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Heavy metals accumulation in freshwater mussels (*Lamellidens marginalis*) as a biological monitor inhabiting in Dhanmondi Lake, Dhaka, Bangladesh.

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Abstract: The concentrations of heavy metals *viz*., Mn, Zn, Pb and Ni were determined in soft tissues and shells of freshwater mussels (*Lamellidens marginalis)* at the various sites of Dhanmondi lake, Dhaka, Bangladesh between the period April, 2010 and March 2011. The heavy metal concentrations in shells and soft tissues of freshwater mussels were tended to vary significantly among sampling points and seasons in Dhanmondi Lake. Distribution of heavy metals in shell and soft tissue of *Lamellidens marginalis* followed the order Mn>Zn>Pb>Ni, respectively. According to the t-test, level of manganese, zinc and lead under investigation between shell and tissue showed statistically significant differences [Mn: t=-11.387; df=16; P=0.000; Zn: t=-2.590; df=16; P=0.020 and Pb: t=-2.8679; df=16; P=0.011].

Key words: Heavy metal; Freshwater mussel; Biological monitor; Dhanmondi Lake.

Introduction

Dhanmondi Lake located in the Dhanmondi area in Dhaka metropolitan city. The lake was originated from a channel of the Karwan Bazar River and was connected to the Turag River and Buriganga river. The lake is partially connected with the Begunbari canal. In 1956, Dhanmondi area was developed as a residential area. In the development plan, about 16% of the total area of Dhanmondi was designated for the lake (Banglapedia 2008). The Department of Environment looks after the aspects of proper environment and protection of aquatic resources of the lake (DoE 2005). Aquatic ecosystem are under constant pressure of anthropogenic pollutants originating from various point and non-point sources as a result of rapid human population growth, expansion of urbanization, increased industrial activities, extensions of irrigation and agricultural practices, exploration and exploitation of natural resources as well as the lack of environmental regulations.

Thus the aquatic bodies near the industrial and urban area are more prone to the accumulation of heavy metals. The presence of heavy metals causes hazardous impact on the flora and fauna of an ecosystem. The concentrations of toxic metals are more in the bottom dwellers of aquatic environment especially in molluscs and polycheats (Fang *et al.,* 2001). Freshwater mussels are an inexpensive secondary indicator of water pollution compared to water or sediment analysis. Some studies specify that molluscs can endure persistent toxins to a greater extant than other organisms and serve as effective biomonitors or indicators (Fang *et al.,* 2001; Salankil *et al.,* 2003 and Somoldes *et al.,* 2003). Knowledge of concentration of heavy metals is desirable for the estimation of metal concentration in lake's water, sediment and biota. Bivalves were chosen for this study because they meet many of the requirements of a good biological monitor (Phillips, 1980). They are somewhat sedentary, regionally abundant, long lived and have adequate tissue mass for analysis. They readily accumulate many metals and their body burden seems to reflect mean exposure levels over time. Consequently, such organisms have been largely used in programs of biological monitoring in either salt water (Avelar *et al.,* 2000) or in freshwater (Rutzke *et al.,* 2000). Studies on heavy metals in rivers, lakes, fish and sediments have been a major environmental focus especially in the last decades. The present study was undertaken to understand the evaluation of the concentration of various heavy metals like Mn, Zn, Pb and Ni in soft tissues and shell of freshwater mussels in Dhanmondi lake, Dhaka, Bangladesh.

Materials and Methods

Sampling Location (Dhanmondi Lake, Dhaka, Bangladesh): The present study was carried out in Dhanmondi lake, a naturally created shallow water body, situated within Dhaka city (23⁰ 43′ 29″ N and 90⁰ 26′ 10″ E) between April 2010 and March 2011. Brief morphometric characteristics of this lake have been presented by Islam and Chowdhury

