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Heavy Metals Dyanamics and Source In Intertidal Mangrove Sediment of Sabah, Borneo Island

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Abstract

There is increasing concern about the impact of anthropogenic activities in many tropical coastal areas such as in mangrove forest. Heavy metal cycling is a serious problem faced in mangrove environments due to the anthropogenic activities. This study was carried out to investigate the dynamics of heavy metals dynamics concentration. The results revealed relatively higher concentrations of heavy metals at high tide compared to low tide due. This observation is complex by other factors such as redox condition, presence of hydroxides and oxyhydroxides. The major source of heavy metals in mangrove surface sediment is anthropogenic such as from agricultural, aquaculture and industrial activities. This finding has updated knowledge about intertidal role on heavy metal dynamics in tropical mangrove sediment. The results also influence the concern of using mangrove ecosystems to be an alternate low cost wastewater treatment system.

Keywords: mangrove surface sediment; heavy metals; intertidal

1. Introduction

Tidal current activity is mainly confined to mangrove channels. Outside the channels, mainly on the upper tidal-flats, tidal current velocities decrease and sediment entrainment is frequently ascribed to wave action. The role of tidal processes on intertidal surface sediments is frequently stated but the differences at these stages have seldom been investigated, apparently because of methodological constraints (Radojevic *et al.,* 2008; Malvarez *et al.,* 2001). The methodological constraints include determination of tidally influenced areas, data requirements to determine tidal range at coastal sites, definition of problems and development of conceptual models (Malvarez *et al*., 2001).

Heavy metals cycling are a serious problem in mangrove environment due to toxicity and bioaccumulation as shown by many studies on mangrove environment (Shriadah, 1999, Tam and Wong, 1995). High concentrations of heavy metals are derived from anthropogenic inputs such as industrial activities, discarded automobiles, batteries and waste water discharge (Marchand *et al.,* 2006; Pekey, 2006; Shriadah, 1999; Bloom and Ayling, 1977). A study done by Defew *et al.* (2005) found that intense anthropogenic activities are potentially harmful to the remaining mangrove forest in Punta Mala Bay, Panama. Mangrove ecosystems in the intertidal zone may act as a sink or source of heavy metals in coastal environments because of their variable physical and chemical properties (Pekey, 2006).

Previous studies have suggested that mangroves are long-term sinks for most heavy metals (Praveena *et al.,* 2008a; Tam and Wong, 1995). However, there is little knowledge about the role of intertidal flows on heavy metal dynamics in tropical mangrove sediment. Geochemical studies of sediments from Malaysian mangrove forests have received little attention and only limited studies have been done regarding detailed investigation of heavy metals sources in mangrove sediment (Kamaruzzaman *et al.,* 2008). In view of the importances of mangrove to various aspects of the environment, heavy metals dynamics and investigation of heavy metals sources was carried out in the Mengkabong mangrove forest, Sabah, Malaysia. The findings will assist to evaluate mangrove ecosystem to be used as an alternate low-cost wastewater treatment system.

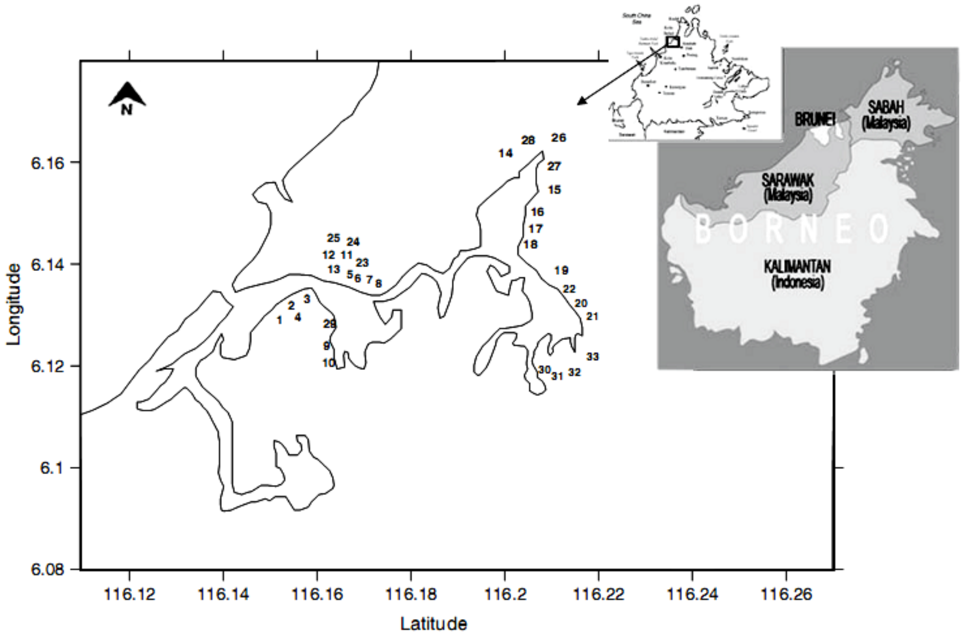

Figure 1. Sampling locations of Mengkabong and mangrove surface sediment sampling sites

2. Materials and Methods

This study was conducted in the Mengkabong mangrove forest, Sabah which is 40 km away from Kota Kinabalu. The total of study area spreads from latitude 06°060 N to 06° 110 N and longitude 116° 080 E to 116° 130 E (Fig. 1). This southern spur of the Mengkabong mangrove forest ends in Salut Bay which is entirely surrounded by an industrial zone i.e Kota Kinabalu Industrial Park (KKIP) and has been signicantly degraded (Environmental Impact Assessment 1992; Town and Regional Planning Department of Sabah 2003). Mangrove surface sediments were sampled randomly and taken in triplicates with an auger at 33 stations from March 200 to November 2006 (Fig. 1) at low and high tides. The sampling was done based on the accessibility to the mangrove forest. Mangrove surface sediments were chosen for this study as this layer controls the exchange of metal between sediments and water (El Nemr *et al.,* 2006). The detailed procedures of heavy metals are found in Praveena *et al.* (2008b).

