Contamination of Heavy Metals in Sediment and Mollusks Collected from Bueng Jode Reservoir, Khon Kaen Province

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Abstract

This study was aimed to use some freshwater mollusk species as passive biomonitor and bioaccumulator for some heavy metals in a lenthic ecosystem so-called Bueng Jode Reservoir. The study was conducted between August 2006 and April 2007. Sediment and mollusk samples were collected at each station along the three seasons. These samples were analyzed for Cd, Cu, Zn, Pb and Hg. Bioaccumulation of heavy metals was examined from two mollusk species (*Filopaludina martensi* and *Pomacea canaliculata*), which were collected from 5 sampling stations. Heavy metal concentrations were directly analyzed by inductively coupled plasma - optical emission spectrometry (ICP-OES) technique. High concentration of heavy metals in mollusks was detected in rainy season. In mollusk tissues, concentrations of Zn were higher than Cu and Pb. Furthermore, the concentrations of Zn in *Filopaludina martensi* were higher than in that *Pomacea canaliculata* during study period. In rainy season, the average concentration of Zn was higher than that of Cu, Pb, Cd and Hg respectively. Whilst in cool and summer seasons, the average concentrations of Zn in sediments were higher than Pb and Cu respectively. Statistical analysis (one-way ANOVA) indicated the different concentrations of metals in mollusks and sediments. The comparative study showed that the accumulation of heavy metals in mollusk tissues were significantly higher than in sediment samples.

Keywords: heavy Metal, *Filopaludina martensi*, *Pomacea canaliculata*, biomonitoring, bioaccumulation

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Introduction

Bueng Jode is a freshwater reservoir located near Pong River which is the principle river in the northeast of Thailand. The reservoir receives effluent from a paper mill factory before flowing down to Pong River.

Heavy metals are stable pollutants in that they are not broken down or change into other forms, so they effectively become permanent additions to the aquatic environment. They accumulate in organisms and some may become biomagnified in food chains, though biomagnifications is the exception rather than the rule. The major uptake route for many aquatic organisms is by direct uptake from the water so that tissue concentrations reflect metals concentration in the water. Carnivores at the top of the food chain such as many aquatic birds and mammal species, including humans, however, obtain most of their pollutant burden from aquatic ecosystems by ingestion, especially from fish, where there is considerable potential biomagnifications (Vernet, 1991). Much attention has been paid to heavy metals contamination in the water environment and their potential hazards to organisms and human beings. Sediments are the most often used matrix to monitor the heavy metals pollution in water. However, the determination of total heavy metal contents in sediments has not been satisfied up to now because the behavior of heavy metals is closely related to their chemical forms, and only those with high bioavailability can be absorbed by organisms and do great harm to organisms and human beings. Thus, the investigation of heavy metal contamination in organisms can be more directly reflect the hazards to human health and the potential heavy metal pollution in water. Lying in the second trophic level in the water ecosystem, mollusks have long been known to accumulate both essential and non-essential trace elements in aquatic ecosystems (Dallinger and Rainbow, 1993).

Mollusks are benthic fauna in the food chain ecosystem, they live and move slowly to feed on the surface of sediments and thus accumulate higher concentrations of heavy metals than other organisms (Eisler, 1980).

Methods

This study was aimed to determine the concentration of heavy metals accumulated in mollusks and sediment surrounding contaminated area.

Five sampling stations were defined as the affected area in Bueng Jode Reservoir (Figure1). Sediment samples and mollusks were collected from each station in three consecutive seasons, these were in August 2006 (rainy season), January 2007 (cold season) and April 2007 (summer season). Sediment samples were collected using a core sampler. All samples were kept air dry for 2 weeks. Mollusks were collected at each station and identified down to species. These were collected manually by divers, then each sample was bagged, labeled and kept frozen prior analysis. Analyses were made within 10 days of collection.

In the determination of heavy metals in sediment samples, they were homogenized, air dry and sieved through a 63 m mesh. Homogenized samples were acid digested using a microwave digestion system (ETHOS touch control) following EPA method 3015 (US EPA, 1994). Concentrations of cadmium (Cd), copper (Cu), zinc (Zn), lead (Pb) and mercury (Hg) were analyzed by Inductively Coupled Plasma - Optical Emission Spectrometry (ICP-OES), PerkinElmer (Optima 4300 AV).

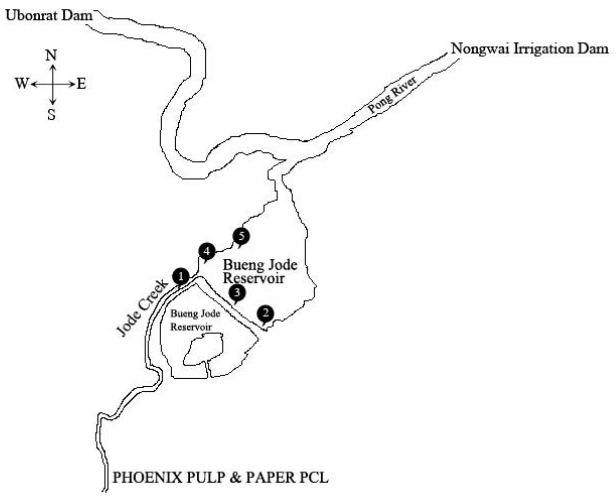

Figure 1. Overview of Bueng Jode reservoir and location of five collecting stations as numbered.

