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Heavy Metal Concentrations in the Mollusc Gastropod, *Cipangopaludina chinensis malleata* from Upo Wetland Reflect the Level of Heavy Metals in the Sediments

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ABSTRACT: Upo wetland is the largest inland wetland in Korea as Ramsar Convention Area. The purposes of the study were to investigate the levels of heavy metals (Cd, Cr, Cu, Ni, Pb and Zn) in the sediment and *Cipangopaludina chinensis malleata* from three sites of the wetland and to assess the potential of the gastropod as a bioindicator for heavy metal levels. The gastropods were dissected into shell and soft tissue without the digestive and excretive organs. The levels of Cd, Cu and Pb were below the guideline of Soil Environment Conservation Act and the heavy metals except Cr were slightly different among the sites. Cd was higher in Upo site (0.32 μg/g) than Sajipo site (0.28 μg/g). Cu and Zn showed the highest value in Sajipo as 43.5 μg/g and 39.8 μg/g, respectively while the concentrations of Pb and Zn were the highest in Upstream as 58.8 μg/g and 138 μg/g, respectively. In the soft tissues and shells of the gastropod, the overall common trend in the concentrations of the heavy metals was revealed with the following order: Zn > Cu > Cr > Ni > Pb > Cd and Ni > Zn > Cr > Cu > Pb > Cd, respectively. Although the soft tissues exhibited higher concentrations of the heavy metals except Ni than the shell in the gastropod, the levels of Cd and Pb in the gastropod were generally below the restrictive values set up by Korea Food & Drug Administration. From Duncan's Multiple Range Test (DMRT) results, the concentrations of Pb and Zn in the sediments among the sites were reflected on the soft tissue (Pb) and the shell (Pb and Zn) of the gastropod in the same order. The lower value of coefficient of variation (CV) in Pb concentration of the shell than in that of the soft tissue supports the usefulness of the shell as a bioindicator for Pb pollution. Although the CV value in the shell was a little higher than in the soft tissue, DMRT results and the stability of incorporated Zn into the shell support the use of the shell of the gastropod as a potential bioindicator for long-term contamination of Zn.

Key words: Biomonitoring, Heavy metal bioindicator, Ramsar Convention Area, River snail, Upo wetland

INTRODUCTION

Molluscs are ubiquitous benthic animals in aquatic ecosystems. Their slow movement makes them to be easily collected and they are frequently consumed by other animals including human and birds as a protein source. Many studies revealed that molluscs of diverse species could accumulate a varying level of heavy metals in their soft tissues and shells depending on inhabitation environment (Hahm and Son 1995, Lau et al. 1998, Fang 2006). The heavy metals accumulated in the tissues have a potential to be transferred to organisms at a higher trophic level (Saha et al. 2006). Therefore, molluscs are considered to be suitable organisms for investigating heavy metal contaminations and the hazard to higher trophic organisms in both freshwater and marine ecosystems (Kang et al. 1999, Gundacker 2000, Cravo et al. 2004, El-Moselhy and Gabal 2004, Berto et al. 2006). However, there is a relative lack of information on potential bioindicators of gastropods in freshwater (Flessas et al. 2000, Gundacker 2000, Dobrowolski and Skowrońska 2002).

Soft tissues are generally more efficient accumulators of metals than shells. In recent years, researchers have focused on shells as a bioindicator of heavy metals in addition to tissues (Foster and Chacko 1995). Some metals were more detected in shells than in soft tissues. Shells show less variability in several metals than that in soft tissues (Foster and Cravo 2003, Cravo et al. 2004). With respect to determining gastropods as a bioindicator of heavy metal accumulations, we need to identify the partitioning of each heavy metal between soft tissues and shells and to consider the variability of each heavy metal in each tissue.

