Trends in

Applied Sciences Research

ISSN 1819-3579

Academic
Journals Inc.

www.academicjournals.com

Trends in Applied Sciences Research 3 (1): 69-75, 2008
ISSN 1819-3579

Determination of Contamination and Bioavailabilities of Heavy Metals (Cu, Cd, Zn, Pb and Ni) in the Serdang Urban Lake by Using Guppy Fish *Poecilia reticulata*

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Abstract: The guppy fish, *Poecilia reticulata* and the lake surface sediments were collected from the Serdang Lake in August 2005. Both the fish and the sediment samples were analyzed for Cu, Cd, Pb, Zn and Ni. The ranges of metal concentrations (μg g^{-1} dry weight) in the fish were 0.160-11.1 μg g^{-1} for Cu; 64.6-174 μg g^{-1} for Zn; 0.400-4.03 μg g^{-1} for Cd; 3.27-12.1 μg g^{-1} for Ni and 19.5-50.9 μg g^{-1} for Pb. In the sediment, the ranges of metal concentrations were 1.97-62.1 μg g^{-1} for Cu; 31.6-274 μg g^{-1} for Zn; 1.92-3.17 μg g^{-1} for Cd; 60.2-94.8 μg g^{-1} for Ni and 3.23-42.1 μg g^{-1} for Pb. It was found that the concentrations of Zn was the highest found in both fish and sediment samples, followed by Pb, Cu, Ni and Cd. The similar pattern of heavy metal occurrence was found in the fish and in the sediment, indicated that the fish could be used as a potential biomonitor for metal contamination in the freshwater ecosystem. Since *P. reticulata* are widely distributed in lakes and in almost all of the urban drainage, this fish species is a very potential biomonitor of heavy metal bioavailabilites in the polluted freshwater ecosystem of Malaysia.

Key words: Guppy fish, *Poecilia reticulata*, urban Lake, heavy metal, sediment, biomonitor

INTRODUCTION

Serdang Lake is situated at the center of Sri Serdang residential area (GPS: N 3°00'16.65" E 101°42'50.84). The lake is also surrounded by a recreation area, restaurants and a school. Although the lake scenery is attractive but rubbish at the lake side which was due to domestic dumping from the residential area has become a concern in the ecotoxicological point of view.

The guppy is one of the most popular freshwater aquarium fish species in the world. It is a small member of the Poecilidae family (female±3.5 cm long and males±2 cm long). The guppy fish feeds on zooplankton, small insects and detritus. Originating from South America and the Caribbean, the diminutive guppy was introduced into many countries during the last century as a means to keep the mosquito population down in the fight against malaria (Fernando and Phang, 1985). The guppy fish can tolerate highly polluted water and can withstand a high degree of salinity. Therefore, it is not surprising to find guppy fish in shallow streams, ponds, open drains and urban canals. The optimum temperature for guppy is between 23.9 to 29.4°C and for the pH, it is around 6.8 to 7.2 (Johnson and Soong, 1963).

Fish can accumulate contaminants from the environment and therefore have been extensively used in aquatic pollution monitoring programs (Clearwater *et al*., 2002; Henry *et al*., 2004; Papagiannis *et al*., 2004). In recent years, much attention has been directed to study the concentrations of heavy metals in freshwater fish and other aquatic organisms (Zhou *et al*., 1998; Mansour and Sidky, 2002; Yilmaz, 2002; Yap *et al*., 2005). This is due to fish samples being considered as one of the

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most significant indicators in freshwater systems for the estimation of metal pollution levels (Rashed, 2001). Furthermore, metals transferred through aquatic food webs to fish, humans and other piscivorous animals are of environmental and human health concern (Henry *et al*., 2004; Mendil *et al*., 2005).

To our knowledge, few or no studies on the heavy metal concentrations in the guppy fish have been reported from Malaysia. Therefore, the objective of this study was to determine the heavy metal concentrations in *P. reticulata* collected from an urban lake at Sri Serdang and a few drainage around the Universiti Putra Malaysia (UPM) campus.

