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# Heavy Metal Concentrations in an Important Mangrove Species, *Sonneratia caseolaris*, in Peninsular Malaysia

Mohd Fazlin Nazli and Nor Rasidah Hashim

*Department of Environmental Sciences, Faculty of Environmental Studies, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia*

**Abstract**

Mangrove forests in Peninsular Malaysia are increasingly threatened by heavy metal pollution. Due to their unique location, mangroves receive heavy metal pollution from upstream areas and the sea. However, little is known about the capacity of mangrove plants to take up and store heavy metals. In this study, the concentrations of cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb) and zinc (Zn) in an important mangrove species, *Sonneratia caseolaris*, were measured. It was found that the total concentrations of Cd, Cr, Cu, Pb, and Zn in the sediments were below the general critical soil concentrations. However, the total concentrations of Cu and Pb in both the roots and leaves of *Sonneratia caseolaris* exceeded the general normal upper range in plants. This study has therefore shown the potential of *Sonneratia caseolaris* as a phytoremediation species for selected heavy metals in Malaysian mangrove ecosystem.

***Keywords:*** heavy metal pollutions; *Sonneratia caseolaris*; mangrove sediments

## 1. Introduction

Malaysian mangrove forests, with an estimated total acreage of 5650 km$^2$, form about four percent of the worldÕs mangrove area (FAO, 2007). Mangrove forests play a major role as a primary producer in the estuarine ecosystems (MacFarlane *et al.,* 2007), and are an important habitat for a wide variety of species such as birds, insects, mammals and reptiles (Nagelkerken *et al.,* 2008).

The loss of mangroves has been significant in recent decades, although in some places mangroves are still extensive (Spalding, 1998). Meanwhile, existing mangroves suffer from direct impacts of environmental pollutants such as heavy metals that are associated with anthropogenic activities (Cuong *et al.,* 2005). Manufacturing industries, agro-based industries and urbanization are the major sources of heavy metal inputs in mangrove ecosystems (DOE, 1999). The addition of fertilizers and pesticides in agricultural activities has become a common practice in Malaysia, as elsewhere in the tropics (Hashim and Hughes, 2009). The insufficient purification of fertilizers usually contains several impurities and among them are heavy metals (Zarcinas *et al.,* 2003).

Heavy metals are not biodegradable and persistent in the environment (MacFarlene and Burchett, 2001). However, plants show several response patterns in heavy metals uptake (Kabata-Pendias and Pendias, 1997). Most are sensitive even to very low concentrations, others have developed resistance and a small number behave as hyperaccumulators of toxic metals (Chapin, 1983; Mingorance *et al.,* 2007). In Peninsular Malaysia, there are several studies on heavy metal contaminations in mangrove sediments and organisms but little is known about heavy metals uptake by mangrove plants (Seng *et al.,* 1987; Ismail *et al.,* 1993; Ismail and Asmah, 1999).

Therefore it is important to study the capacity of mangrove plants to take up heavy metals to find out the suitable candidate for phytoremediation species as well as for the conservation of mangrove ecosystems. For these reasons, the objective of this study was to analyze the uptake of selected heavy metals (cadmium, chromium, copper, lead and zinc) by an important mangrove species, *Sonneratia caseolaris*, in Peninsular Malaysia.

## 2. Materials and Methods

### *2.1. Study site*

Mangrove forest for this study is located in Rembau-Linggi Estuary, Negeri Sembilan (2.6˚N; 102.0˚E) which is forming by two major rivers; (1) Rembau River and (2) Linggi River. Land use within three kilometres radius around this mangrove forest was numerous such as oil palm plantations, rubber and human settlements, some of which provide the main sources of heavy metals into the rivers and mangroves. Boat activities were carried out daily by fishermen for fishing and ecotourism purposes.