Upo wetland is the largest inland wetland in Korea and has been conserved under the Korean environmental law. The wetland is important as a habitat for many kinds of plants and animals, especially for migratory birds (Ministry of Environment 1987). Therefore, this wetland was designated as a Natural Ecosystem Conservation Area by the Ministry of Environment of Korea in 1997 and as a Ramsar Convention Area in 1998. Nevertheless, the information of the

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levels of heavy metals in biota from the Upo wetland is completely lacking and the wetland has been constantly influenced by anthropogenic activities in the surrounding areas. Therefore, this study will provide basic information on the level of heavy metal contaminations in the Upo wetland.

Cipangopaludina chinensis malleata, a river snail is abundant and widespread throughout the Upo wetland. The snail is edible species and has been gathered for commercial sale (Ministry of Environment 1987). For these reasons, this species was chosen as a target benthic animal for identifying the level of heavy metal concentrations in the study sites.

The purposes of this study were to gather quantitative information on heavy metals concentrations in the sediments and the gastropod from the Upo wetland and to assess the potential of the gastropod as a bioindicator for heavy metal levels by evaluating the relation between metal contents in soft tissues and shells of the gastropod and in the sediments they inhabit.

MATERIALS AND METHODS

Study Area and Sampling

Upo wetland is situated in Changnyeong-gun of Gyeongsang-nam-do province, southeastern Korea (N 35°33′, E 128°25′). The wetland as the largest riverine wetland in Korea, has high biodiversity and is important as habitat of migratory birds (Ministry of Environment 1987). The wetland comprises of four smaller wetlands of Upo, Mokpo (northern part of the Upo), Sajipo (northeastern part of the Upo) and Jjokjibeol (southwestern part of the Upo). The total surface area of the wetland is about 170 ha (Park et al. 2000). Water in the Upo wetland comes from Topyeong stream and is gets out into Nakdong River, about 5 km west of the wetland. Samples were collected at three sites of the wetland: Upstream (the mouth of Upo that Topyeong stream flows into), Upo and Sajipo (Fig. 1).

In March 2005, sediment samples were taken at a depth of 0~5 cm from surface in each sampling site using hand grab sampler. Five replicates were collected at each site. The sediment was kept in a polyethylene bag and air dried in the laboratory. In May 2005, *C. chinensis malleata* was collected in the same sites. The gastropod specimens were collected from the sediment where they usually dwelled. They were stored at 4℃ until sample processing. Ten to eleven specimens were selected from the three populations considering the available size range. The number of gastropods analyzed and their shell height are presented in Table 1.

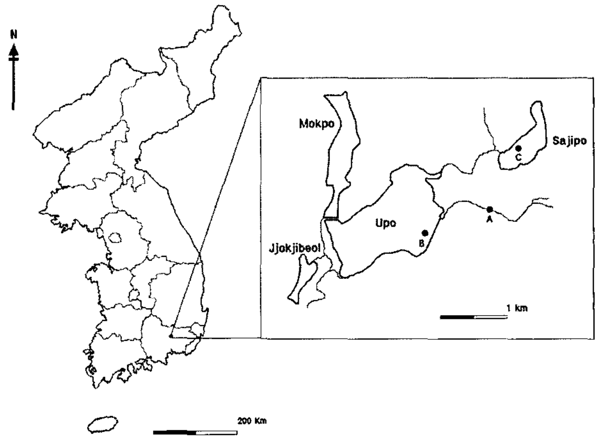

Fig. 1. An index map of sampling sites (A: Upstream, B: Upo, C: Sajipo).

Table 1. The numbers and shell height of *C. chinensis malleata*

Sites	n	Shell height (cm)
Upstream	10	3.3~5.2
Upo	11	3.6~6.5
Sajipo	11	3.8~5.6

Sample Processing and Determination of Heavy Metals

Dried sediment samples were passed through a 0.5 mm sieve and the fraction < 0.5 mm was chosen for chemical analysis (Usero 2005). The sieved samples were weighed to 0.5 g into the digestion vessels. The first digestion of sediments was carried out with 5 mL of concentrated nitric acid and 2 mL of 48% hydrofluoric acid. After 8 mL of 4% boric acid was added to the first digested samples, the samples were digested again.