MATERIALS AND METHODS

Sample Storage and Sampling

There are four sampling sites at drainage around UPM besides Serdang Lake namely:

- MARDI (Malaysia Agriculture Research and Development Institute), which is located near to UPM where a drainage system of a residential area was found.
- Lecture hall 1 drainage system, situated in front of Lecture hall 1, UPM.
- Main drainage system of UPM, located beneath the overhead bridge connecting the main campus and a residential college, Kolej Mohamad Rashid.
- Residential colleges drainage system, located between Kolej Mohamad Rashid and the Main Football Field, UPM.

During the sampling, the fishes and the top 3.0 or 5.0 cm of the lake surface sediment were collected and then were put into polyethylene bags and kept in a cool box at <5°C until transported to the laboratory. The sediment samples were sampled using a plastic spatula and placed in a clean plastic bag and deep frozen prior to analysis. The samples were brought back to the laboratory and kept at -10°C until metal analysis

Sample Preparation

In the laboratory, the frozen fish samples were removed from the plastic bags and washed under running Double Distilled Water (DDW). Later, the samples were thawed at room temperature. The dry weights of total fish pooled from 3-5 individuals were determined by drying the whole fish in the defined group for 72 h at 60°C to constant dry weights. Sediment samples were dried at 60°C for at least 72 h until constant dry weights. The sediment samples were sieved through a 63 µm stainless steel sieve and were shaken vigorously to produce homogeneity.

Sample Digestion/Extraction

Both the fish and sediments were digested. For the sediments, about 0.5-1.0 g of dried samples were digested in 10 mL of a combination solution of concentrated HNO_3 (AnalaR grade, BDH 69%) and concentrated $HClO_4$ (AnalaR grade, BDH 60%) in the ratio of 4:1. For the fish samples, about 0.5-1.0 g of the tissues were digested in 10 mL of concentrated HNO_3 (AnalaR grade, BDH 69%). All samples were weighed and later placed into digestion tubes. The tubes were put into a digestion block and they were digested first at 40°C for 1 h and then the temperature was increased to 140°C for at least 3 h. After completing the digestion, the sample was diluted with double distilled water to a certain volume of 40 mL and then was filtered through a Whatman No. 1 (Filter speed: Medium; Whatman International Ltd. Maidstone, England) filter paper into an acid-washed polyethylene bottle until metal analysis.

Determinations for Heavy Metals

All samples were analyzed for Cd, Cu, Ni, Pb and Ni using air-acetylene Perkin-Elmer™ flame atomic absorption spectrophotometer Model AAnalyst 800. Procedural blanks and quality control samples made from the standard solution for each metal were analyzed once for every five samples in order to check for accuracy. Percentages of all metal recoveries were satisfactory, being between 90-120%.

RESULTS AND DISCUSSION

Guppy fish from site 7 recorded the highest concentrations of Cu, Cd, Pb and Ni thus indicating the high bioavailability of these metals at this particular site of the Sri Serdang Lake (Fig. 1). In the mean time, the metal concentrations in the guppy fish from the Serdang lake was compared with the guppy fish from the four drainage systems (Table 1). It was found that, higher concentrations of Cd, Ni and Pb (Table 2) were found in the guppy from the drainage systems, indicating that the drainage systems have higher bioavailabilities of these metals.

The higher concentration of Zn found in the total body of the guppy fish from all the sites (Table 2) might be due to its essentiality in the basal metabolism of guppy fish besides anthropogenic inputs. The Pb concentrations found in the guppy fish might be due to the road dust. Eisler (1988) mentioned that, little or no biomagnifications of Cu is evident in the freshwater food chain. According to Bryan (1976), Cu adsorption from solution by most aquatic organisms involve passive diffusion of the metal, probably as a soluble complex, down gradients created by adsorption from the surface (cuticle, mucous layer, etc) and binding by constituents of the surface cells, body fluids and internal organ. For Cd, which is not an essential metal to the living organism, it is an immobile component which is hardly released (unlike Zn), therefore, the organisms will minimize the uptake of this metal through some detoxification processes.