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(1979). Three sampling stations (Site-1: Dhanmondi Road 2A, GPS value of this site is 23°44.364´ N and 90°22.631´ E. Site-2: Dhanmondi Road 6A, GPS value of this site is 23°44.507´N and 90°22.474´E. and Site-3: Dhanmondi Road 12A, GPS value of this site is 23°45.045´N and 90°22.599´E) were selected for the present investigation (Figure 1). Site-1 (Dhanmondi Road 2A) located at the western portion of the lake, in front of Dhaka Paediatric Neonatal and General Hospital and adjacent to Zia Chattar. People sometimes use this area for dumping garbage. The quality of mud of this area is clay. Site-2 (Dhanmondi Road 6A) is near most middle of the lake. The quality of the soil of this area is sandy. It is located in adjacent to Madenova Medical Service. Site-3 (Dhanmondi Road 12A) is located at the eastern portion of lake near Russel Square opposite to Dhanmondi Road #32. This area is also used for angling. The soil quality of this area is clay.

Sampling procedure: The freshwater mussels (*Lamellidens marginalis*) were randomly collected at three seasons namely winter (November-February), summer (March-June) and monsoon (July-October). After collection, the samples were identified and were taken in an ice compartment during transportation to the laboratory. The mussels samples were washed with clean water before frozen at -20°C. In the laboratory, ten fresh water mussels of similar size from each sampling sites were randomly taken in each season. They were washed with deionized distilled water each individual was then dissected and shells were separated from soft tissues. All the separated parts were pooled and dried for 48 hours at 60° C in an incubator to get constant dry weight. The detail process for metals analysis was conducted by following the procedure by Yap *et al.,* (2003). The dried samples were digested in 5% nitric acid (HNO_3) and were placed in a CEM Microwave digester at room temperature and then fully digested at 200°C for 15 minutes. The digested samples were then diluted to certain volume water. After filtration heavy metals were determined for Mn, Zn, Pb and Ni by using an air-acetylene flame atomic absorption spectrophotometer (AAS, Perkin Elmer Model-A Analyst 800 series). The data were presented in mg/l for dry weight. All used glassware and equipment were washed using acid with 1% double distilled water to avoid possible contamination. Statistical Data Analysis was done by using SPSS (Ver. 11.5, window based software, USA). The difference in heavy metal concentrations between seasons and sampling sites were evaluated by one-way analysis of variance (ANOVA) and the difference in heavy metal concentrations between shell and tissues were evaluated by student t-test. The level of significance was set at 5% level.

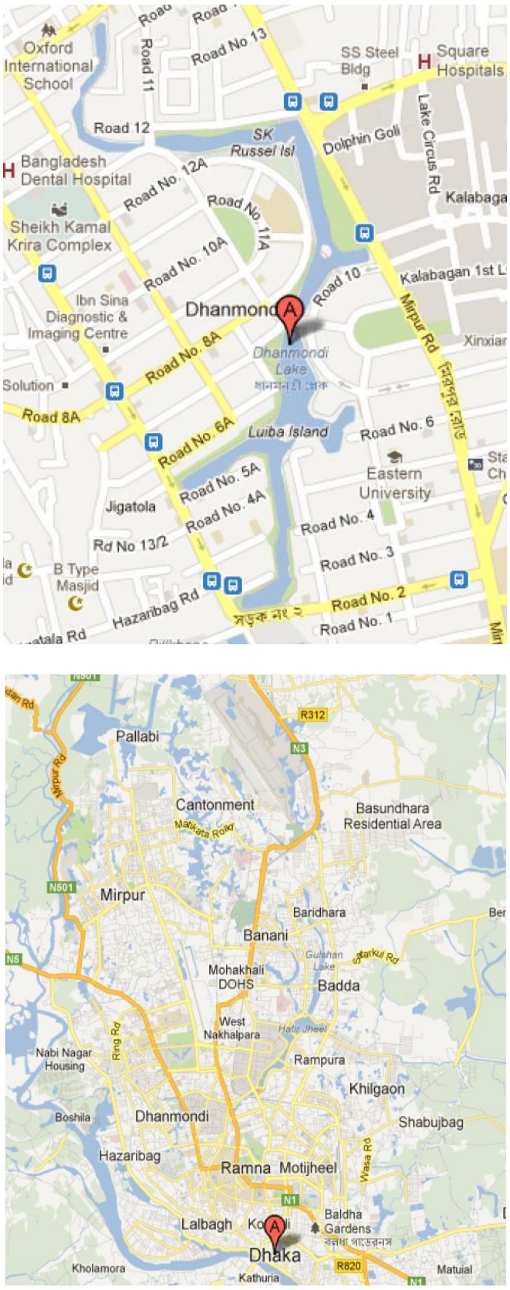

Figure 1: Map of Dhanmondi Lake, Dhaka, Bangladesh with sampling locations (Left), [B]. Map of Dhaka city showing Dhanmondi (Right), Source: Google