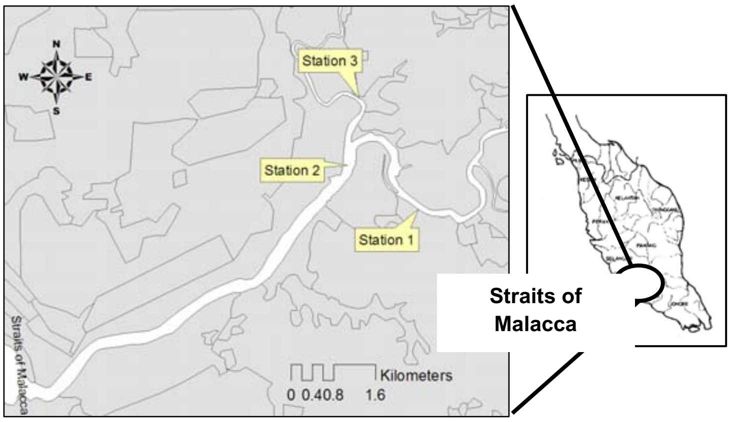


Figure 1. Location of sampling stations. Station 1=Rembau River, Station 2=river confluence and Station 3=Linggi River.

*2.2. Study species*

*Sonneratia caseolaris* Engl. is a mangrove species belonging to family Sonneratiaceae (Keng, 1969). It is found near the banks of tidal rivers in brackish water and provide essential congregating place for fireflies (Wan Jusoh and Hashim, 2009). The fermented juices of this mangrove species is said to be useful in arresting haemorrhage whereas the half-ripe fruit can be used to treat coughs (Perry, 1980).

*2.3. Sampling techniques*

The plants and mangrove sediments samples were collected from three sampling stations which were: (1) Rembau River, (2) river confluence and (3) Linggi River (Fig. 1). For each sampling station, three samples replicate were taken ($n=3$).

For the sediment samples, a depth of 10 cm was dug from the surface of the sediments to collect the samples using wet soil auger. After the samples were collected, they were immediately placed in sealed plastic bags and labelled.

For plant parts, roots and leaves were collected at the same sites where the sediment samples were taken. The roots were carefully hand picked from the sediments while the leaves were collected using a pair of scissors. The samples were immediately wrapped with an aluminium foil and labelled. All the samples were kept in a cooler box with ice at 4˚C for storage following Prica (2007) during transporting back to the laboratory at the Department of Environmental Sciences, Universiti Putra Malaysia.

*2.4. Sediment analysis*

The samples were dried in an oven for three days at 80˚C to a constant dry weight. Then, the samples were crushed to powder using mortar and pestle and sifted through 63µm stainless steel aperture. After being shaken vigorously the samples were stored in acid wash plastic bags.

The digestion of samples was done using direct Aqua Regia digestion method. One gram of the samples was weighed and placed in the digestion tubes. Ten millilitres of double mix acid solution (Nitric acid 69% and perchloric acid 60% in ratio 1:4) were added to each digestion tubes. Then, the digestion tubes were placed in the digesting block with scrubber for one hour at 40˚C and then the temperature was levelled up to 140˚C for three hours. The digestion was completed after the last solution was clear and no brownish fumes were released from the digestion tubes. When the sample had cooled, it was diluted to 40 millilitres with distilled water and filtered through Whatman No.1 filter paper into the beakers. The determinations of heavy metals were done using Flame Atomic Absorption Spectrophotometer (FAAS).

*2.5. Roots and leaves analysis*

The roots and leaves of *Sonneratia caseolaris* were placed in an aluminium foil and dried in an oven at 80˚C for one day to prepare the samples. Dry Ashing method was used to analyze the heavy metal samples. For this, the root and leaf samples were put in the muffle furnace with the temperature of 550˚C for six hours. After the samples had cooled, 0.1 gram of ashed tissue was dissolved in a ten millilitres dilute nitric acid-hydrochloric acid digestion (100 millilitres $HNO_3$ and 300 millilitres HCL acid in one litre pure water) in 50 millilitres beaker. Finally, the samples were filtered using Whatman No.1 filter paper to remove the suspended solids before analyze the samples. The determinations of heavy metals were done using Flame Atomic Absorption Spectrophotometer (FAAS).