Figure 2 shows the relationships of heavy metal accumulations between the sediment and the fish collected from the drainage systems (MARDI, Lecture hall 1, Overhead-bridge and Residential college) and the Serdang lake. A linear relationship of metal accumulations was exhibit by both the sediment and the fish in all the sampling locations except for the accumulation of Ni, where an exponential relationship was shown between Ni concentration in the sediment and the fish. The points above strengthen the case for using *P. reticulata* as a biomonitoring agent for Cu, Cd, Zn and Pb. From this study, it was found that *P. reticulata* has the ability to accumulate heavy metals in their soft body. The metals could be accumulated in the various tissues and organs and may be biomagnified in the food chain. Chemical factors like acidity, buffer capacity and the presence of Ca and organic compounds, may act together with biological factors like habitat preferences, feeding behavior and growth rates, to influence the bioavailabilites and accumulation of heavy metals in fish (Hermens and Leeuwangh, 1982; Khangarot and Ray, 1987; Khangarot and Ray, 1990).

According to Pourang (1995), heavy metals may enter the fish body in three possible ways: 1stly) through the body surface, 2ndly) through the gills or 3rdly) the digestive tract. The gills are regarded as important sites for direct uptake from the water (Dallinger *et al*., 1987). This can occur probably by simple diffusion and possibly through the gills (Bryan, 1979). According to Clearwater *et al*. (2002), metals accumulated by fish are influenced by the bioavailabilities and toxicities of diet borne Cu and Zn.

It was found that the Serdang lake sediment recorded higher concentrations of heavy metal (compared with mean of the drainage) except for Pb (Table 3). The heavy metal concentrations in the sediment samples collected from the drainage and the Serdang lake were also compared with the Interim Freshwater Sediment Quality Guideline (ISQG) and Probable Effect Level (PEL) values set by the Canadian Council of Minister of the Environment (CCME, 2001). For the drainage systems, it was found that the concentrations of Cd and Pb exceeded the values set in the ISQG meanwhile for the Serdang lake, the concentrations of Cu, Zn, Cd and Pb exceeded the values set in the ISQG.

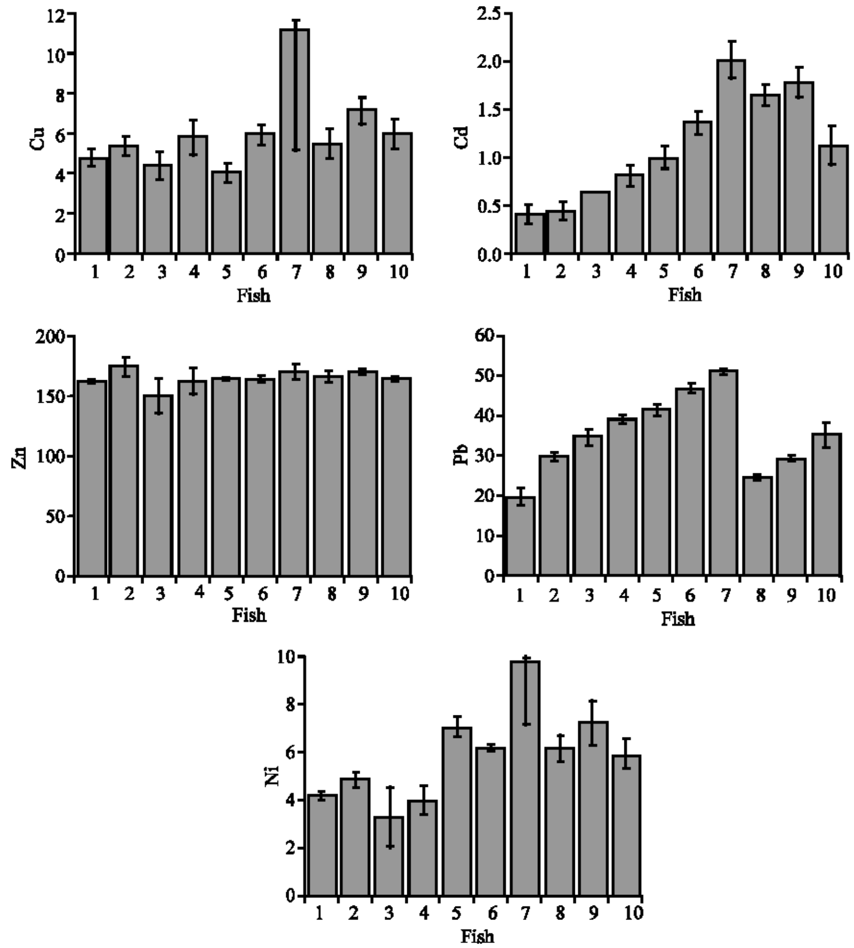

Fig. 1: The total concentration (μg g^{-1}) of heavy metals (Cu, Cd, Zn, Pb and Ni) in the ten groups of fish collected from the Serdang Lake