Results and Discussion

The concentrations of Mn, Zn, Pb and Ni were determined in the bivalve freshwater mussel (*Lamellidens marginalis*) collected from three different sites (Dhanmondi 2A, Dhanmondi 6A and Dhanmondi 12A) in Dhanmondi lake, Dhaka, Bangladesh.

Manganese (Mn): In the present study seasonally concentrations of manganese (Mn) for shell ranged from 2.33 (±0.15) to 4.61 (±0.76) mg/l. The highest value was occurred in winter and the lowest in monsoon. These values among three seasons showed significant differenaces (F=5.868, df= 2,6, p=0.0390). In case of tissue, it fluctuated from 67.33 (±5.60) mg/l in summer to 63.06 (±12.80) mg/l in monsoon. These values among three seasons did not show differences (F=0.045, df=2,6, p=0.961)[Table-1]. Seasonal variations of heavy metals in aquatic organisms, especially bivalves, have been reported earlier by Peerzada and Kozlik (1992) from Darwin Harbor, Northern Territory, Australia. They found lower concentrations of manganese in the Scallop *Chlmys opercularis* during the spring and summer months and higher concentrations in autumn and winter. Sitewise the concentrations of manganese for shell varied from 2.96 (±0.46) to 4.00 (±1.03) mg/l. The higest value was observed in Dhanmondi 12A and it was lowest in Dhanmondi 2A. The value of Mn among three sites did not show differences (F=0.602, df=2,6, p=0.578). On the other hand the concentration of manganese for tissue ranged from 49.90 (±7.56) to 76.00 (±8.62) mg/l. The maximum value was observed in Dhanmondi 2A and it was found lowest in Dhanmondi 12A. The value among three sites did not exibit differences (F=3.411, df=2,6, 0.102) [Table-2]. The test of significance shows that the Manganese under investigation between shell (3.65±0.42) and tissue (65.18±5.38) was significanly different (t=-11.387; df=16; P=0.000). The soft tissues of *Lamellidens marginalis* accumulated more Mn than the shells. This may be due to Mn being needed for metabolism in the soft tissues of *Lamellidens marginalis*. The higher concentration of Mn found in the soft tissues than in the shells was in agreement with the results reported by the Carvo *et al.,* (2004).

Table 1: Concentrations of heavy metal found in shell and tissue of *Lamellidens marginalis* at different seasons with F-test of significance in Dhanmondi Lake, Dhaka, Bangladesh

Metals	Seasons	Shell/Tissue	Value(±SE)	df	F	Sig
	Winter	Shell	4.616(±0.766)			
Mn	Summer	Shell	4.003(±0.325)	2,6	5.868*	0.039
	Monsoon	Shell	2.330(±0.153)			
	Winter	Shell	0.100(±0.036)			
Zn	Summer	Shell	5.530(±1.530)	2,6	11.538**	0.009
	Monsoon	Shell	0.233(±0.050)			
	Winter	Shell	0.656(±0.084)			
Pb	Summer	Shell	0.343(±0.047)	2,6	9.141*	0.015
	Monsoon	Shell	0.393(±0.003)			
	Winter	Shell	0.25(±0.81)			
Ni	Summer	Shell	0.243(±0.026)	2,6	0.791	0.496
	Monsoon	Shell	0.166(±0.008)			
	Winter	Tissue	65.166(±12.180)			
Mn	Summer	Tissue	63.066(±12.806)	2,6	0.040	0.961
	Monsoon	Tissue	67.333(±5.607)			
	Winter	Tissue	3.766(±0.317)			
Zn	Summer	Tissue	6.000(±1.401)	2,6	1.592	0.279
	Monsoon	Tissue	4.633(±0.569)			
	Winter	Tissue	0.423(±0.107)			
Pb	Summer	Tissue	0.096(±0.185)	2,6	6.985*	0.027
	Monsoon	Tissue	0.173(±0.026)			
	Winter	Tissue	0.240(±0.0152)			
Ni	Summer	Tissue	0.160(±0.006)	2,6	5.405*	0.045
	Monsoon	Tissue	0.113(±0.045)			

