คุณภาพน้ำและปริมาณโลหะหนักในตะกอนดินและหอยกินได้ที่บึงโจด จังหวัดขอนแก่น

Water Quality and Heavy Metals Contamination in Sediment and Edible Mollusks at Beung Jode Reservoir, Khon Kaen Province

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บทคัดย่อ

บึงโจดเป็นบึงน้ำที่ตั้งอยู่ใกล้ลำน้ำพองที่ซึ่งเป็นลำน้ำสายหลักในภาคตะวันออกเฉียงเหนือของประเทศไทย บึงโจดรองรับน้ำทิ้งจากโรงงานฟีนิกซ์ก่อนที่จะปล่อยลงสู่ลำน้ำพอง ทำการศึกษาระหว่างเดือนสิงหาคม 2549 เดือนมกราคม และเดือนเมษายน 2550 ศึกษา 5 จุดเก็บตัวอย่างตามพื้นที่ที่ได้รับผลกระทบใน 3 ฤดู โดยแต่ละจุดทำการเก็บตัวอย่างน้ำเพื่อวัดคุณภาพน้ำทางกายภาพ เคมี และปริมาณสารอาหารในตัวอย่างน้ำ นอกจากนี้ยังทำการวัดปริมาณความเข้มข้นของโลหะหนัก 5 ชนิด ได้แก่ Cd, Cu, Zn, Pb และ Hg ในตะกอนดินและจากเนื้อเยื่อหอยด้วยเทคนิค ICP-OES สำหรับตัวอย่างหอยจะนำมาจำแนกถึงระดับชนิด โดยผลการศึกษาพบหอยจำนวน 8 ชนิด ได้แก่ *Filopaludina martensi*, *Pomacea canaliculata*, *Scabies crispata*, *Lymnaea (Radix) auricularia rubiginosa*, *Pilsbryoconcha exilis*, *Corbicula* sp., *Pila polita* และ *Clea helena* คุณภาพน้ำทางกายภาพ และ เคมีไม่มีความแตกต่างกันในแต่ละฤดูกาล ปริมาณความเข้มข้นของโลหะหนักในเนื้อเยื่อหอยมีค่าสูงในฤดูฝน โดยปริมาณความเข้มข้นของ Zn ทั้งสามฤดูมีค่าสูงกว่า Cu และ Pb นอกจากนี้ยังพบว่าตลอดระยะเวลาที่ศึกษาปริมาณความเข้มข้นของ Zn ในเนื้อเยื่อหอย *Filopaludina martensi* มีค่าสูงกว่าในหอย *Pomacea canaliculata* ส่วนในฤดูฝนค่าเฉลี่ยปริมาณความเข้มข้นของ Zn มีค่าสูงกว่า Cu, Pb, Cd และ Hg ตามลำดับ ในขณะที่ฤดูหนาวและฤดูร้อนค่าเฉลี่ยปริมาณความเข้มข้นของ Zn ในตะกอนดินมีค่าสูงกว่า Pb และ Cu ตามลำดับ ผลการศึกษานี้แสดงให้เห็นว่าการสะสมของโลหะหนักในเนื้อเยื่อหอยสูงกว่าในตะกอนดิน

Abstract

Beung Jode is a water reservoir located near the 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 the Pong River. This study was conducted between August 2006 and January, April 2007. Five sampling stations along impacted areas were defined. Samples of water, sediments and mollusks were collected at each station during the three seasons. Physical, chemical and nutrient parameters were measured from water samples. Sediment and mollusk samples were analyzed for Cd, Cu, Zn, Pb and Hg by the Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) technique. Eight living mollusk species including *Filopaludina*

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martensi, *Pomacea canaliculata*, *Scabies crispata*, *Lymnaea (Radix) auricularia rubiginosa*, *Pilsbryoconcha exilis*, *Corbicula* sp., *Pila polita* and *Clea helena* were found in the sampling locations. Physical and Chemical parameters of water were not significantly different between seasons. In the rainy season, heavy metal concentrations in mollusks were high. The concentration of Zn was higher than Cu and Pb respectively in mollusk tissues in the three seasons. Furthermore, the concentrations of Zn in *Filopaludina martensi* were higher than in *Pomacea canaliculata* throughout the study period. In the rainy season, the average concentration of Zn was higher than Cu, Pb, Cd and Hg respectively. In winter and summer, the average concentrations of Zn in sediments were higher than Pb and Cu respectively. The comparative study showed that the accumulations of heavy metals in mollusk tissues were higher than in sediments.