Table 1. Total concentrations of heavy metals (µg/g) in mangrove sediments of Peninsular Malaysia (this study) relative to other countries. General critical soil concentrations follow Alloway (1990).

| | Cd | Cr | Cu | Pb | Zn | References |
|---|---|---|---|---|---|---|
| Peninsular Malaysia (This study) | 0.8±0.5 | 6.0±0.6 | 31.9±2.0 | 83.1±3.1 | 4.3±0.1 | This study |
| Singapore (Buloh River) 2005 | 0.181±0.189 | 16.61±7.23 | 7.06±6.03 | 12.28±5.18 | 51.24±39.97 | Cuong *et al.,* |
| Singapore (Khatib Bongsu River) | 0.266±0.171 | 32.07±7.67 | 32.00±14.32 | 30.98±6.16 | 120.23±13.90 | Cuong *et al.,* 2005 |
| Australia (Brisbane River) | <0.1-1.9 | 13.3-54.3 | 3.1-30.2 | 20.1-81.9 | 40.8-144.0 | Mackey *et al.,* 1992 |
| Hong Kong (Mai Po) | 0.5-0.6 | 7.8-17.4 | 41.9-49.8 | 161.6-219.8 | 277.2-321.2 | Ong Chee, 1999 |
| General critical soil concentrations | 8 | 100 | 125 | 400 | 400 | Alloway, 1990 |

### *2.6. Statistical analysis*

The data was analyzed using ANOVA to detect if any significant differences in means of each heavy metal exist between mangrove sediments, roots and leaves. Post hoc test LSD was used to elucidate further the differences between two variables (sediment, roots and leaves). Significance value was set at 5%.

## 3. Results and Discussion

### *3.1. Heavy metals in mangrove sediments*

It was found that the total concentration of Pb (83.1 µg/g) was higher in the sediments followed by Cu (31.9 µg/g), Cd (0.8µg/g), Cr (6.0 µg/g) and Zn (4.3 µg/g) (Table 1). However, when compared to the general critical soil concentrations, the total concentrations for all selected heavy metals in the sediments were below the general critical soil concentration values (sensu Alloway, 1990).

Meanwhile, the comparison of the total concentrations of the selected heavy metals in the sediments with those from other countries showed that the concentration of Cd in this study was higher than those measured in Singapore (Buloh River and Khatib Bongsu River), Australia (Brisbane River) and Hong Kong (Mai Po) (Cuong *et al.,* 2005; Mackey *et al.,* 1992; Ong Chee, 1999). The concentration of Pb in this studyÕs mangrove sediments was relatively higher than those measured in Singapore and Australia while concentrations of Cr and Zn were lower compared to these countries. Moreover, the concentration of Cu was comparable to the one reported in Singapore (Khatib Bongsu River).

#### *3.1.1. Sources of heavy metals in mangrove sediments*

The location of the mangrove and the land use types in the surrounding area are important factors that influenced the variation of heavy metals concentrations in mangrove sediments with other countries. Due to its location, which is near to the estuary, the mangrove forest in our study received the heavy metals contaminations from the Straits of Malacca. According to the Department of Environment (DOE, 1998), mangrove swamp conversion, land reclamation and sea-based inputs (shipping, dumping, mining, oil exploration and fishing) were the human activities that contributed to adverse environmental changes in the west coast of Peninsular Malaysia and the Straits of Malacca.

Land use around the mangrove forest such as oil palm and rubber plantations, and human settlements were also major sources of heavy metals. However, the availability of heavy metals in mangrove sediments to plants is influenced by the sediment characteristics such as pH, cation exchange, redox condition and chlorine contents (Du Laing *et al.,* 2002). Therefore, further study is needed to investigate these characteristics in order to understand the mobility, bioavailability and toxicity of the heavy metals in mangrove sediments.