The gastropods were dissected into soft tissues and shells. The digestive and excretive organs were removed from the soft tissues. The shells were cleaned by scrubbing in distilled water with a toothbrush to remove superficial epiphyta and sediments. The tissues were washed with distilled water and oven-dried at 105℃ over 48 hours. The dried tissues were ground in a mortar and preserved at 4℃ for further analysis. The tissue samples were weighed to 0.5 g and digested with 10 mL of concentrated nitric acid and 3 mL of 30% hydrogen peroxide. After 2 mL of 60% perchloric acid was added to the first digested samples, the samples were digested again.

The digestion was carried out in a microwave digester (Mars-Xpress, CEM, USA) using microwave digestion programme listed in Table 2. The digested samples were diluted to 15 mL in volumetric plastic tube with double distilled water. Heavy metal concentrations were determined by inductively coupled plasma mass spectrometer (ICP-MS) (ELAN 6100, Perkin-Elmer, USA) at National center for inter-university research facilities, Seoul National University.

Table 2. The programme of microwave acid digestion for the sediments and the gastropod

	Stage	Power	% power	Ramp time (min.)	Temp.	Hold time (min.)
Sediment	(1)	1200w	100%	10:00	200℃	10:00
	(2)	1200w	100%	5:00	180℃	20:00
	(3)	1200w	25%	5:00	180℃	5:00
Gastropod	(1)	1200w	100%	15:00	200℃	15:00
	(2)	1200w	100%	5:00	160℃	5:00

Analytical Quality Control and Statistical Analysis

The accuracy of the microwave digester system was tested with Certified Reference Material (CRM): Buffalo River Sediment (RM 8704) from National Institute of Standards & Technology (NIST), Oyster Tissue (108-05-001) from Korea Research Institute of Standards and Science (KRISS) and Dogfish Muscle (DORM-2) from National Research Council Canada (CNRC). The detection limits of the ICP-MS heavy-metal determination and comparison of measured metal concentrations in the CRM with certified values are shown in Table 3.

One-way analysis of variance (ANOVA) was applied to test significant differences in metal concentrations between samples from different sites. Duncan's multiple range test (DMRT) was ca-rried out to assess differences among samples and to determine the ranking of the samples from the sites with respect to metal concentration. In this study, a coefficient of variation (CV) value was used to determine the degree of variability of metal concentrations in the soft tissues and the shells of *C. chinensis malleata* (Yap et al. 2003). The *CV* values were calculated by the formula shown below.

$$CV(\%) = \frac{Standard\ deviation}{Mean} \times 100$$

RESULTS

Heavy Metal Concentrations in the Sediments and the Gastropod

The heavy metal concentrations in the sediments of the study sites are given in Table 4. While Zn in all three sites showed the highest concentration in the range of 111.3~137.9 μg/g, Cd concentrations seemed to be relatively low (from 0.28 to 0.32 μg/g). This tendency is similar to other studies in spite of the differences of the metal level in the sediments according to the lithological source and anthropogenic influx (Lau et al. 1998, Fang 2006).

Table 5 and 6 shows the concentrations (μg/g dry weight) of Cd, Cr, Cu, Ni, Pb and Zn in the soft tissues and the shells of *C. chinensis malleata* collected at three sites in the Upo wetland. In the soft tissues, Zn exhibited much higher concentration than other metals in the range of 125~269 μg/g dry weight. Ni concentration was the highest in the shells (21.0~26.2 μg/g dry weight). Cd concentration was the lowest in both the soft tissues and the shells.

The metal concentrations in the soft tissues decreased in the order of Ni >> Zn > Cr > Cu > Pb >> Cd though Zn concentration was lower than Cr concentration in the Upo site.

