Bull. Environ. Contam. Toxicol. (2005) 74:1065–1071

DOI: 10.1007/s00128-005-0689-9

Bulletin of Environmental Contamination and Toxicology

Concentrations of Heavy Metals in the Benthic Microgastropods *Sermyla riqueti* and *Stenothyra devalis* at the Mai Po Inner Deep Bay Ramsar Site of Hong Kong

M. Y. Lai,[1] P. P. Shen,[1] Z. Zhao,[1] H. Zhou,[2] J.-D. Gu[1,3]

[1] Laboratory of Environmental Toxicology, Department of Ecology and Biodiversity, The University of Hong Kong, Pokfulam Road, Hong Kong SAR, People's Republic of China
[2] School of Marine Life Science, Ocean University of China, Qingdao, People's Republic of China
[3] The Swire Institute of Marine Science, The University of Hong Kong, Shek O, Cape d'Aguilar, Hong Kong SAR, People's Republic of China

Received: 28 May 2003/Accepted: 24 February 2005

Mai Po Inner Deep Bay Ramsar site (22°29' to 22°31'N and 113°59' to 114°03'E), which is situated at the border between the north-western part of the New Territories of Hong Kong and the south-eastern part of the Shenzhen Special Economic Zone of the People's Republic of China, is the largest intertidal wetland ecosystem in Hong Kong. Each year, more than 900 native species of mammals, birds, reptiles, amphibians, fishes, invertebrates and plants have been documented to be living in this area (Tsim and Lock, 2002). Migratory birds also use this area as refuelling station along the Siberia-Australian journey. However, the recent urbanization and industrial developments in the city of Shenzhen near Hong Kong discharged significant quantities of heavy metals, now posing an increasing threat to the floral and faunal communities in this area (Yu et al., 2000; Laboratory of Environmental Toxicology, 2003). Although the concentrations of heavy metals in barnacles (Rainbow and Smith, 1992), bivalves (Fang et al., 2003), shrimps (Ong Che and Cheung, 1998), fishes (Zhou et al., 1998) and plants (Ong Che, 1999) of the Mai Po Inner Deep Bay areas were reported previously, information on the much smaller benthic infaunal community is still lacking. Due to the close association of the benthic infaunal community with sediment and possibly sensitive response to the environmental changes, heavy metal concentrations in benthic infauna can often be used as an important indicator for the extent of heavy metal contamination in a particular environment and also be used to predict the potential risk of heavy metals to organisms at the higher trophic levels of the food chains as the benthic infauna often serve as an important food source for birds, fishes and crabs, etc. (McChesney, 1997; Cha, 1999).

The objectives of this research were to measure the concentrations of zinc (Zn), copper (Cu), lead (Pb) and chromium (Cr) in the bodies of two most abundant microgastropod species, *Sermyla riqueti* and *Stenothyra devalis* from sediment and thus to provide indication on the potential environmental health of heavy metals in the higher trophic levels, particularly in birds in the Mai Po Inner Deep Bay Ramsar site.

Correspondence to: J.-D. Gu

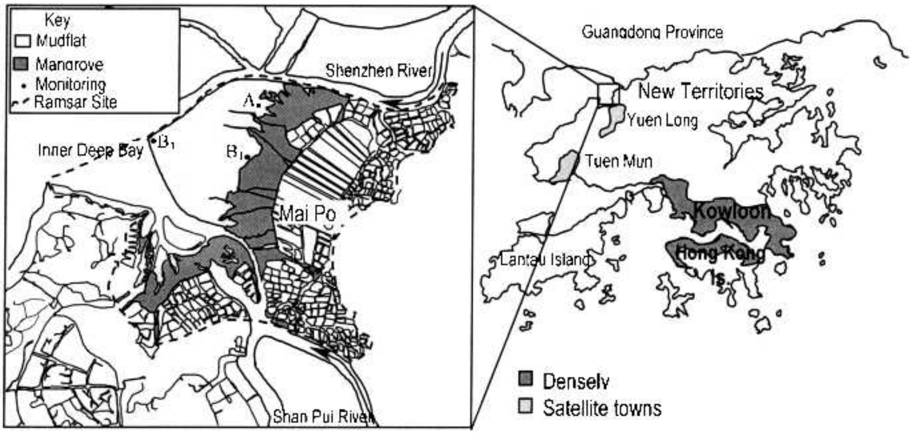

Figure 1. Sampling locations at Mai Po Nature Reserve of Hong Kong Special Administrative Region of the People's Republic of China

