each sampling site and they were dissected and separated into three parts (shells, opercula and total soft tissues). The snails were then dissected and separated into three parts, namely, shells, opercula and total soft tissues. All the samples were dried for 72 hours at 60ºC in an oven to constant dry weights. About 0.5g of homogenized samples (shells, opercula and total soft tissues) was digested in 5ml concentrated nitric acid (AnalaR grade, BDH 69%). They were placed in a digestion block at 40ºC for

1 hour and were later fully digested at 140ºC for 2-3 hours (Yap *et al*., 2002a). For the analyses of the sediment samples, the direct aqua regia method was applied. About 1g of each dried sample was digested in 5ml of a combination of concentrated nitric acid (69%) and perchloric acid (60%) in the ratio of 4:1; first at a low temperature (40ºC) for one hour, and followed by increasing the temperature to 140ºC for three hours. Then, the digested samples were diluted to 20 ml with double distilled water (DDW). After dilution, the samples were filtered with Whatman No. 1 filter paper and stored for further Ni determination.

All the samples stored in the acid-washed pill boxes were analyzed for Ni by using air-acetylene Perkin-Elmer™ flame Atomic Absorption Spectrophotometer (AAS) Model Analyst 800. Standard solution of Ni was prepared from 1000ppm stock solution provided by MERCK Titrisol for Ni (Yap *et al*., 2002a). All the data were presented in µg/g dry weight basis. The data were converted into µg/g by multiplying the data measured (C in mg/L) with dilution factor or total volume (D.F in ml). This was then divided with dry weight of sample (W in gram) in the following equation:

$$\text{Heavy metal concentration in gram sample } (\mu g/g) = \frac{C \times D.F}{W}$$

To avoid possible contamination, all glassware and equipment used were acid-washed and the accuracy of the analysis was checked against the procedural blank standard addition testing procedure (Yap *et al*., 2004). The percentage of recovery was 101% for Ni.

The Pearson's correlation coefficients were applied to find the correlation of Ni between the different tissues and sediments by using Statistical software (SPSS software version 15.0 for Windows).

RESULTS AND DISCUSSION

Table 1 shows the concentrations (µg/g dry weight) of Ni in the soft tissues, shells and opercula of *N. lineata*. The Ni concentrations in the soft tissues ranged from 0.40 – 10.51. As for opercula, the metal ranges were 10.84 – 34.90. It was found that the Ni concentrations ranges in the shells were 14.41 - 34.98.

In total in the soft tissues, the highest Ni concentration was recorded from the Kukup samples (10.90 ±0.75) while those from Tg. Harapan (2.93 ± 0.38) recorded the lowest level of Ni. Meanwhile, the highest level of Ni was found in the opercula of Kuala Lukut Besar (36.33 ± 0.10), whereas the samples from Tg. Harapan had the lowest level of Ni (11.88 ± 0.52) in the opercula. The shells of the snails were found to contain the highest level of Ni (35.83 ± 0.18) in the samples collected from the Kuala Lukut Besar population. On the other hand, the lowest level of Ni was found in the shells collected in 2010 from the Sg. Ayam (13.53 ± 0.13) population.

As for the samples collected from two different periods of time (namely, 2005 and 2010), the heavy metal concentrations showed some variations. In more specific, the Ni concentrations of all the tissues

TABLE 1
Mean µg/g dry weight, minimum and maximum concentrations of Ni in the soft tissues (ST), opercula and shells of *Nerita lineata* (n=15) and sediments (total) (n=11) collected from the west coast of Peninsular Malaysia.