คำสำคัญ: โลหะหนัก หอย การสะสมทางชีวภาพ

Keywords: heavy metal, mollusk, bioaccumulation

Introduction

Beung Jode reservoir is located in Ban Gudnamsai, Nampong district, Khon Kaen Province. It is close to the Pong River which is the principle river in this region, where the Moon River is the continuation of this water-way into the lower northwest Esarn region. Beung Jode reservoir receives a considerable amount of effluent from a paper mill factory before flowing down to the Pong River. Thus, any water pollution would have a combined effect on this effluent. People living in Loei, Nongbualamphu and Khon Kaen provinces utilize water in this river for daily consumption and agriculture. Despite reports of water pollution in the Pong River since 1986, there was still a major crisis of water pollution reported in 1992. Sources of pollution came from several industries, signaling high impact on the Pong River. These industries are for example paper mill factory, combined gas turbine power plant, distillery plant, sugar factory and wood working plants. In addition, there are several small industries located within the vicinity along the Pong River. These must be major causes of heavy metal contamination in the Pong river coming from industries along with traces from pesticides, chemical fertilizers and other wastes from the community.

Heavy metals are stable pollutants in that they are not broken down or changed 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 satisfactory 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 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).

This study is aimed to survey the diversity of mollusks in the area contaminated by heavy metals that accumulate in mollusks (Faculty of Engineering, 2003). In as much as 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.

Methods

Five sample collecting stations were defined as the affected area in Beung Jode Reservoir (Fig.1). Samples of water, sediments and mollusks were collected at each station in three consecutive seasons, which were on Sunday 24th August 2006 (rainy season), Saturday 6th January 2007 (cold-dry season) and Saturday 1st April 2007 (hot-dry season). Water samples were collected using bottles with 20 centimeter depth for physical and chemical analysis. Temperature, pH, conductivity, ammonia nitrogen, nitrate nitrogen and orthophosphates were measured at each station using a HACH DR/2400 spectrophotometer. No metals were measured from the water sample. In addition, Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) were measured according to the Azide Modification method (APHA, 1992). Sediment samples were collected using a core sampler. All samples were kept air dry for 2 weeks. The concentration of Cd, Cu, Zn, Pb and Hg were determined from collected samples. Mollusks were collected at each station and identified down to species by Brandt (1974), Chithamvong (1992), Keawjam (1986), Klinhon (1989), Kijviriya (1990), Tarbsripair (1998) and Upatham et al. (1983). These were collected manually by divers, then each sample was bagged, labeled and kept frozen prior to analysis. Analyses were made within 10 days of collection.

In the determination of heavy metals in sediment samples, they were homogenized, air dried and sieved through a 63 µm mesh. Homogenized samples were acid digested using a microwave digestion system (ETHOS touch control) following EPA method 3015 (US EPA, 1994). Concentrations of Cd, Cu, Zn, Pb and Hg were analyzed by a PerkinElmer (Optima 4300 AV) Optical Emission Spectrometer.

Mollusks collected in the field were identified to species. 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 tissue was 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 given on dry weight basis.