MATERIALS AND METHODS

Sediment samples were collected from three ecological monitoring sites (i.e. Sites A, B1 and B3) (Fig. 1) defined by the Agriculture, Fisheries and Conservation Department (AFCD) in Hong Kong on the Mai Po Inner Deep Bay mudflat from November 2001 to May 2003 (Laboratory of Environmental Toxicology 2003). At each of the sampling sites, 15 sediment cores (20 cm in diameter and 15 cm in depth) were taken using an Acrylic tubes sampler at low tide. The samples were then immediately kept in individual Ziploc® plastic bag and placed in an ice-box at 4°C before transferring back to the laboratory for organism extraction and heavy metals analysis.

In the laboratory, the sediment samples were then washed through a 0.5 mm sieve for extraction of the organisms. The two most abundant microgastropod species, *Sermyla riqueti* and *Stenothyra devalis* retained on the sieve were collected, identified, enumerated, dried at 70-80°C, and pulverized with a mortar and pestle. In order to prevent any decomposition and predation of the benthic infauna within the samples, all sediment samples were stored at 4°C until the processing of organism extraction and the whole process were completed within 1-3 days from sampling (Laboratory of Environmental Toxicology 2003).

About 0.1-0.5 g of the dried microgastropod samples (*Sermyla riqueti* or *Stenothyra devalis*), obtained in total from the 15 sediment cores of each sampling, were weighed, respectively for acid digestion. Depending on the amount of the microgastropod samples used, they were pre-digested with 3 or 4 ml of 69% nitric acid (HNO_3) at room temperature overnight, and then were fully digested at 150°C on Block Thermostats (OBT4, Grant). A glass marble was put on the top of each test tube in order to minimize the evaporation of HNO_3 (Kwan 1999). After the acid digestion, the digested solution was then filtered through filter paper (Advantec No. 1, MFS Inc., Japan) and the filtrate was collected and diluted to the final volume of 5 ml with 2% HNO_3 and stored in an acid-rinsed polyethylene bottle at 4°C prior to the heavy metals analysis (i.e. Zn, Cu, Pb and Cr) on the Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES, 3100XL, Perkin Elmer Optima). The values of metal concentration determined by the ICP-AES below the detection limits were considered zero for calculations (Fontes and Gomes 2003).

In order to account for potential contaminations and random errors during the whole process of acid digestion, a procedural blank was employed for background correction. Standard reference material, DORM-2 (Dogfish Muscle, National Research Council of Canada) was also used to verify the accuracy of the acid digestion procedure. The percentages of metal recovery from the standard reference material were 90.27±2.14%, 115.39±0.31% and 64.19±1.11% for Zn, Cu and Cr, respectively. All glasswares and polyethylene bottles involved were pre-soaked in 10% HCl (v/v) for at least 24 hours and rinsed with ultra-pure water several times before used, and the HNO_3 used during the acid digestion process was analytical reagent grade or better. All metals concentrations in microgastropods were expressed as μg/g dry weight.