Mollusk samples were identified to species level by Brandt (1974). Each mollusk was homogenized and sub-samples were analyzed for Cd (wavelength 228.802 nm), Cu (wavelength 327.393 nm), Zn (wavelength 206.200 nm), Pb (wavelength 220.353 nm) and Hg (wavelength 253.652 nm). Homogenized tissues were digested using a microwave system (ETOS touch control) following EPA method 3052 (US EPA, 1996) and analyzed for the same heavy metals as in sediment using the same procedure. Results are reported in dry weight basis.

Statistical analysis

Statistical analyses were performed using SPSS program version 6. Mean and standard deviation (SD) values were shown. The t-test and one-way analysis of variance (ANOVA) were used to compare the sediment and mollusk data which the significance level was $p < 0.05$

Results

Heavy metals concentrations in mollusks

Mollusk samples were collected from five stations at Bueng Jode Reservoir. The two species including *Filopaludina martensi* and *Pomacea canaliculata* (Figure 2) were identified.

(a)

(b)

Figure 2. Species of mollusks in Bueng Jode reservoir from five collecting stations: *Filopaludina martensi* (a), *Pomacea canaliculata* (b).

Table 1. Concentrations of heavy metals in mollusk in three season (% by dry weight)

Parameter	Cd ($mg.kg^{-1}$)	Cu ($mg.kg^{-1}$)	Pb ($mg.kg^{-1}$)	Hg ($mg.kg^{-1}$)	Zn ($mg.kg^{-1}$)
Rainy season					
Station 1 (P. *canaliculata*)	0.24	22.04	1.04	ND	125.85
Station 2 (F. *martensi*)	0.14	87.37	2.81	0.31	650.46
Station 3 (P. *canaliculata*)	0.20	13.00	0.78	0.37	167.42
Station 4 (P. *canaliculata*)	0.24	18.31	0.48	ND	157.69
Station 5 (F. *martensi*)	0.22	40.75	2.88	0.29	633.67
Average	**0.21**	**36.29**	**1.60**	**0.32**	**347.02**
Cold season					
Station 1 (P. *canaliculata*)	ND	2.18	0.20	ND	16.97
Station 2 (F. *martensi*)	ND	17.38	0.85	ND	108.29
Station 3 (P. *canaliculata*)	ND	1.46	0.22	ND	15.41
Station 4 (P. *canaliculata*)	ND	0.46	0.30	ND	14.02
Station 5	–	–	–	–	–
Average	**-**	**5.37**	**0.39**	**-**	**38.67**
Summer season					
Station 1 (F. *martensi*)	ND	12.81	0.26	ND	98.10
Station 2 –	–	–	–	–	
Station 3 –	–	–	–	–	
Station 4 (P. *canaliculata*)	ND	3.24	0.40	ND	12.46
Station 5 (F. *martensi*)	ND	6.88	0.65	ND	110.11
Average	**-**	**7.64**	**0.44**	**-**	**73.56**

Remark: – : no mollusks were found in these stations

ND=Not detected [Limit of Detection (LOD) for Cd = 0.075 $mg.kg^{-1}$, Hg = 0.175 $mg.kg^{-1}$]

Table 2. Concentrations of heavy metals in sediments in three seasons (% by dry weight)

Parameter	Cd ($mg.kg^{-1}$)	Cu ($mg.kg^{-1}$)	Pb ($mg.kg^{-1}$)	Hg ($mg.kg^{-1}$)	Zn ($mg.kg^{-1}$)
Rainy season					
Station1	0.17	8.89	8.09	ND	28.31
Station 2	0.10	23.60	16.91	ND	38.00
Station 3	0.09	25.88	4.44	ND	21.91
Station 4	ND	18.53	14.15	ND	29.13
Station 5	ND	3.54	5.95	ND	11.03
Average	**0.12**	**16.09**	**9.91**	ND	**25.68**
Cold season					
Station 1	ND	4.75	6.87	ND	24.04
Station 2	ND	12.46	11.39	ND	41.85
Station 3	ND	7.01	10.92	ND	11.19
Station 4	ND	12.46	12.93	ND	24.43
Station 5	ND	3.13	20.04	ND	71.40
Average	ND	**7.96**	**12.43**	ND	**34.58**
Summer season					
Station 1	ND	7.67	10.82	ND	33.00
Station 2	ND	12.91	29.27	ND	27.63
Station 3	ND	14.28	17.18	ND	33.19
Station 4	ND	12.13	15.63	ND	26.85
Station 5	ND	4.77	8.19	ND	18.25
Average	ND	**10.35**	**16.22**	ND	**27.78**

Remark: - ND=Not detected

Statistical analysis (one-way ANOVA)