Results

3.1 Species of mollusk and physicochemical characteristics of the water samples

The results of this study revealed eight species of mollusks from five collecting stations (Table 1). They were *Filopaludina martensi*, *Pomacea canaliculata*, *Scabies crispata*, *Lymnaea (Radix) auricularia rubiginosa*, *Pilsbryoconcha exilis*, *Corbicula* sp., *Pila polita*, and *Clea helena* respectively (Figure 2). The mollusks species found in every season were *Filopaludina martensi*, , *Pomacea canaliculata*, *Lymnaea auricularia* and *Scabies crispata*. The sequential highest number of mollusks species were *Filopaludina martensi* and *Pomacea canaliculata*, respectively. The affected area was 300 rais (0.5 hectre) and there were plenty of water hyacinth. Sediments collected from the affected area were dark brown, viscous and smelled of H_2S. Physical and chemical characteristics of the water samples are presented in Table 2. Temperatures of water were higher as compared to the surrounding air during rainy and cold season. In contrast, the temperatures in the air were higher than water during the hot season. Water pH had an average of 7.49 – 7.78 with little variation between sites. Water conductivities were 342.83 ดS.cm^{-1} in the rainy season, 313.50 µS.cm^{-1} in the cold season and 358.17 µS.cm^{-1} in the hot season. Mean oxygen concentrations were lower in the cold season (1.88 mg.L^{-1}) but showed normal levels in the rainy and hot seasons (5.08 mg.L^{-1} and 6.36 mg.L^{-1}, respectively). Biochemical Oxygen Demand (BOD) was lower in the cold season (0.78 mg.L^{-1}) while in the rainy and hot season it was 3.89 and 5.01 mg.L^{-1}, respectively. Ammonia nitrogen cannot be detected but nitrate nitrogen averaged 2.22 mg.L^{-1} (rainy season), 0.22 mg.L^{-1} (cold season) and 0.25 mg.L^{-1} (hot season). Orthophosphates concentration was lower in the cold season (0.06 mg.L^{-1}) while it was 0.46 and 0.14 mg.L^{-1} in the rainy and hot seasons, respectively.

3.2 Heavy metals concentrations in mollusks

We collected a total of two species from five collecting stations at Beung Jode. The two species were *Filopaludina martensi* (Khom) and *Pomacea canaliculata* (Cherry). Results from the analyses of metals in these species are given in Table 3. Mean concentrations of Zinc in mollusks were high in all seasons. In addition, the concentration of Zinc in mollusks in the rainy season was much higher than that found in the hot and cold seasons (347.02, 73.56 and 38.67 mg.kg^{-1}, respectively). Mean concentrations of Mercury and Cadmium were of similar values (0.21, 0.32 mg.kg^{-1}, respectively) in the rainy season while in the cold and hot seasons they could not be detected. It was found that concentration of Zn was higher than Cu and Pb in mollusks in all three seasons. Comparing data between two species of mollusks, we found that concentrations of Zinc in *Filopaludina martensi* (Khom) were higher than in *Pomacea canaliculata* (Cherry). Additionally, no differences were found for other heavy metals in these two species.

3.3 Heavy metals concentration in sediments

Concentrations of heavy metals in sediments from five collection stations within the affected area are illustrated in Table 4. The mean Zinc concentration was higher in the three seasons compared with other remaining metals. In addition, the concentration of Zinc was highest in the cold season, followed by hot and rainy seasons (34.58, 27.78 and 25.68 mg.kg^{-1}, respectively). The concentrations of Mercury could not be detected in the three seasons (LOD = 0.175 $mg.kg^{-1}$). Mean concentration of Lead was highest in the hot season followed by cold and rainy seasons (16.22, 12.43 and 9.91 $mg.kg^{-1}$, respectively). The concentrations of Copper were higher in the rainy season compared with hot and cold seasons while the concentrations of Cadmium were detected with an average of 0.12 $mg.kg^{-1}$ in the rainy season but could not be detected in the cold and hot seasons. The mean concentrations of various heavy metals when compared in sequential order were Zn, Cu, Pb, Cd and Hg in sediments in the rainy season while Zn was higher than Pb and Cu in sediments in the cold and hot seasons.