RESULTS AND DISCUSSION

Sediments were sampled quarterly and infauna were extracted, enumerated and identified since November 2001. A total of 48 morphospecies belonging to 7 phyla was recorded including Annelida, Mollusca, Arthropoda, Sarcomastigophora, Nematoda, Nemertea and Chordata (Laboratory of Environmental Toxicology, 2003). Abundance of animals ranged between 1,771 individuals·m^{-2} at B2 in November 2001 and 50,189 individuals·m^{-2} at C (a site where pig manure discharge was recoded) in August 2002; biomass fluctuated from 18.96 g wet wt·m^{-2} at B2 to 280.1 g wet wt·m^{-2} at C both in February 2002. The grand total mean abundance and biomass of the mudflat infauna was estimated to be 15,647 individuals·m^{-2} and 51.76 g wet wt·m^{-2}, respectively. The Mai Po mudflat infauna community is characteristically dominated by low species richness and high dominance of a few small and opportunistic species including *Sermyla riqueti* and *Stenothyra devalis*.

In Figs 2 and 3, the mean concentrations of Zn, Cu, Pb and Cr in the bodies of the two most abundant microgastropod species, *Sermyla riqueti* and *Stenothyra devalis* in the Mai Po Inner Deep Bay mudflat at different sampling times are

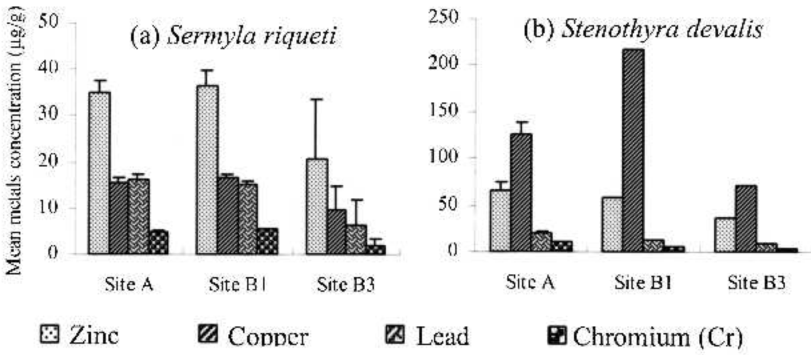

Figure 2. Mean concentrations of Zn, Cu, Pb and Cr in the bodies of *Sermyla riqueti* and *Stenothyra devalis* in winter 2001. The vertical bar denotes the standard error (SE) of replicates

shown. Similar heavy metal concentration patterns were observed in all sampling sites (i.e. Sites A, B1 and B3) and seasons (i.e. winter and summer) for each species, but there were clear differences between the two microgastropod species, with the mean metal concentrations decreased in the order of 31.64±14.04 μg/g Zn > 14.24±5.11 μg/g Cu ~ 13.79±7.54 μg/g Pb > 3.06±3.06 μg/g Cr in *S. riqueti* and 123.74±42.32 μg/g Cu >> 50.74±15.52 μg/g Zn > 16.55±4.01 μg/g Pb > 6.79±2.74 μg/g Cr in *S. devalis*, respectively. *S. devalis* apparently showed higher concentration of Cu than *S. riqueti*, and the difference was almost 10 times. Concentration of other metals, e.g., Zn, Pb and Cr, in the former tended to be lower than the latter. Comparable findings also showed accumulation in the hepatopancreas of three gastropod species, *Cerithium vulgatum*, *Monodonta articulate* and *Murex trunculus* in Greece (Nott and Nicolaidou 1989). The major difference of the concentration patterns of heavy metals in both of the microgastropod species in this study may be mainly due to the differences in their specific physiological responses to heavy metals and biochemical mechanism responsible for bioaccumulation or detoxification inside their bodies (Rainbow 1997; Fang et al. 2003).