No	Location		ST	Opercula	Shells	Sediment
1	Jetty to Pulau Ketam (2005)	mean±se	4.72 ± 0.51	15.53 ± 0.13	16.37 ± 0.12	10.30 ± 0.01
		min - max	4.15 - 5.74	15.37 - 15.79	16.16 - 16.56	10.30 - 10.30
	Jetty to Pulau Ketam (2010)	mean±se	3.46 ± 0.23	13.39 ± 0.87	14.43 ± 0.98	10.3 ± 0.01
		min - max	3.03 - 3.79	11.82 - 14.84	13.40 - 16.40	10.30 - 10.30
2	Star Cruise	mean±se	6.61 ± 0.34	19.21 ± 0.45	25.09 ± 4.95	na
		min - max	5.97 - 7.10	18.32 - 19.77	19.89 - 34.98	na
3	Tj. Harapan (2005)	mean±se	2.93 ± 0.38	11.89 ± 0.52	15.53 ± 0.57	na
		min - max	2.26 - 3.57	10.84 - 12.44	14.41 - 16.29	na
	Tj. Harapan (2010)	mean±se	2.69 ± 0.27	16.51 ± 3.59	15.14 ± 0.95	13.59 ± 0.15
		min - max	2.15 - 3.00	12.09 - 23.62	13.70 - 16.94	13.32 - 14.08
4	Pengkalan Permatang	mean±se	6.02 ± 0.29	25.81 ± 0.50	26.67 ± 0.21	11.70 ± 0.07
		min - max	5.46 - 6.43	25.23 - 26.80	26.28 - 27.01	11.60 - 11.80
5	Sg. Janggut (2005)	mean±se	8.34 ± 1.14	23.09 ± 0.92	21.08 ± 0.93	7.96 ± 0.27
		min - max	6.66 - 10.51	21.31 - 24.41	19.71 - 22.84	7.49 - 8.44
	Sg. Janggut (2010)	mean±se	3.08 ± 0.57	14.91 ± 0.70	18.77 ± 0.81	7.19 ± 1.05
		min - max	2.16 - 4.13	13.66 - 16.10	17.28 - 20.05	7.14 - 7.41
6	Deralik	mean±se	4.77 ± 1.22	21.30 ± 0.51	20.09 ± 0.06	6.04 ± 0.08
		min - max	3.44 - 7.20	20.38 - 22.13	19.98 - 20.20	5.90 - 6.17
7	Kg. Sitiawan	mean±se	7.99 ± 0.67	21.57 ± 0.55	23.09 ± 0.40	12.00 ± 0.60
		min - max	6.67 - 8.87	20.95 - 22.67	22.31 - 23.66	11.00 - 13.10
8	J.R.P. Bainun	mean±se	4.92 ± 1.15	33.86 ± 0.59	33.68 ± 0.44	12.80 ± 0.11
		min - max	3.49 - 7.20	32.85 - 34.90	33.07 - 34.53	12.60 - 13.00
9	Sg. Sepang Besar (2005)	mean±se	6.58 ± 0.67	19.46 ± 0.28	19.59 ± 0.24	11.20 ± 0.19
		min - max	5.31 - 7.57	18.90 - 19.77	19.28 - 20.06	10.90 - 11.50

Table 1 (*continued*)

	Sg. Sepang Besar (2010)	mean±se	8.36	±	1.73	15.04	±	0.63	15.29	±	0.99	7.96	±	0.58
		min - max	0.32	-	0.56	2.62	-	4.08	4.31	-	6.99	5.17	-	5.84
10	Kuala Lukut Besar	mean±se	7.94	±	0.32	36.33	±	0.10	35.83	±	0.18	4.47	±	0.08
		min - max	7.34	-	8.43	36.13	-	36.43	35.62	-	36.19	4.33	-	4.61
11	Pasir Panjang	mean±se	3.62	±	1.62	21.25	±	0.38	22.02	±	0.22	22.60	±	0.93
		min - max	0.40	-	5.53	20.83	-	22.00	21.70	-	22.45	21.00	-	24.20
12	Sg. Balang Laut	mean±se	6.14	±	0.27	24.54	±	0.26	26.09	±	0.26	16.10	±	0.04
		min - max	5.64	-	6.57	24.10	-	24.99	25.76	-	26.59	16.00	-	16.20
13	Sg. Ayam (2006)	mean±se	5.90	±	1.15	24.71	±	0.53	25.65	±	0.14	20.60	±	0.40
		min - max	3.67	-	7.51	23.64	-	25.29	25.48	-	25.92	19.90	-	21.30
	Sg. Ayam (2010)	mean±se	4.52	±	0.34	11.91	±	1.09	13.53	±	0.81	23.16	±	0.43
		min - max	3.89	-	5.06	9.74	-	13.11	12.13		14.94	22.55	-	23.99
14	Pontian	mean±se	5.92	±	0.69	23.76	±	0.84	24.40	±	0.18		na	
		min - max	4.75	-	7.15	22.08	-	24.63	24.06	-	24.66		na	
15	Tj. Langsat (2006)	mean±se	5.32	±	1.57	27.80	±	0.47	27.45	±	0.20		na	
		min - max	2.18	-	6.94	27.00	-	28.64	27.06	-	27.73		na	
	Tj. Langsat (2010)	mean±se	6.00	±	0.42	26.70	±	1.16	19.80	±	0.42	13.76	±	0.73
		min - max	5.49	-	6.84	24.40	-	28.11	19.29	-	20.63	10.63	-	11.91
16	Kg. Pasir Puteh	mean±se	7.56	±	0.92	22.55	±	3.15	28.24	±	1.93	17.30	±	0.39
		min - max	5.71	-	8.49	17.34	-	22.10	24.91	-	31.60	16.86	-	17.53
17	Kukup	mean±se	10.90	±	0.75	22.96	±	1.17	22.26	±	0.97	14.98	±	0.38
		min - max	9.72	-	12.29	20.93	-	24.98	20.33	-	23.41	11.13	-	11.51
18	Tj. Piai	mean±se	7.57	±	2.23	22.32	±	0.81	19.63	±	1.24		na	
		min - max	5.07	-	12.01	21.38	-	23.94	22.02	-	17.90		na	
19	Kg. Sg. Melayu	mean±se	9.17	±	0.91	20.52	±	1.22	15.24	±	1.21	14.75	±	1.15
		min - max	8.74	-	10.92	18.15	-	22.24	13.84	-	17.64	13.40	-	15.38
20	Lukut	mean±se	9.00	±	0.89	16.04	±	0.14	19.94	±	0.86	11.63	±	0.78
		min - max	7.25	-	10.16	15.82	-	16.29	18.38	-	21.34	24.06	-	25.08