Discussion/Conclusion

Eight species of mollusks were found to be living in the affected sampling areas (*Filopaludina martensi*, *Pomacea canaliculat*a, *Scabies crispata*, *Lymnaea (Radix) auricularia rubiginosa*, *Pilsbryoconcha exilis*, *Corbicula* sp., *Pila polita* and *Clea helena*). Classification was as follows: Gastropods were *Clea helena*, *Filopaludina martensi*, *Lymnaea (Radix) auricularia rubiginosa*, *Pila polita*, *Pomacea canaliculata* and bivalves were *Corbicula* sp., *Pilsbryoconcha exilis*, *Scabies crispata*. The most dominant species were *Filopaludina martensi* and *Pomacea canaliculata*. These species showed high tolerance to waste water. Physical and chemical parameters of water were not significantly different for each season. Heavy metal concentrations in mollusks were found to be relatively high during the 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 Zinc in *Filopaludina martensi* (Khom) were higher than that found in *Pomacea canaliculata* (cherry). 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 compared to other species. The concentrations of Zinc in sediments were found to be higher in all three seasons. The mean concentration of Zn was higher than Cu, Pb, Cd and Hg in sediments in the rainy season while in sediments the concentration of Zn was higher than Pb and Cu in cold and hot season. By comparing the accumulation of heavy metals between mollusks and sediments, this study found that the concentrations of metals were higher in mollusks. Thus, the data from the study showed that mollusks living in the effluent from the study area accumulate heavy metals in their body tissue.

Acknowledgments

This paper has been produced under financial support for fundamental research by the Graduate School of Chiang Mai University. We thank all personnel from the Phoenix Pulp and Paper Company for guiding the way and collecting samples. Heavy metals analysis was performed at the Laboratory Center for Food and Agricultural Products Company Limited (LCFA), Khon Kaen branch. We also wish to thank the Freshwater Biology Laboratory at the Department of Biology, Faculty of Science, Khon Kaen University for physical-chemical measurement and mollusk identification.

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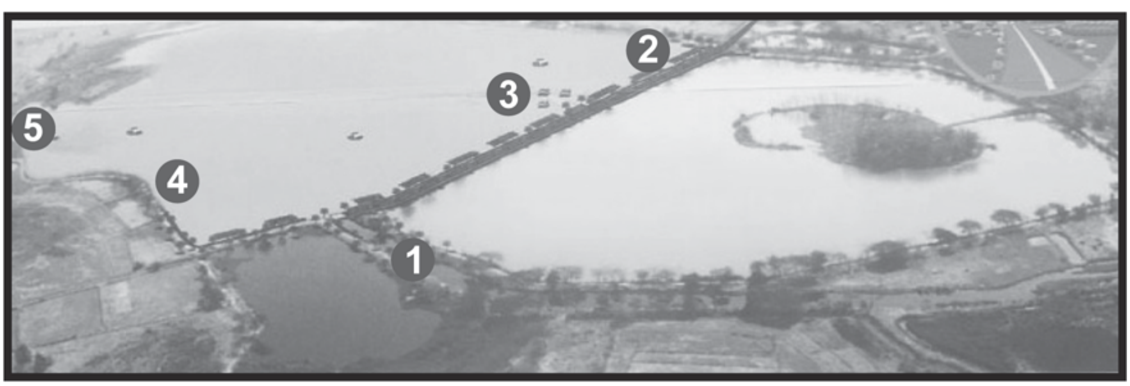

Figure 1 Overview of Beung Jode reservoir and location of five collecting stations