Previously studies showed that the concentration of heavy metals in various living organisms, especially benthic infauna are not best correlated to the total concentrations of heavy metals in the environment, but the concentrations of heavy metals in particular geochemical fractions of sediments. This phenomenon could be explained on the basis of the bioavailability of heavy metals in each of the geochemical fractions (Zhou et al. 1998). High percentages of heavy metals in the geochemically available fractions (>56%) in the mudflat sediment of the Mai Po Inner Deep Bay may be one of the most important contributing factor accounting for the heavy metal concentrations in the bodies of both microgastropod species in this study (Lai 2004). However, the Cu concentration

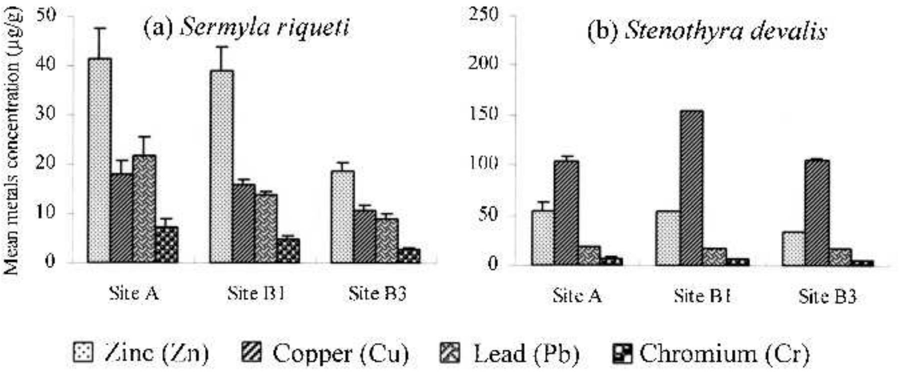

Figure 3. Mean concentrations of Zn, Cu, Pb and Cr in the bodies of *Sermyla riqueti* and *Stenothyra devalis* in summer 2002. The vertical bar denotes the standard error (SE) of replicates

in *S. devalis* was particular high and was above the total concentration in the environment showing clearly that bioaccumulation has taken place (Table 1). Similar correlation was also detected in different floral and faunal communities previously (Zhou et al. 1998).

Table 1. Total concentrations of heavy metals in sediment at Mai Po Inner Deep Bay and Ramsar Site and the benthic infauna *Sermyla riqueti* and *Stenothyra devalis*

	Zn (µg/g)	Cu (µg/g)	Cr (µg/g)	Pb (µg/g)
Site A	238.4	93.72	88.53	70.24
Site B1	215.2	86.29	86.29	69.19
Site B3	221.9	84.93	76.67	67.75
Sermyla riqueti	31.64	14.24	3.06	13.79
Stenothyra devalis	50.74	123.74	6.79	16.55

When the total concentration of metals in sediment and those in the benthic infauna was compared, only a fraction of the total metals was found in the infauna biomass on average from different locations except for Cu in *S. devalis* (Table 1). On the other hand, Cr was excluded from the organisms more when compared with Pb. The very high concentration of Cu in one organism, but not *S. riqueti*, is a strong indication that selective accumulation through resistance or detoxification is feasible in *S. devalis*. In addition, Cu may also have special biochemical role in this organisms. Cu concentration in *Crassostrea rivularis* was between 749 and 756µg/g from this area (Fang et al., 2003).

Seasonal variation of concentrations of Zn, Cu, Pb and Cr in both microgastropod species at all sampling sites were also observed in this study. The highest heavy metal bioaccumulation was found in summer for *S. riqueti* and in winter for *S. devalis*, respectively (Fig. 1 and 2). Variations of the environmental factors in sediments (e.g., temperature, salinity and pH, etc.) and/or the metabolic factors in living organisms (e.g., growth and recruitment) with seasons are the two major factors controlling the seasonal variation of heavy metal bioaccumulation in both microgastropods. The higher acidity and anoxia in sediment of summer together with the recruitment and the increment of the feeding rate of *S. riqueti* in summer (McChesney 1997) may be responsible for the rapid biological uptake of heavy metals from sediment and resulted in the highest bioaccumulation in the bodies of this species in summer of this study. On the other hand, the seasonal fluctuation of the metabolic activity of *S. devalis* may be suggested to be the major factor elucidating the seasonal variation of heavy metal bioaccumulation in this species. Further investigation of the biology of *S. devalis* (e.g., life cycle) is necessary in the future to elucidate the mechanism of Cu accumulation.