Comparison of Metal Concentrations between the Soft Tissues and the Shells

The partitioning factors (PF) defined as the ratio between the

Table 3. Certified metal concentrations (CC) and analyzed concentrations (AC) in Certified Reference Materials

(mean ± standard deviation, μg/g dry weight)

	Cd (DL: 0.045)		Cr (DL: 0.45)		Cu (DL: 0.45)	
	CC	AC*	CC	AC	CC	AC
RM8704	2.94 ± 0.29	3.13 ± 0.04	121.9 ± 3.8	99.5 ± 0.7	–	–
108-04-001	7.40 ± 0.22	8.0 ± 0.1	0.45 ± 0.07	2.90 ± 1.00	330.1 ± 4.9	321.4 ± 48.8
DORM-2	0.043 ± 0.008	0.054 ± 0.002	34.7 ± 5.5	23.6 ± 3.4	2.34 ± 0.16	1.89 ± 0.04

	Ni (DL: 0.45)		Pb (DL: 0.225)		Zn (DL: 0.45)	
	CC	AC	CC	AC	CC	AC
RM8704	42.9 ± 3.7	43.9 ± 1.6	150 ± 17	153 ± 3	408 ± 15	345 ± 4
108-04-001	–	–	1.52 ± 0.11	1.78 ± 0.07	835.4 ± 10.0	955.6 ± 51.1
DORM-2	19.4 ± 3.1	13.5 ± 1.8	0.065 ± 0.007	ND	25.6 ± 2.3	24.5 ± 0.5

DL: detection limit, ND: not detected, *n=3, –: no data.

Table 4. Metal concentrations in the sediments of Upo wetland (μg/g dry weight)

	Upstream			Upo			Sajipo		
	Mean ± S.D.	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.	Min.	Max.
Cd	–	–	–	0.32 ± 0.02	0.30	0.36	0.28 ± 0.02	0.25	0.30
Cr	53.1 ± 1.0	51.7	54.7	49.7 ± 1.4	47.6	50.9	55.6 ± 7.0	50.7	71.8
Cu	38.3 ± 1.3	37.2	39.6	30.9 ± 1.4	29.0	32.8	43.5 ± 9.1	37.6	55.5
Ni	34.9 ± 0.6	33.9	59.3	29.1 ± 3.9	26.9	62.8	39.8 ± 5.7	35.0	49.5
Pb	58.8 ± 0.9	57.8	36.2	56.3 ± 1.7	53.2	31.2	39.6 ± 6.5	35.9	50.9
Zn	138 ± 2	135	141	123 ± 4	118	126	111 ± 17	103	141

–: no data.

Table 5. Metal concentrations in the soft tissue of the gastropod (μg/g dry weight)

	Upstream			Upo			Sajipo		
	Mean ± S.D.	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.	Min.	Max.
Cd	–	ND	0.18	–	ND	0.14	–	ND	0.08
Cr	34.7 ± 35.4	2.7	74.8	34.8 ± 96.1	3.3	324.2	5.9 ± 1.8	3.8	9.9
Cu	74.4 ± 17.8	54.7	100.6	46.1 ± 12.2	28.6	66.1	20.7 ± 7.3	9.8	36.4
Ni	3.0 ± 0.9	1.8	4.2	4.8 ± 2.2	2.0	7.7	2.8 ± 1.2	0.5	4.4
Pb	1.60 ± 1.18	0.72	4.52	1.67 ± 0.65	0.99	3.32	0.71 ± 0.18	0.45	1.08
Zn	207 ± 36	168	269	198 ± 45	128	245	193 ± 46	125	267

ND: not detected.