Table 1: The descriptions of the sampling sites

Sampling site	Sampling date	Descriptions
Drainage		
MARDI	August 2005	Area: sewage and domestic untreated from residential area.
		Temperature: 28.5°C
		Water pH: 6.98
Lecture hall	August 2005	Area: drainage system for the lecture hall area.
		Temperature: 28°C
		Water pH: 7.03
Bridge site	August 2005	Area: main drainage system from the domestic
		Temperature: 30°C
		Water pH: 6.76
College site	August 2005	Area: drainage system from Mohamad Rashid college
		Temperature: 28°C
Lake		
Serdang Lake	August 2005	Restaurant, sewage, dumping, recreation site

Fortunately, the metal concentrations in all the sampling sites were still below the value of PEL set by CCME. Concentrations exceeding the PEL values may cause mortality to the living organisms in the areas.

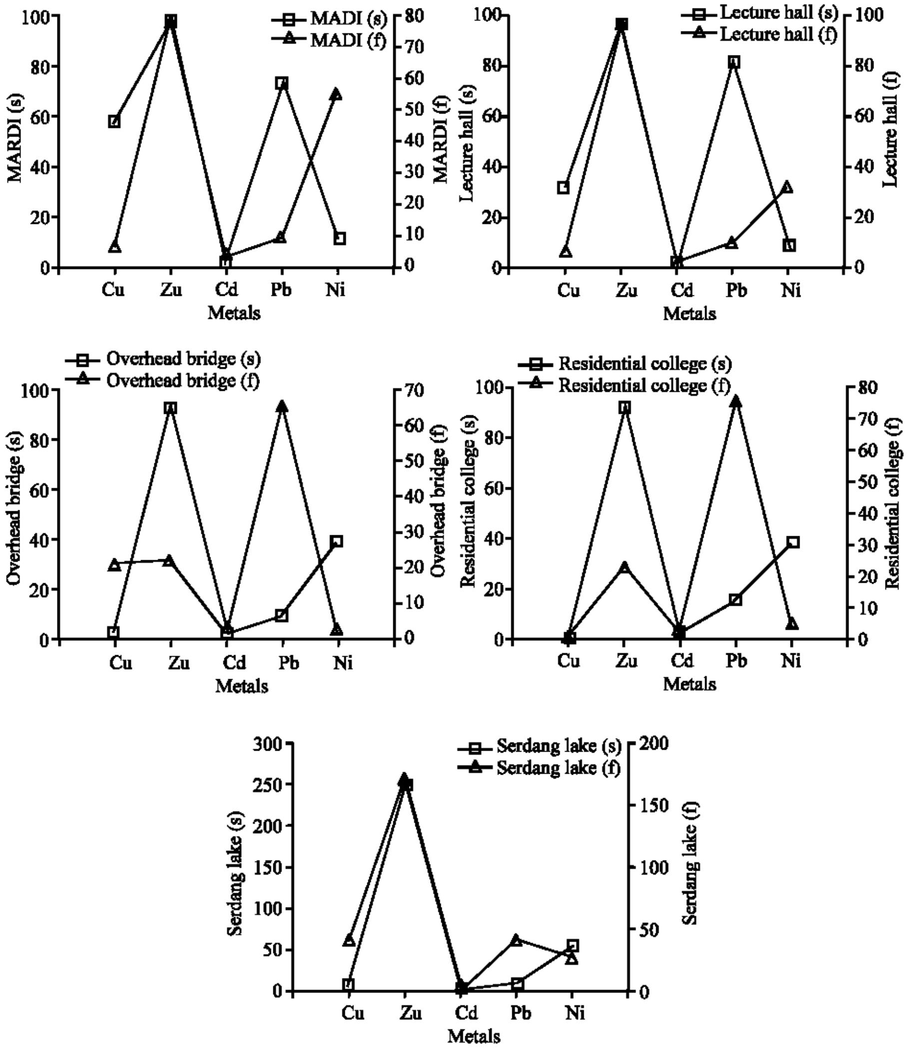

Fig. 2: Comparison of heavy metal concentrations between the sediment and the fish collected from the drainage systems (MARDI, Lecture hall 1, Overhead bridge and Residential college) and the Serdang lake Note: f = Fish; s = Sediment