In summary, the benthic infaunal community in the Mai Po Inner Deep Bay mudflat was dominated by a few pollution tolerant species, among them *Sermyla riqueti* and *Stenothyra devalis* accounted for the largest percentage of organism abundance and biomass. Significantly high Cu accumulation in the microgastropod species *S. devalis* had been observed in this study. Such information may implicate the ecological impact of the Mai Po Inner Deep Bay Ramsar site from long-term exposure. As a consequence, the ecological health of the indigenous and migratory birds may be affected if the ecological condition is not significantly improved.

Acknowledgments We thank AFCD of Hong Kong SAR Government for partial financial support and assistance in field sampling. We would also like to thank the technical support of Jessie Lai.

REFERENCES

Cha M W (1999) A survey of mudflat gastropods in Deep Bay, Hong Kong. In: Lee SY (ed) The Mangrove Ecosystem of Deep Bay and the Mai Po Marshes, Hong Kong. Proceedings of the International Workshop on the Mangrove Ecosystem of Deep Bay and the Mai Po Marshes, Hong Kong, 3–20 September 1993. Hong Kong University Press, Hong Kong, p 33–43

Fang ZQ, Cheung RYH, Wong MH (2003) Heavy metals in oysters, mussels and clams collected from coastal sites along the Pearl River Delta, South China. J Environ Sci China 15:9–24

Fontes MPF, Gomes PC (2003) Simultaneous competitive adsorption of heavy metals by the mineral matrix of tropical soils. Appl Geochem 18:795–804

Kwan SP (1999) Heavy metals in Hong Kong Rabbitfish (*Siganus canaliculatus*). MPhil Thesis. The University of Hong Kong

Laboratory of Environmental Toxicology (2003) Tender Reference No. AFD/SQ/28/01 Baseline Ecological Monitoring Programme for the Mai Po and Inner Deep Bay Ramsar Site (October 2001 – September 2002): Final Report. The University of Hong Kong, Hong Kong

Lai MY (2004) Fractionation, mobilization and bioaccumulation of heavy metals and mineralogical characteristics of the Mai Po Inner Deep Bay mudflat. MPhil Thesis. The University of Hong Kong

McChesney S (1997) The benthic invertebrate community of the intertidal mudflat at the Mai Po Marshes Reserve, with special reference to resources for migrant shorebirds. MPhil Thesis. The University of Hong Kong

Nott JA, Nicolaidou A (1989) The cytology of heavy metal accumulations in the digestive glands of three marine gastropods. Proc Royal Society B 237:347–362

Ong Che R G (1999) Concentration of 7 heavy metals in sediments and mangrove root samples from Mai Po, Hong Kong. Mar Pollut Bull 39:269–279

Ong Che R G, Cheung SG (1998) Heavy metals in *Metapenaeus ensis*, *Wriocheir sinensis* and sediment from the Mai Po marshes, Hong Kong. Sci Total Environ 214:87–97

Rainbow PS, Smith BD (1992) Biomonitoring of Hong Kong coastal trace metals by barnacles, 1986-1989. In: Morton B (ed) The Marine Flora and Fauna of Hong Kong and Southern China III. Proceedings of the Fourth International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, Hong Kong, 11–29 April 1989. Hong Kong University Press, Hong Kong, p 585–597

Tsim ST, Lock FNY (2002) Knowing Ramsar Wetland. Stokes E (ed). Friends of the Country Parks, Hong Kong

Yu KY, Lam MHW, Yen YF, Leung APK (2000) Behavior of trace metals in the sediment pore water of intertidal mudflats of a tropical wetland. Environ Toxicol Chem 19:533–542

Zhou HY, Cheung RYH, Chan KM, Wong MH (1998) Metal concentrations in sediments and *Tilapia* collected from inland waters of Hong Kong. Wat Res 32:3331–3340