Table 6. Metal concentrations in the shell of the gastropod (μg/g dry weight)

	Upstream			Upo			Sajipo		
	Mean ± S.D.	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.	Min.	Max.
Cd	ND			ND			ND		
Cr	2.1 ± 0.6	1.7	3.2	4.3 ± 1.9	2.8	8.7	2.1 ± 0.3	1.7	2.8
Cu	1.5 ± 0.7	0.7	2.8	1.1 ± 0.6	0.5	2.1	0.8 ± 0.3	0.3	1.4
Ni	22.9 ± 0.9	21.3	24.0	22.6 ± 0.8	21.0	24.3	23.6 ± 1.2	22.4	26.2
Pb	0.48 ± 0.08	0.33	0.60	0.53 ± 0.10	0.38	0.71	0.26 ± 0.10	0.05	0.37
Zn	7.5 ± 4.4	4.2	16.0	3.6 ± 1.0	1.8	5.6	4.6 ± 0.7	3.8	5.7

mean metal concentrations in the soft tissue and in the shell from each site (Cravo et al. 2004) were shown in Table 7. With respect to Cd, it is possible that the concentration was higher in the soft tissues than in the shells from the result that Cd was detected only in some soft tissues, not in all shells. Showing the PF values in the range of 2.7 (Sajipo) and 3.3 (Upstream), Pb were consistently lower in the shells than in the soft tissues. Cu and Zn showed high PF values in the range of 26.5~50.0 and 27.6~55.0, respectively while the PF values of Ni were the lowest among the metals (0.12 ~0.21). These results might indicate that Ni has a much greater inclination to be incorporated into the shell while Cu and Zn are easier to be incorporated into the soft tissues rather than in the shell. Furthermore, Cu and Zn are also needed for metabolism in soft tissues of molluscs. Overall, the concentrations of all metals

Table 7. Partitioning factors of the gastropod from the study sites

	Upstream	Upo	Sajipo
Cr	16.7	8.1	2.8
Cu	50.0	41.7	26.5
Ni	0.13	0.21	0.12
Pb	3.3	3.2	2.7
Zn	27.6	55.0	42.1

excluding Ni were much higher in the soft tissues than in the shells.

DISCUSSION

The Level of Heavy Metal Concentrations in the Sediments and the Gastropod

Although comparable data on the concentrations of heavy metals in the gastropod and sediments of inland wetland were sparse in Korea, heavy metal concentrations in sediments reflect the metal loading in the past (Kim and Rejmánková 2001, Kim and Rejmánková 2002, Kim 2003, 2005). Therefore, we can reasonably evaluate the metal contamination of the wetland through comparison of depth-profile of metal concentrations with the history of anthropogenic activities. Although heavy metal concentrations in the Upo tend to slightly increase (unpublished data), the level of the metal contamination was below the guideline by the Soil Environment Conservation Act (Cd < 1.5 μg/g, Cu < 50 μg/g and Pb < 100 μg/g).

The metal concentrations except Cd and Pb in the soft tissue of the gastropods from the Upo wetland exhibited slightly higher than the *Cipangopaludina* species from Junam reservoir and Nakdong river in Korea (Table 8). However, concerning the concentrations of Cd and Pb in the soft tissues of *C. chinensis malleata*, the levels of heavy metal contaminations were below the restrictive values set up by Korea Food & Drug Administration (Pb < 2 μg/g wet weight, Cd < 2 μg/g wet weight). In spite of the difference of metal concentration in the sediment as the background and the different dissect method, the lower concentrations of non-essential element such as Pb and Cd indicate that the metal contamination of biota from the Upo wetland was markedly in the lower level. Consequently, the present work provides reference data on the concentration of Cd, Cr, Cu, Ni, Pb and Zn in the gastropod from the Upo wetland for comparable information of following studies.