Table 2: Heavy metal concentrations (µg g^{-1} dry weight) in the total soft tissues of guppy fish *Poecilia reticulata* from the drainage and the Serdang Lake (n = 3)

Site	Cu	Zn	Cd	Ni	Pb
Drainage					
Mean	4.02±1.68	78.16±6.42	2.57±0.52	9.71±1.18	36.36±6.36
Ranges	(0.16-7.02)	(64.6-95.1)	(1.79-4.03)	(6.49-12.11)	(30.8-55.2)
Lake					
Serdang Lake	5.98±0.713	164±2.28	1.12±0.201	5.91±0.69	34.9±3.43
(N = 10)	(3.96-11.1)	(150-174)	(0.400-2.01)	(3.27-9.73)	(19.5-50.9)

Anthropogenic activities such as vehicular activities could contribute to Pb pollution, in addition to untreated sewage from the residential area. Therefore, the elevated concentrations of heavy metals found in the sediments of this lake could be due to the runoffs, semi-treated or untreated

Table 3: Heavy metal concentrations in the sediment (μg g^{-1}) collected from the drainage and the Serdang lake (n = 3)

Site	Cu	Zn	Cd	Pb	Ni
Drainage					
Mean	30.6±11.3	64.1±19.3	2.23±0.32	85.9±5.19	7.81±1.97
Range	(1.97-57.41)	(29.7-98.2)	(1.77-3.17)	(72.9-94.8)	(3.23-12.4)
Lake					
Serdang Lake	59.6±2.41	258±11.7	2.29±0.074	62.8±1.75	40.5±1.87
(N = 10)	(54.8-62.1)	(234-274)	(2.14-2.39)	(60.2-66.1)	(38.5-42.1)
ISQG value set by CCME (2001)	35.7	123	0.600	35.0	NA
PEL value set by CCME (2001)	197	3152	3.5	91.3	NA

ISQG = Interim Freshwater Sediment Quality Guidelines

domestic effluents from residential and commercial areas through the drainage system as reported by Ismail *et al*. (2004) for another urban lake in Malaysia.

A study conducted by Widianarko *et al*. (2000) had confirmed the potential use of *P. reticulata* as a biomonitor of metal pollution since they found the fish occurrence in 63 streams of Semarang, (Indonesia) which indicated that the guppies did not avoid the highly polluted sites. Widianarko *et al*. (2000) also found that, in general, abiotic parameters and body size had no influence on the metal flux from sediment to water and into fish. Finally, their results suggested that metal concentrations in the sediments were the most important factor governing the body metal concentrations of the guppy fish. Therefore, the present study indicated that the guppy, *P. reticulata*, from an urban lake is a potential biomonitor of metal pollution.

CONCLUSIONS

In conclusion, the results of this study have provided valuable information about the metal concentrations in *P. reticulata* from different sampling sites of drainage from Malaysia. The present data based on the heavy metal concentrations in the fish had identified the potential sources of anthropogenic metals into the sampling sites by using *P. reticulata* as a biomonitoring agent. Based on the present results, which showed *P. reticulata* is readily accumulating Cd, Cu, Ni, Pb and Zn which to a certain extent is correlated positively with the sediment data, the small and easily sampled guppy fish is therefore a potential biomonitor of heavy metal contamination and bioavailability in the lake and drainage ecosystems. However, further experimental works are needed to test its suitability as a biomonitor of heavy metal pollution.

ACKNOWLEDGMENT

This research was partly supported by Research University Grant Scheme (RUGS) 2007, University Putra Malaysia, Vot: 91229.

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