### *3.2. Heavy metals in the leaves of Sonneratia caseolaris*

It was found that the total concentration of Pb (35.5 µg/g) was higher in the leaves of *Sonneratia caseolaris* followed by Cu (26.8 µg/g), Cr (9.5 µg/g), Zn (5.9 µg/g) and Cd (1.0 µg/g) (Fig. 2). The total concentrations of selected heavy metals in the leaves

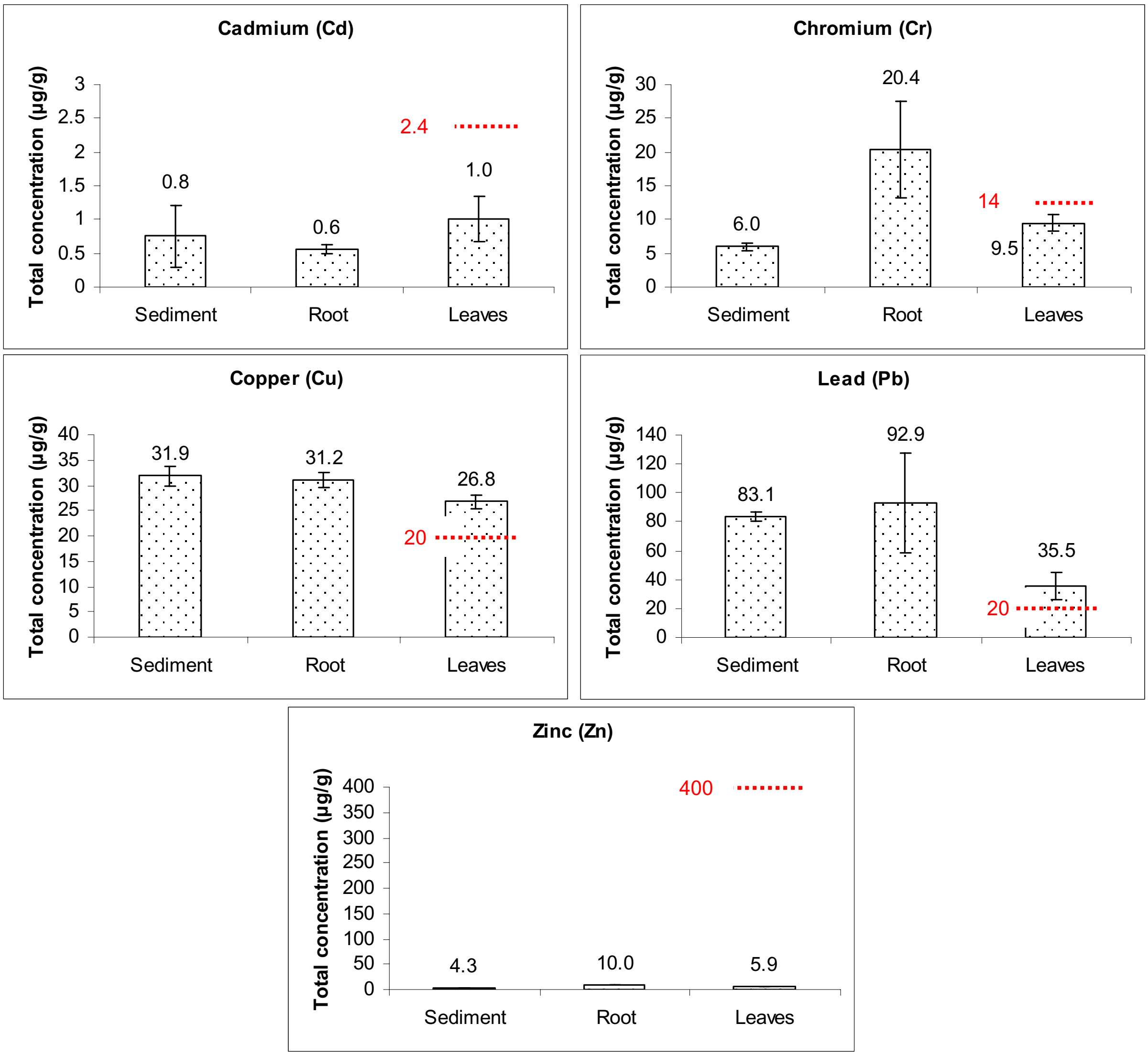


Figure 2. The total concentrations of cadmium ($p=0.756$), chromium ($p=0.011$), copper ($p=0.001$), lead ($p=0.005$) and zinc ($p=0$) in the mangrove sediments, roots and leaves of *Sonneratia caseolaris* were compared ($n=6$). The red dashed-line showed the general normal upper range in plant (Alloway, 1990).