Table 3. Comparison of heavy metal concentration in sediment and mollusk samples

Season	Cd	Cu	Pb	Zn
All Seasons	0.011***	0.331	0.000***	0.046***
Rainy Season	ND	0.192	0.024***	0.056
Cold Season	ND	0.553	0.002***	0.867
Summer Season	ND	0.420	0.017***	0.274

Remark: ND= no data for analysis, ***p <0.05

Results from the analyses of metals in these species are given in Table 1. Mean concentrations of Zn found in mollusks were high in all seasons. In addition, the concentration of Zn in mollusks during rainy season was much higher than that found in summer and cold seasons (347.02, 73.56 and 38.67 $mg.kg^{-1}$, respectively). Mean concentrations of Hg and Cd showed similar values (0.21, 0.32 $mg.kg^{-1}$, respectively) in rainy season while in summer and cold seasons, the heavy metals could not be detected. It was found that concentration of Zn was higher than Cu and Pb in mollusks in all three seasons. For comparisons of data between two species of mollusks, concentrations of Zn in *Filopaludina martensi* were higher than that of *Pomacea canaliculata*. In addition, no difference was found on other heavy metals in these two mollusk species.

Heavy metals concentration in sediments

Concentrations of heavy metals in sediments from five collecting stations within the affected area are illustrated in Table 2. The average concentration of Zn was higher in three seasons compared with other metals. Furthermore, the highest concentrations of Zn were detected in cold season, followed by summer and rainy season (34.58, 27.78 and 25.68 $mg.kg^{-1}$, respectively). Nevertheless, the concentrations of Hg were not detected in all three seasons (LOD = 0.175 $mg.kg^{-1}$). The highest average concentration of Pd was in summer followed by cold and rainy seasons (16.22, 12.43 and 9.91 $mg.kg^{-1}$, respectively). The concentrations of Cu were higher on rainy season than summer and cold seasons, while concentrations of Cd were detected with an average of 0.12 $mg.kg^{-1}$ in rainy season but were not detected in summer and cold seasons. In rainy season, the average concentrations of heavy metals in sediments were compared in sequential order as Zn was higher than Cu, Pb, Cd and Hg respectively. For remaining heavy metals in sediments, the concentrations of Zn were higher than Pb and Cu during summer and cold seasons.

ANOVA p values and significant level for analysis of metals concentrations in sediment and mollusk showed in Table 3. The concentrations of metals were slightly higher in mollusk than detected in sediment. There were significant differences in Cd, Pb and Zn concentrations (Cd, p=0.011; Pb, p=0.000; Zn, p=0.046) between mollusk and sediment samples all year. However, there was no significant differences in Cu and Zn concentrations in each season (rainy, cold and summer season, respectively), except for Pb (p<0.05).

Discussion/Conclusion

Filopaludina martensi and *Pomacea canaliculat*a showed to possess high tolerance to waste water. Heavy metal concentrations in mollusks were found to be relatively high during rainy season. The concentrations of heavy metals were found in sequential order as Zn higher than Cu and Pb in mollusks in all three seasons. Additionally, we found that concentrations of Zn in *Filopaludina martensi* were higher than that found in *Pomacea canaliculata*. This is due to the fact that *Filopaludina martensi* live in water longer than *Pomacea canaliculata*. These data showed that mollusk species of *Filopaludina martensi* could accumulate heavy metals in higher concentrations as compare to other species. The concentrations of Zn in sediments were found to be higher in all three seasons. The means concentration of Zn was higher than Cu, Pb, Cd and Hg in sediments in rainy season while in sediments the concentration of Zn was higher than Pb and Cu in summer and cold seasons respectively. By comparing the accumulation of heavy metals between mollusks and sediments, this study found that the concentrations of metals were higher in mollusks and there was significant difference in metals concentrations between mollusk and sediment. Thus, the data from the study showed that mollusks living in the effluent from the study area accumulate heavy metals in their body tissue.

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References

Brandt, R. A. M. 1974. The non-marine aquatic mollusca of Thailand. **Archiv für Molluskenkunde**. 105: 1- 423.

Dallinger, R. and Rainbow P. 1993. Ecotoxicology of metals in invertebrates. Lewis, Chelsea, MI : **SETAC Special Publications**.

Eisler, R. 1980. Trace metal concentration in marine organisms. El Shenawy, N.S. : Pergamon Press, N. Y.; 2000. Ecotoxicological studies on the effects of the organic pesticides (Atrazine and Lindane) on the marine mussel, Mytillus edulis. Ph.D. thesis, Suez Canal University, Islamia, Egypt : 1980.

Keawjam, R. S. 1986. The apple snail of Thailand:distribution, habitats and shell morphology. **Malacological Review**. 19: 61-81.

US Environmental Protection Agency. 1996. **Method 3052: Microwave assisted acid digestion of siliceous and organically based matrices.** Washington DC.

Vernet, J.-P. 1991. **Heavy Metals in the Environment.** Institude F. - A. Forel, University of Geneva, Versoix, Switzerland.