Denotes level of significance at 5% level and ** Denotes level of significance at 1% level

Zinc (Zn): Zinc is an essential element to animals. Seasonally, the concentrations of Zn in shell ranged from 0.10 (±0.03) to 5.53 (±1.53). The highest value was observed in summer and the lowest in winter. The value of Zn between seasons showed significant differences (F=11.538; df=2,6; p=0.009). While in tissue, it ranged from 6.00 (±1.40) to 3.76 (±0.31) [Table-1]. The maximum value was found in summer and the lowest in winter. The concentration of Zn between seasons did not show differences (F=1.592, df=2,6; P=0.279). Peerzada and Kozlik (1992) found that the lower concentrations of Zinc in the Scallop *Chlmys opercularis* during the spring and summer months and higher concentrations in autumn and winter. Site wise the concentrations of Zn in shell varied from 0.88 (±0.75) in Dhanmondi 12A to 2.61(±2.45) in Dhanmondi 6A while in tissue it varied from 3.33 (±0.088) in Dhanmondi 12A to 5.70(±1.22) in Dhanmondi 6A. The site wise concentrations of Zn among shell (F=0,231; df=2.6; P=0.801) and among tissue (F=2.443; df=2,6; P=0.167) did not show any differences [Table-2]. The concentrations of Zinc between shell(1.90±0.97) and tissue (4.80±0.55) showed significant differences(t=-2.590; df=16; P=0.020) [Table-3]. The soft tissues of *Lamellidens marginalis* accumulated more Zn than the shells. This may be due to metals being needed for metabolism in the soft tissues of *Lamellidens marginalis*. The higher concentration of Zn in the soft tissues than in the shells was in agreement with the finding reported by the Carvo *et al.,* (2004), who found that Fe and Zn concentration were consistently lower in the shells than in the soft tissues of gastropods *Patella aspera* from the south coast of Portugal. The relatively high levels of Zn in the soft tissues than in the shells may also be due to the role of Zn as an activator of many enzymes in the organs of some organisms (Ireland and Kuwabara 1985).

Lead (Pb): Lead is a highly toxic substance, exposure to which can produce a wide range of adverse effect to animal health. Seasonally, the concentrations of Pb in shell ranged from 0.65 (±0.08) mg/l to 0.34 (±0.04) mg/l. The highest value was observed in winter and the lowest in summer while incase of tissue it ranged from 0.09 (±0.18) mg/l to 0.42 (±0.10) mg/l. The maximum value was found in winter and the lowest in summer. These values among seasons for shell (F=9.141; df=2, 6; p=0.015) and for tissue (F=6.985; df=2,6; P=0.027) showed statistically differences[Table-1]. Site wise the concentrations of Pb in shell varied from 0.39(±0.07) in Dhanmondi 2A to 0.53 (±0.13) mg/l in Dhanmondi 6A while in tissue it varied from 0.15(±0.02) mg/l in Dhanmondi 12A to 0.276(0.137) mg/l in Dhanmondi 6A. These values among sites for shell (F=0.477, df=2, 6; P=0.643) and for tissue (F=0.370; df=2,6; p=0.705) did not show significant differences[Table-2]. Interestingly according to this study results, the concentrations of lead between shell (0.464 ±0.056) and tissue (0.231±0.058) showed significant differences(t=-2.8679; df=16; P=0.011) [Table-3]. The higher concentration of Pb in shells than in the soft tissue was also observed by Flower (1990) and Dambo and Ekweozor (2000). The higher concentration of Pb in the shell may be due to the fact that the crystalline structures of the shell matrix have a higher capacity for incorporation of Pb than the soft tissue (Al-Dabbas *et al.,* 1984).