Note: na = not available

(soft tissues, opercula and shells) collected from the jetty to Pulau Ketam, Sg. Janggut, Sg. Sepang Besar and Sg. Ayam in 2005 were higher compared to those collected in 2010 (Table 1). Nonetheless, the Ni concentrations from the soft tissues and shells collected from Tj. Harapan did not show much difference between the two periods of sample collections and they only showed an increase in the opercula from 2005 to 2006 (Table 1). As for Tj. Langsat, the Ni concentrations of in the soft tissues and shells were lower in the samples collected in 2005 as compared to those taken in 2010, while the opercula showed a higher Ni concentration in the samples from 2005 compared to those in 2010 (Table 1).

Generally, the pattern of accumulation of Ni, from high to low, was in the sequence of shells≈opercula>soft tissues, as depicted in Table 1. This is similar to the results found by Amin *et al*. (2006b) on this snail. The lower metal concentration of Ni in the soft tissues compared to those in the shells could be due to Ni not being an essential metal for this species and therefore it was regulated downwards in the soft tissues. Meanwhile, the elevated levels of Ni in the soft tissues of marine gastropods were detoxified by making them biologically unavailable as insoluble phosphate salts (Nott & Nicolaidou, 1996). Other marine molluscs, such as *Perna viridis* (Yap *et al*., 2003) and *Telescopium telescopium*

TABLE 2
Correlation coefficient of Ni in the soft tissues, opercula and shells of *Nerita lineata* with those in the SET fractions of sediments collected in 2005 and 2006 (N= 11).

	Ni soft tissues	Ni opercula	Ni shells
Aqua Regia Fraction	-.486	-.205	-.093
EFLE	-.342	-.095	.002
Acid Reducible	-.539	.028	.092
Oxidisable	-.089	.202	.338
Resistant	-.455	-.229	-.154

** Correlation is significant at 0.01 level (2-tailed).
* Correlation is significant at 0.05 level (2-tailed).

TABLE 3
Correlation coefficient of Ni in the soft tissues, opercula and shells of *Nerita lineata* with those in the SET fractions of sediments collected in 2010 (N= 10).

	Ni soft tissues	Ni opercula	Ni shells
Aqua regia Fraction	.353	.295	.267
EFLE	-.110	.104	.233
Acid Reducible	.152	.015	.386*
Oxidisable	-.056	-.229	-.087
Resistant	.094	.157	.047

** Correlation is significant at 0.01 level (2-tailed).
* Correlation is significant at 0.05 level (2-tailed).

TABLE 4
Descriptions of sampling sites and means of shell length (mm), shell width (mm) and shell (mm) height of *Nerita lineata* from the west coast of Peninsular Malaysia (N=30 individuals for each population).