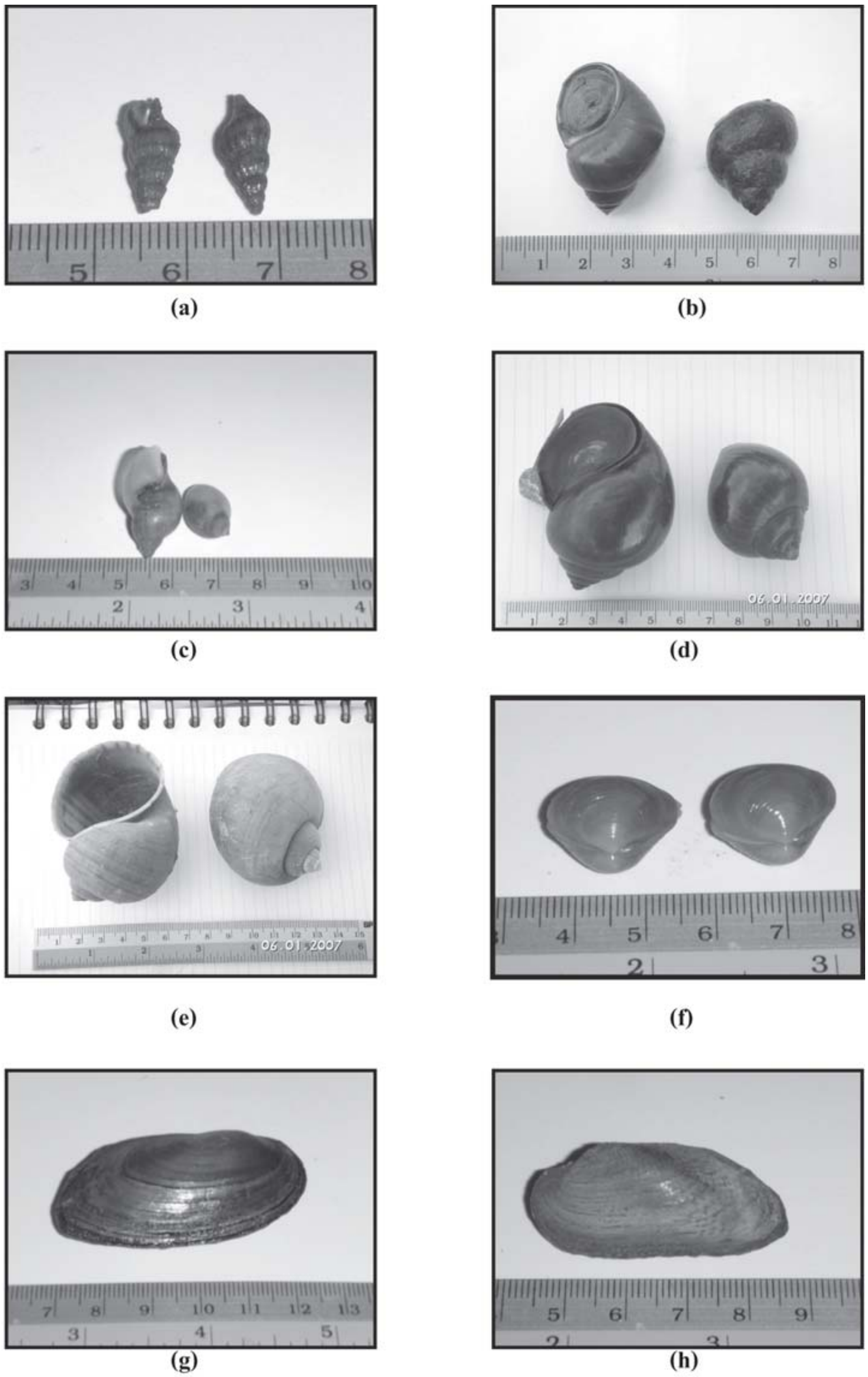

Figure 2. Species of mollusks in Beung Jode reservoir from five collecting stations: *Clea helena* (a), *Filopaludina martensi* (b), *Lymnaea (Radix) auricularia rubiginosa* (c), *Pila polita* (d), *Pomacea canaliculata* (e), *Corbicula* sp. (f), *Pilsbryoconcha exilis* (g) and *Scabies crispata* (h)

Table 1 Species of mollusks from samples collected in three seasons (+ : found, - : not found)