Nickel (Ni): Nickel is a silver-white metal with siderophilic properties that facilitate the formation of nickel-iron alloys (Naimo et al.1992). In contrast to the soluble nickel salts (chloride, nitrate, sulfate), metallic nickel, nickel sulfides, and nickel oxides are poorly water-soluble. Drinking water and food are the main sources of exposure for the general population. Seasonally, the concentrations of Ni in shell ranged from 0.16(±0.008) to 0.24(±0.81) mg/l. The highest value was observed in winter and the lowest in monsoon while incase of tissue it ranged from 0.12(±0.05) mg/l in monsoon to 0.24(±0.02) mg/l in winter. These concentrations among seasons for shell (F=0.791, df=2, 6; P=0.496) did not show differences but for tissue (F=5.405, df=2, 6; P=0.045) showed significant differences [Table-1]. Egborge (1991) and Oguzie (2000) also found that the higher levels of Ni in shells and soft tissues of mollusks which were observed in the winter season in the Niger Delta, Egypt. Site wise the concentrations of Ni in shell varied from 0.17(±0.06) mg/l in Dhanmondi 12A to 0.23 (±0.04) mg/l in Dhanmondi 2A while in tissue it varied from 0.15(±0.03) in Dhanmondi 12A to 0.20(±0.017) mg/l in Dhanmondi 2A. These concentrations of Nickel among sites for shell (F=0.567, df=2,6; P=0.595) and for tissue (F=0.333, df=2,6; P=0.729) did not show differences [Table-2]. In Danmondi 2A higher concentration of metals for shells and soft tissues of *Lamellidens marginalis* may be related to the more anthropogenic activities in the sampling sites. The concentrations of Nickel between shell (0.27±0.02) and tissue (0.17± 0.02) did not show significant differences (t=1.287; df=16; P=0.216) [Table-3]. The higher concentration of Ni found in the shell may be due to the fact that the crystalline structures of the shell matrix have a higher capacity for incorporation of Ni than the soft tissue (Al-Dabbas *et al.,* 1984).

Table 2: Concentrations of heavy metal found in Shell and tissue of *Lamellidens marginalis* at different sampling sites
with F-test in Dhanmondi Lake, Dhaka, Bangladesh

Metals	Sites	Shell/tissue	Value(±SE)	df	F	*Sig*
	2A	Shell	2.96(±0.45)			
Mn	6A	Shell	3.98(±0.69)	2,6	0.602	*0.578*
	12A	Shell	4.00(±1.03)			
	2A	Shell	2.20(±2.00)			
Zn	6A	Shell	2.61(±2.44)	2,6	0.231	*0.801*
	12A	Shell	0.88(±0.75)			
	2A	Shell	0.39(±0.07)			
Pb	6A	Shell	0.53(±0.13)	2,6	0.477	*0.643*
	12A	Shell	0.47(±0.08)			
	2A	Shell	0.23(±0.04)			
Ni	6A	Shell	0.24(±0.04)	2,6	0.567	*0.595*
	12A	Shell	0.17(±0.06)			
	2A	Tissue	76.00(±8.62)			
Mn	6A	Tissue	69.66(±5.60)	2,6	3.411	*0.102*
	12A	Tissue	49.90(±7.56)			
Zn	2A	Tissue	5.36(±0.70)	2,6	2.443	*0.167*

	6A	Tissue	5.70(±1.22)			
	12A	Tissue	3.33(±0.08)			
	2A	Tissue	0.26(±0.13)			
Pb	6A	Tissue	0.27(±0.13)	2,6	0.370	*0.705*
	12A	Tissue	0.15(±0.02)			
	2A	Tissue	0.20(±0.01)			
Ni	6A	Tissue	0.16(±0.06)	2,6	0.333	*0.729*
	12A	*Tissue*	*0.15(±0.03)*			