of *Sonneratia caseolaris* were compared to the general heavy metal concentration for plant. The general heavy metal concentration for plant was based on the heavy metals concentrations measured in the mature leaves tissue of various plant species (sensu Alloway, 1990). The comparison showed that the total concentrations of Cu and Pb in the leaves of *Sonneratia caseolaris* exceeded the general normal upper range in plant (Fig. 2).

### *3.3. The comparison of heavy metals in mangrove sediments, roots and leaves*

The results showed that the total concentrations of Cr, Pb and Zn in the roots of *Sonneratia caseolaris* were higher than in the mangrove sediments (Fig. 2). The post hoc LSD also showed significant difference of the heavy metals (Cr, Pb and Zn) concentrations between mangrove sediments and the roots of *Sonneratia caseolaris* (Cr, $p=0.011$; Pb, $p=0.005$; Zn, $p=0.00$).

Our results also revealed that the total concentrations of Cd, Cr and Zn in the leaves of *Sonneratia caseolaris* were higher than in the sediments. However, the post hoc LSD showed only Zn ($p=0.00$) has significant difference between *Sonneratia caseolaris's* leaves and the sediments. The total concentration of Cd ($p=0.756$) which was also higher than in the roots of *Sonneratia caseolaris* showed no significant difference. For the comparison of the heavy metals concentrations between the roots and leaves of *Sonneratia caseolaris*, all the heavy metals except for Cd were higher in the roots. The post hoc LSD showed significantly high concentrations of Pb ($p=0.005$) and Zn ($p=0.00$) in the roots of *Sonneratia caseolaris*.

### *3.4. The potential of Sonneratia caseolaris as a phytoremediation species*

The high concentrations of certain heavy metals (Cr, Pb and Zn) in *Sonneratia caseolaris's* roots showed its high capacity to take up and accumulate the heavy metals from the sediments. In addition to the heavy metals accumulations via roots, plants can also derive significant amounts of certain heavy metals through foliar absorption especially in polluted industrial area (Chua and Hashim, 2008). However, this study's mangrove forest is located far from any industrial area that could be the atmospheric source of heavy metals. Therefore the heavy metal inputs into the mangrove forest of this study were via surface runoffs and domestic effluents from the surrounding land use such as oil palm and rubber plantations, and human settlement.

It was found that the total concentrations of Cr and Zn in the leaves were higher than in the sediments but lower than in the roots. This finding supported the suggestion that mangrove roots may act as a barrier for heavy metals translocation to the leaves of many mangrove plants (Tam and Wong, 1997). Nonetheless it might indicate that the leaves of *Sonneratia caseolaris* are able to take up and store certain heavy metals. Moreover, the sampled *Sonneratia caseolaris's* leaves did not show any sign of injury when Cu and Pb concentrations exceeded the general normal upper range in plant. This suggests that *Sonneratia caseolaris's* leaves were tolerant to the heavy metals by imparting minimal physiological effects to the leaves (De Lacerda *et al.,* 1993).

## 4. Conclusions

This study has showed that *Sonneratia caseolaris* possess the capacity to take up selected heavy metals via its roots and storing certain heavy metals in its leaves without any sign of injury. This suggests the potential of *Sonneratia caseolaris* as a phytoremediation species for Peninsular Malaysian mangrove ecosystem. As such, further study is recommended to ascertain the true potential of *Sonneratia caseolaris* as a phytoremediation species.

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**Correspondence to**
Dr. Nor Rasidah Hashim
Department of Environmental Sciences
Faculty of Environmental Studies
Universiti Putra Malaysia
43400 UPM Serdang, Selangor,
Malaysia.
Tel: (603)8946 7462
Fax: (603)8946 7463
E-mail: rasidah@env.upm.edu.my