Mollusk species (Scientific Name)	Sample Collecting Station				
	1	2	3	4	5
Rainy season					
Gastropod					
Clea (Anentome) helena (Philippi, 1847)	-	-	-	-	-
Filopaludina martensi (Frauenfeld, 1865)	+	-	+	+	+
Lymnaea(Radix) auricularia rubiginosa (Michelin, 1831)	-	+	-	-	-
Pila polita (Deshayes, 1830)	-	-	-	-	-
Pomacea canaliculata (Lamarck, 1819)	+	+	+	+	+
Bivalve					
Corbicula sp. (M hlfell, 1811)	-	-	-	-	-
Pilsbryoconcha exilis (Lea, 1839)	-	-	-	+	-
Scabies crispata (Gould, 1848)	+	-	-	-	-
Cold-dry season					
Gastropod					
Clea (Anentome) helena (Philippi, 1847)	-	-	-	-	+
Filopaludina martensi (Frauenfeld, 1865)	+	+	+	+	+
Lymnaea(Radix) auricularia rubiginosa (Michelin, 1831)	-	-	+	-	+
Pila polita (Deshayes, 1830)	-	+	+	-	+
Pomacea canaliculata (Lamarck, 1819)	+	+	+	+	+
Bivalve					
Corbicula sp. (M hlfell, 1811)	+	-	-	-	-
Pilsbryoconcha exilis (Lea, 1839)	-	-	-	-	-
Scabies crispata (Gould, 1848)	+	-	-	-	-
Hot-dry season					
Gastropod					
Clea helena (Philippi, 1847)	-	-	-	-	-
Filopaludina martensi (Frauenfeld, 1865)	+	+	+	+	+
Lymnaea (Radix) auricularia rubiginosa (Michelin, 1831)	-	+	+	+	-
Pila polita (Deshayes, 1830)	-	-	-	-	-
Pomacea canaliculata (Lamarck, 1819)	+	+	-	-	+
Bivalve					
Corbicula sp. (M hlfell, 1811)	+	-	-	-	-
Pilsbryoconcha exilis (Lea, 1839)	+	-	-	-	-
Scabies crispata (Gould, 1848)	+	-	-	-	-

Table 2 Physical and chemical parameters of water from samples collected during three seasons

Parameter	t (air)	t (water)	pH	Conductivity ($\mu S.cm^{-1}$)	DO ($mg.L^{-1}$)	BOD ($mg.L^{-1}$)	NH_3 ($mg.L^{-1}$)	NO^-_3 ($mg.L^{-1}$)	PO^{3-}_4 ($mg.L^{-1}$)
Rainy season									
Station 1	29.50	30.00	7.56	356.00	5.85	4.60	-	3.10	0.89
Station 2	29.50	30.50	7.48	550.00	4.60	3.45	-	2.70	0.30
Station 3	31.00	30.00	7.48	432.00	5.35	4.25	-	1.90	0.68
Station 4	30.00	28.90	7.57	235.00	5.15	4.15	-	1.70	0.20
Station 5	28.50	31.50	7.61	136.00	4.75	3.85	-	1.60	0.05
Station 6	31.00	30.00	7.26	348.00	4.80	3.05	-	2.30	0.62
Average	**29.92**	**30.15**	**7.49**	**342.83**	**5.08**	**3.89**	**-**	**2.22**	**0.46**
Cold-dry season									
Station 1	22.50	24.00	7.53	365.00	1.90	1.40	-	0.40	0.15
Station 2	21.00	23.00	7.38	256.00	1.65	1.05	-	0.40	0.01
Station 3	23.00	24.00	7.36	348.00	1.60	0.55	-	0.20	0.10
Station 4	25.00	24.00	8.08	324.00	2.10	0.55	-	0.20	0.01
Station 5	24.50	26.00	7.97	238.00	2.05	0.45	-	0.10	0.04
Station 6	23.00	24.00	7.95	350.00	2.00	0.65	-	0.03	0.03
Average	**23.08**	**24.17**	**7.71**	**313.50**	**1.88**	**0.78**	**-**	**0.22**	**0.06**
Hot-dry season									
Station 1	33.00	29.00	7.43	167.00	6.10	5.55	-	0.40	0.39
Station 2	31.00	30.00	7.88	174.00	6.70	5.75	-	0.30	0.01
Station 3	31.00	31.00	7.95	805.00	6.60	5.15	-	0.30	0.10
Station 4	32.50	29.50	7.65	160.00	6.50	4.70	-	0.20	0.13
Station 5	32.00	29.50	8.13	669.00	5.50	3.95	-	0	0.04
Station 6	31.00	31.00	7.66	174.00	6.75	4.95	-	0.30	0.14
Average	**31.75**	**30.00**	**7.78**	**358.17**	**6.36**	**5.01**	**-**	**0.25**	**0.14**