The combination of results showed that heavy metals (Mn, Zn, Pb and Ni) concentration in shells and soft tissues of *Lamellidens marginalis* were distributed differently at different sampling sites and seasons (Table-1 and 2). Seasonally, concentrations of Mn, Zn, Pb and Ni in the shell were recorded as 4.61±0.76, 0.10±0.03, 0.65±0.08 and 0.25±0.81 mg/l i.e.Mn>Pb>Ni>Zn at winter season, 4.00±0.33, 5.53±1.53, 0.34±0.04 and 0.24±0.02 mg/l i.e. Zn>Mn>Pb>Ni at summer and 2.33±0.15, 0.23±0.05, 0.39±0.00 and 0.16±0.00 mg/l i.e. Mn>Pb>Zn>Ni at monsoon respectively. On the other hand the concentrations of Mn, Zn, Pb and Ni in the soft tissues were recorded as 65.16±12.18, 3.76±0.32, 0.42±0.10 and 0.24±0.01 mg/l respectively i.e. Mn>Zn>Pb>Ni at Winter, 63.06±12.80, 6.00±1.40, 0.09±018 and 0.16±0.00 mg/l respectively i.e. Mn>Zn>Ni>Pb at summer and 67.33±5.60, 4.63±0.56, 0.17±0.02, 0.11±0.04 mg/l respectively i.e. Mn>Zn>Pb>Ni at monsoon respectively (Table 1). In general *Lamellidens marginalis* showed the heavy metal concentration in order to shell and soft tissues were Mn>Zn>Pb>Ni respectively. In particular, accumulation of heavy metals for tissue 81.83(±8.88), 75.80(±4.70) and 53.54 (±7.60) mg/l and for shell 5.79(±2.24), 7.36(±2.81) and 5.53(±1.23) mg/l was recorded at site Dhanmondi 2A, Dhanmondi 6A and Dhanmondi 12A respectively (Fig-1). In Dhanmondi 2A sites higher concentration of metals for shell and soft tissue of *Lamellidens marginalis* may be related to the more anthropogenic activities in the sampling sites.

Table 3: Showing the comparison of concentrations of heavy metal between Shell and tissue of *Lamellidens marginalis* with significant t-test in Dhanmondi Lake, Dhaka, Bangladesh.

Heavy metals	Mean(±SE)	t	df	Sig. (2-tailed)
Mn	Shell: 3.65(±0.42) Tissue: 65.18(±5.38)	-11.387**	16	0.000
Zn	Shell: 1.90(±0.97) Tissue: 4.80(±0.55)	-2.590*	16	0.020
Pb	Shell: 0.46(±0.05) Tissue: 0.23(±0.05)	2.869**	16	0.011
Ni	Shell: 0.21(±0.02) Tissue: 0.1711(±0.02)	1.287	16	0.216

*Denotes level of significance at 5% level and ** Denotes level of significance at 1% level

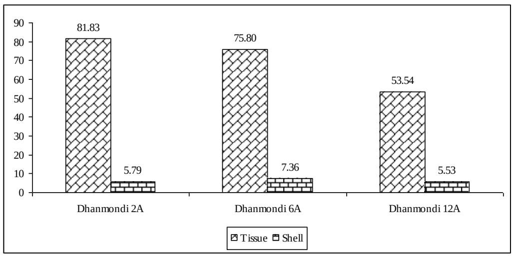

Figure 2: Variations of heavy metals in soft tissues and shells of freshwater mussel *Lamellidens marginalis* at Dhanmondi lake sites Dhaka, Bangladesh

Conclusion

The soft tissues of molluscs are generally recognized as more efficient accumulators of metal than shells (Brown and Deplege 1998). There are many factors which may affect the bioavailability and intake of heavy metals by the organisms, such as variations in the physico-chemical parameters in the surrounding water which may cause dilution of the concentrations of heavy metals in water (Camusso *et al.,* 1994) and variations in the physiology of organisms (Naimo *et al.,* 1992). In general higher concentration of metals in *Lamellidens marginalis* whether in shells and soft tissues in the Dhanmondi lake 2A sites may be related to the more anthropogenic activities in the sites. The concentrations of heavy metals in the mussel samples were quite variable and no patterns of distribution and behavior were noted. However, high concentrations of some heavy metals measured in the soft tissues suggested that the mussels were capable of concentrating the metals in their shells or soft tissues from the aquatic environment.

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