Bioaccumulation of Heavy Metals in the Soft Tissues and Shells of the Gastropod

Concerning the partitioning of Cd, Cu, Ni, Pb and Zn between the soft tissues and the shells of *C. chinensis malleata*, the present results generally showed similar tendencies to other studies. Regardless of species and habitat difference, most of molluscs showed much higher concentrations of Cu and Zn in soft tissues than in shells (Puente et al. 1996, Gundacker 1999, 2000, De Wolf et al. 2001, Yap et al. 2003, Cravo et al. 2004). Being essential constituents for metabolically important biomolecules including enzymes and respiratory pigment hemocyanin, Zn and Cu generally showed high contents in soft tissues of molluscs (Langston and Spence 1995, Gundacker 2000, Liang et al. 2004). However, the level of other metal concentrations as well as Zn and Cu seemed to exhibit a wide range of the value depending on the analyzed species, the physiological condition and the habitat environment (Cubadda et al. 2001, Conti and Cecchetti 2003, Cravo et al. 2004, Cravo and Bebianno 2005). With respect to Ni, the result of *C. chinensis malleata* was in agreement with seawater mollusc, *Mytilus galloprovincialis* (Puente et al. 1996) though being contrary to data of *Patella aspera* (Cravo et al. 2004).

The concentrations of Cd and Pb in shells was lower than in soft tissues of bivalve molluscs in freshwater such as *Dreissena polymorpha*, *Anodonta* sp. and *Unio pictorum* (Gundacker 2000). However, the Pb of the shell showed higher concentrations than the soft tissues in freshwater molluscs, *Melanoides tuberculata* (Lau et al. 1998) and Cd as well as Pb was higher in shells than in soft tissues

Table 8. The heavy metal concentrations in the soft tissue of *C. chinensis malleata* and *C. japonica*

Sites	Species	Cd	Cr	Cu	Ni	Pb	Zn
		Min.~Max.	Min.~Max.	Min.~Max.	Min.~Max.	Min.~Max.	Min.~Max.
Upo*	*C. chinensis malleata*	nd~0.02	0.32 ~38.90	1.18~12.07	0.06~0.92	0.05~0.54	15.0~32.3
Junam**	*C. chinensis malleata*	nd	0.012~0.099	1.27~ 4.88	–	nd~2.631	9.4~35.8
Nakdong river***	*C. japonica*	0.02~0.24	0.22 ~1.97	1.85~ 2.96	–	1.44~3.42	7.2~11.9

The values of Upo and Nakdong river have been converted to wet weight contents by calculated as 88% water content according to Dumont et al. (1975).
*: from this study, **: from Hahm and Son (1995), ***: from Kim and Kim (1987).

of seawater mollusc, *Perna viridis* (Yap et al. 2003). The discrepancy might be due to the difference of detoxification mechanism and the crystalline structures of the shell matrix among species, which would affect the biodepostion in shells. Also, the partitioning of certain metals such as Fe and Zn between soft tissues and shells could depend on the pollution level of habitat (Cravo et al. 2004).

However, data on trace metal contents of shells of freshwater gastropod were relatively lacking because studies investigating shells as a tissue for potential use in environmental trace metal monitoring have been mainly directed to marine molluscs (Foster and Chacko 1995, Watson et al. 1995, De Wolf et al. 2001, Cravo et al. 2002, Foster and Cravo 2003, Yap et al. 2003, Cravo et al. 2004). Studies on the metal concentrations of *C. chinensis malleata* can be useful but there are few (Kim and Kim 1987, Hahm and Son 1995). Especially for the shells, comparable data on the gastropod does not exist. Therefore, the analysis on shells as well as soft tissues of molluscs might be needed for biomonitoring heavy metals in further study.

Relationship between Metal Concentration in the Sediments and in the Gastropod

The differences in the heavy metal concentrations of the sediments among the sites are presented in Table 9. There were significant differences in the heavy metal concentrations in the sediments except Cr among the sites. Although we have no data on the Cd concentration in the sediment of the Upstream, Upo and Sajipo had a significant difference in Cd concentration of the sediments ($p < 0.01$). Thus the study sites had the different level of each heavy metal in the sediments. The sediment is the habitat for benthic animals and *C. chinensis malleatais* the benthic gastropod in freshwater (Kwon et al. 1993). The benthic animals sampled from the sites were exposed to different environments in the metal conditions.