No	Sampling Sites	GPS	Sampling Date	Shell Length (min-max)	Shell Width (min-max)	Shell Height (min-max)	Sites descriptions
1	Jetty to Pulau Ketam	N 03º 01'12''	12-Dec-05	21.9 ± 0.590 (16.5-29.1)	16.3 ± 0.520 (12.7-28.1)	11.9 ± 0.340 (8.75-16.2)	A jetty with shipping activities.
		E 101º 21'42''	18-May-10	26.81 ± 0.34 (25.28 ± 28.34)	18.64 ± 0.17 (17.51 - 19.31)	14.67 ± 0.28 (13.27 - 16.04)	
2	Star Cruise	N 02º 59'12''	12-Dec-05	21.1 ± 0.480 (16.0-26.8)	15.2 ± 0.290 (11.9-18.0)	11.6 ± 0.270 (8.45-14.6)	Shipping activities.
		E 101º 20'42''					
3	Tg. Harapan	N 03º 5'58''	12-Dec-05	22.6 ± 0.620 (12.2-28.7)	16.1 ± 0.360 (9.70-19.1)	12.6 ± 0.370 (6.75-16.3)	Rocky beach, industrial area, a jetties and port area
		E 101º 21'38''	18-May-10	19.33 ± 0.34 (17.71 - 20.75)	14.50 ± 0.22 (13.52 - 15.52)	10.63 ± 0.20 (9.80 - 11.53)	(near to the north port)
4	Pengkalan.	N 03º 21' 24''	24-Feb-06	23.2 ± 0.560 (16.1-28.7)	16.7 ± 0.300 (12.8-19.9)	12.9 ± 0.300 (8.62-15.8)	A fishing village and a jetty.
	Permatang	E 101º 14' 38''					
5	Sg. Janggut	N 04º 8'10''	20-Mac-06	27.3 ± 0.720 (14-14)	19.3 ± 0.360 (11.3-22.0)	15.4 ± 0.400 (7.90-17.8)	River, water irrigation.
		E 101º 22'31''	18-May-10	30.06 ± 0.83 (33.82 - 25.19)	21.07 ± 0.40 (18.93 - 22.47)	16.94 ± 0.39 (14.70 - 18.19)	
6	Deralik	N 04º 14' 53.8''	25-Feb-06	25.5 ± 0.910 (12.1-33.8)	18.6 ± 0.510 (9.62-22.4)	14.4 ± 0.500 (6.47-18.6)	A jetty and fishing village (near Sitiawan) .
		E 100º 42'09''					
7	Kg. Sitiawan	N 04º 14' 44''	25-Feb-06	26.2 ± 0.630 (20.7-33.5)	19.5 ± 0.510 (15.5-28.8)	10.9 ± 18.0 (10.9-18.0)	Recreational park (kayaking).
		E 100º 41' 35''					

Table 4 (*continued*)

8	J.R.P. Bainun	N 04º 16' 46"	27-Feb-06	22.1 ± 0.880 (12.9-31.4)	16.2 ± 0.540 (9.95-21.1)	12.4 ± 0.480 (7.25-17.0)	Near industrial and a highway.
		E 100º 39'50"					
9	Sg. Sepang Besar	N 2° 36'4"	20-Dec-05	22.5 ± 0.670 (15.4-30.6)	16.6 ± 0.440 (11.3-22.2)	12.1 ± 0.400 (8.20-16.5)	An estuary receiving pig-farming effluents in 2000.
		E 101° 42'22"	5-May-10	22.53 ± 0.77 (19.56 - 27.87)	15.97 ± 0.29 (14.56 - 17.68)	11.12 ± 1.21 (0.75 - 14.61)	
10	Kuala Lukut	N 02° 34' 49"	28-Apr-06	23.8 ± 0.710 (15.9-31.1)	17.4 ± 0.440 (12.2-21.0)	13.5 ± 0.410 (8.75-18.7)	Receiving water exchange from a prawn aquacultural
	Besar	E 101° 49' 34"					area.
11	Pasir Panjang	N 02° 24' 55"	28-Apr-06	17.5 ± 0.400 (15.0-25.9)	12.7 ± 0.170 (11.3-14.8)	10.3 ± 0.360 (8.35-18.2)	Receiving domestic wastes.
		E 101° 56' 31"					
12	Sg. Balang Laut	N 01° 52' 21"	29-Apr-06	21.9 ± 0.550 (14.8-26.6)	16.3 ± 0.350 (11.0-18.8)	12.3 ± 0.520 (7.60-21.5)	Receiving water exchange from a prawn aquacultural
		E 102° 44' 16"					area.
13	Sg. Ayam	N 01° 45' 12"	29-Apr-06	23.2 ± 0.860 (15.9-31.3)	17.0 ± 0.550 (12.6-21.9)	12.6 ± 0.490 (8.20-17.3)	A fishing village with a jetty.
		E 102° 55' 45"	18-June-10	26.30 ± 0.56 (23.78 - 30.40)	18.65 ± 0.43 (16.86 - 21.66)	14.21 ± 0.30 (13.18 - 15.94)	
14	Pontian	N 01° 29' 23"	29-Apr-06	20.6 ± 0.790 (15.5-31.0)	15.8 ± 0.500 (12.2-22.2)	11.1 ± 0.450 (7.75-17.1)	A rocky beach and receiving domestic wastes.
		E 103°23' 08"					
15	Tg. Langsat	N 01 °28' 19"	30-Apr-06	19.5 ± 0.780 (11.5-27.5)	14.3 ± 0.530 (7.25-19.2)	11.0 ± 0.550 (5.65-18.2)	Near a port (Tg. Langsat Port).