Remark: At Station 6 water level depth at 20 meters, t: temperature, -: not detected

Table 3 Concentrations of heavy metals in mollusks in three seasons (% by dry weight)

Parameter	Cd	Cu	Pb	Hg	Zn
	($mg.kg^{-1}$)	($mg.kg^{-1}$)	($mg.kg^{-1}$)	($mg.kg^{-1}$)	($mg.kg^{-1}$)
Rainy season					
Station1 (cherry)	0.24	22.04	1.04	Not detected	125.85
Station 2 (khom)	0.14	87.37	2.81	0.31	650.46
Station 3 (cherry)	0.20	13.00	0.78	0.37	167.42
Station 4 (cherry)	0.24	18.31	0.48	Not detected	157.69
Station 5 (khom)	0.22	40.75	2.88	0.29	633.67
Average	**0.21**	**36.29**	**1.60**	**0.32**	**347.02**
Cold-dry season					
Station 1 (cherry)	Not detected	2.18	0.20	Not detected	16.97
Station 2 (khom)	Not detected	17.38	0.85	Not detected	108.29
Station3 (cherry)	Not detected	1.46	0.22	Not detected	15.41
Station 4 (cherry)	Not detected	0.46	0.30	Not detected	14.02
Station 5	-	-	-	-	-
Average	**-**	**5.37**	**0.39**	**-**	**38.67**
Hot-dry season					
Station 1 (khom)	Not detected	12.81	0.26	Not detected	98.10
Station 2	-	-	-	-	-
Station 3	-	-	-	-	-
Station 4 (cherry)	Not detected	3.24	0.40	Not detected	12.46
Station 5 (khom)	Not detected	6.88	0.65	Not detected	110.11
Average	**-**	**7.64**	**0.44**	**-**	**73.56**

Remark: - means no mollusks were found in these stations.

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

Table 4 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	Not detected	28.31
Station 2	0.10	23.60	16.91	Not detected	38.00
Station 3	0.09	25.88	4.44	Not detected	21.91
Station 4	Not detected	18.53	14.15	Not detected	29.13
Station 5	Not detected	3.54	5.95	Not detected	11.03
Average	**0.12**	**16.09**	**9.91**	Not detected	**25.68**
Cold-dry season					
Station 1	Not detected	4.75	6.87	Not detected	24.04
Station 2	Not detected	12.46	11.39	Not detected	41.85
Station 3	Not detected	7.01	10.92	Not detected	11.19
Station 4	Not detected	12.46	12.93	Not detected	24.43
Station 5	Not detected	3.13	20.04	Not detected	71.40
Average	Not detected	**7.96**	**12.43**	Not detected	**34.58**
Hot-dry season					
Station 1	Not detected	7.67	10.82	Not detected	33.00
Station 2	Not detected	12.91	29.27	Not detected	27.63
Station 3	Not detected	14.28	17.18	Not detected	33.19
Station 4	Not detected	12.13	15.63	Not detected	26.85
Station 5	Not detected	4.77	8.19	Not detected	18.25
Average	Not detected	**10.35**	**16.22**	Not detected	**27.78**

Remark: Limit of Detection (LOD) for Cd = 0.075 $mg.kg^{-1}$, Hg = 0.175 $mg.kg^{-1}$