In the soft tissues, significant differences were shown in Cu and Pb, and the metals (Cr, Pb and Zn) in the shells exhibited significant differences among the sites ($p<0.01$). Although Cd was detected in some samples of the three sites, it is possible that there is a little difference between Upo and Sajipo. As compared with the result of DMRT on the metal concentrations in the sediments of the three sites, the site orders of difference in the metal concentrations were reflected on the result of DMRT on Pb and Zn concentrations of the gastropod. The DMRT of Pb concentrations in both soft tissues and shells showed exactly the same order of the concentration in the sediments of the three sites (Upstream = Upo > Sajipo) while Zn revealed same order only in the shells (Upstream > Upo = Sajipo). Cd concentrations in the soft tissues have seem to have reflected the difference of the sediments.

Table 9. Duncan's Multiple Range Test and Coefficient of variance on the heavy metal concentrations from the sites

	Sites	Cr	Cu	Ni	Pb	Zn
Sediments	Upstream	a	a	a	a	a
	Upo	a	b	b	a	b
	Sajipo	a	a	a	b	b
	Significance level		**	**	**	**
Soft tissues	Upstream	a	a	b	a	a
	Upo	a	b	a	a	a
	Sajipo	a	c	b	b	a
	Significance level		**	*	**	
	Coefficient of variance	136.3	28.6	39.6	46.2	21.3
Shells	Upstream	b	a	ab	a	a
	Upo	a	ab	b	a	b
	Sajipo	b	b	a	b	b
	Significance level	**	*		**	**
	Coefficient of variance	28.9	47.1	4.2	23.4	33.2

*: $p<0.05$, **: $p<0.01$.

Table 9 also shows that coefficients of variance (CV, %) in the soft tissues were 46.2 for Pb and 21.3 for Zn while those in the shells were 23.4 for Pb and 33.2 for Zn. Therefore, the results indicated that lower degrees of variability of Pb in the shells of *C. chinensis malleata* than in the soft tissues. The Zn variability in the shells was higher than in the soft tissues. Yap et al. (2003) reported that the Pb variability in the mussel *Perna viridis* shells was much lower than in the soft tissues and the Pb concentrations incorporated into the shell could be hardly affected by the physiological conditions of the mussel while the Pb concentration in the soft tissue could be. A lower variability of metal concentration in the mussel shells than in the soft tissues indicated that there was greater precision when the shell was used as a bioindicator for heavy metals (Puente et al. 1996). Therefore, the lower CV value of Pb concentration in the gastropod shells and the same result of DMRT on the concentrations in the sediments and the gastropod suggest that the shells of *C. chinensis malleata* as well as the soft tissues can be useful to biomonitor a change of Pb concentration in the sediment.

Zn concentration of the shell maintained unchangeably the accumulated levels even after a drastic decrease of the metal concentration in ambient environment (Yep et al. 2003). While the Zn concentration of the soft tissues sharply decreased after the change of ambient condition. It is suggested that Zn concentration in shells might be relatively stable regardless of sampling time while the concentration in soft tissues might be variable depending on the change of instant ambient environment and the physiological condition. Although higher CV values and lower levels of Zn in the shells than in the soft tissues did not strongly support the usefulness of shells as bioindicator for Zn, violent fluctuation of Zn as a essential element for enzyme activity in soft tissues and the result of DMRT indicated that the shell could stably reflect long-term accumulation of Zn incorporated into the shell.

Although the result of DMRT on the concentration of Ni in the shells did not appeared in the exactly same order, the fact that the variability in the shell showed extremely low value (4.2%) and the DMRT result on the shell showed a similar pattern might leave the possibility that the shells need to be investigated for biomonitoring material of Ni in further study.

CONCLUSION

Pb and Zn concentrations in the benthic gastropod, *C. chinensis malleata* reflect the difference of the metal concentration in the sediment, their habitat environment. Furthermore, high precision (lower CV) in the determination of Pb concentration in the shell support that the shell of the gastropod is a suitable bioindicator for the heavy metal rather than the soft tissue. While both the soft tissues and the shells of the gastropod can be a good bioindicator for Pb, the shell of the gastropod is recommended as a potential bioindicator for long-term contamination of Zn.

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