Table 4 (*continued*)

		E 104 °00’ 41”	20-June-10	27.13 ± 0.63 (24.46 - 31.46)	19.22 ± 0.43 (18.11 - 22.80	14.19 ± 0.33 (12.71 - 16.53)	
16	Kg. Pasir Puteh	N 01° 26’08” E 103° 56’09”	20-June-10	25.02 ± 0.85 (22.54 - 30.91)	18.63 ± 0.54 (16.87 - 21.78)	13.44 ± 0.40 (12.01 - 15.88)	A jetty with restaurants, fishing village, shipping and industrial activities.
17	Kukup	N 01° 19.46’ E 103° 26’52”	18-June-10	26.04 ± 0.88 (23.08 - 30.82)	18.50 ± 0.56 (16.58 - 21.78)	13.51 ± 0.49 (12.10 - 16.52)	A fishing village and shipping activities.
18	Tj. Piai	N 01° 19’ 49’ E 103° 26’52”	18-June-10	20.51 ± 0.20 (19.51-21.56)	14.86 ± 0.14 (14.28 - 15.58)	11.26 ± 0.12 (10.55 - 11.78)	It is a reserved area and a tourist attraction site.
19	Kg. Sg. Melayu	N 01° 27’04” E 103° 41’69”	19-June-10	23.28 ± 0.50 (21.05 - 26.44)	16.88 ± 0.31 (15.98 - 18.50)	12.07 ± 0.29 (11.16 - 13.86)	A jetty, fishing village, shipping activities and mussel aquaculture.
20	Lukut	N 02° 34.511’ E 101°47.529”	5-Dec-10	21.88 ± 0.48 (19.56 - 24.40)	15.52 ± 0.22 (14.24 -16.31)	11.99 ± 0.26 (10.54 - 13.09)	Industrial and urban area and a fishing village.

(Amin *et al*., 2006a), also recorded higher concentrations of essential metals (Cu and Zn) over non-essential metals (Cd and Pb) in the soft tissues.

As for shells, Amin *et al*. (2006b) reported that the shells of *N. lineata* collected from Dumai had higher affinity for Ni compared to that of the soft tissues. Minor elements and trace metals might be incorporated into the carbonate crystalline lattices of the shells by replacing calcium ions in calcite or aragonite (Foster & Cravo, 2003; Yap *et al*., 2003). Once the metals were incorporated into the crystalline lattices in the shell matrices they would not be affected by the reproductive and physiological states of the organism (Yap *et al*., 2003). The shells might also act as a biodeposition site of unwanted chemical species (Bertine & Goldberg, 1972; Yap *et al*., 2003), and this could be the reason for the higher concentrations of Ni in the shells. This pattern of accumulation was found to be similar with that of *Telescopium telescopium* (Yap *et al*., 2008), where the Ni concentration in the shells was found to be higher than in the remainder soft tissues.

However, no significant correlations ($P>0.05$) were found between the sediments with soft tissues, opercula and shells of the *N. lineata* collected in 2005 and 2006 (Table 2). The samples collected from 2010 also showed no significant correlations ($P>0.05$) between the sediments and all the tissues, except for the shells and the acid reducible fraction ($P<0.05$), as shown in Table 3. This finding indicates that *N. lineata* is not reflecting the Ni contamination of the sampling sites although they serve as the biomonitors of the Ni bioavailability of these sites (Rainbows, 2004). It should be highlighted here that future genetic studies on the genetic similarity of the different geographical populations of this particular snail should be conducted since a good biomonitor should be a single species (Yap *et al*., 2002b) with genetically similar population in different locations.

CONCLUSION

The results showed that the *N. lineata* was able to accumulate metal such as Ni from the environment. However, further studies on the correlation of metal levels between the snails and the environmental samples are needed in order to validate its usefulness as a good biomonitor of the Ni pollution.

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