3. Results and Discussion

3.1. Heavy metals dynamics by tidal effect

The descriptive values of heavy metals at high and low tides are presented in Table 1. All the heavy metals displayed relatively higher concentration at high tide compared to low tide. It shows that tides control the water-flows that carry the sediments in the mangrove forest. This simple explanation of conditions at high and low tides is vastly complicated by the presence of hydroxides and oxyhydroxide coating on the particles.

Table 1. Descriptive basic statistics of heavy metals at high and low tides (*n=33*)

Parameter		Min	Max	Mean	SD
Al	High Tide	4.4E3	3.5E4	1.5E4	8.1E3
	Low Tide	2.4E3	2.4E4	9.5E4	6.0E3
Cu	High Tide	4.1E1	4.9E1	2.8E1	1.4E1
	Low Tide	2.1E1	4.4E1	1.9E1	1.3E1
Fe	High Tide	3.4E3	1.4E4	7.7E3	2.7E3
	Low Tide	1.4E3	1.8E4	6.8E3	4.0E3
Pb	High Tide	2.4E1	6.9E1	5.2E1	1.1E1
	Low Tide	3.4E1	4.7E1	4.1E1	2.9E1
Zn	High Tide	2.4E1	9.3E1	5.7E1	1.7E1
	Low Tide	1.1E1	7.3E1	4.1E1	1.6E1

The elevated concentration of metals during high tide compared to low tide is due to redox conditions in sediment columns (Akpan *et al.,* 2002). According to Marchand *et al*. (2004) estuarine sediments are usually in reduced condition and have pore water with high concentration of metals. Alloway (1995) explained that heavy metals in interstitial water are the mobile fraction. De Lacerda (2004) illustrated the mobile fraction of heavy metals tends to migrate in the sediment through interstitial water until it comes in contact with oxygen. Thus precipitation of hydrous metal oxides will occur. The precipitates of these heavy metals are no longer soluble and therefore incorporated into sediments at high tide, resulting in high concentrations of these metals at high tide (Grande *et al*., 2003). These findings are similar with the studies done by Marchand *et al*. (2004) and Akpan *et al*. (2002), where high concentration of metals were observed during high tide. Marchand *et al*. (2004) explained that co-precipitation with oxy-hydroxides at upper oxic layer of surface sediment may explain why many metals were at a maximum in the solid phase.

At low tide, the low oxygen condition of insoluble hydrous oxides of heavy metals is then reduced to more soluble forms At the same time, sulfate present will be reduced to sulfide. The reduced precipitated metal hydrous oxides will be released to the water column or sediment interstitial waters as metal sulfides (Vanloon and Duffy, 2005; Hsue and Chen, 2000). Limited studies of heavy metals adsorption on sulfide minerals suggest that the adsorption is dominated by the surface hydroxyl groups. The surface interactions of metals with sulfide minerals likely influence the fate and transport of metals in anoxic environments. Bryd *et al.* (1990) in Guem Estuary, Korea found that dissolved lead, cadmium, zinc, manganese and copper concentrations are highest at low salinities in the water column. It has been attributed to the flocculation and dissolution of aluminosilicate phases and colloidal iron oxyhydroxides. The increase concentrations of these heavy metals at high salinity indicate the possibility that pore waters enriched in remobilized metals are mixed into the water column and sediment.

3.2. Source of heavy metals

Enrichment factor (EF) is the relative abundance of a chemical element in a soil compared to the bedrock (Hernandez *et al.,* 2003). EF for each element was calculated from the formula below Kehrig *et al.* (2003). Aluminium (Al) can be a substitute for Fe^{3+}, Y^{3+} and Ti^{3+} and it has been already used for calculating anthropogenic metal enrichments (Shotyk et al., 2000). In this study, we have chosen to normalize metal concentration using aluminium as a grain size proxy. Al is a conservative and major constituent of clay minerals which has been successfully by numerous studies (Neto *et al.,* 2006; Huang and Lin, 2003). In order to evaluate if the present-day heavy metal content in sediment is derived from natural or anthropogenic sources, enrichment factor was calculated using Al as a reference element. The Hernandez *et al.* (2003) formula has been applied in this study to assess the anthropogenic and lithogenic contributions.

Since EF values of Pb, Zn and Cu which are higher 1 (Fig. 2), the anthropogenic and lithogenic percentage were calculated using formula employed by Hernandez *et al.* (2003). Malin *et al.* (2003) and Alloway (1995), discussing the sources of heavy metals contaminants (Cu, Pb, Zn) in soils, stated that although heavy metals are ubiquitous in soil parents, the major anthropogenic sources of studied heavy metals in study area are agricultural wastes, sewage sludge, fossil fuel combustion, etc. Pollution sources identified in Mengkabong mangrove forest are from industrial sources and construction. The increasing development pressure in the area causes the deterioration of the sediment quality. Moreover, other pollution sources are such as from pig farms along Tuaran road where the pig farms directly discharge into the nearest surface water body, large aquaculture development and domestic sources (Environmental Impact Assessment 1992).

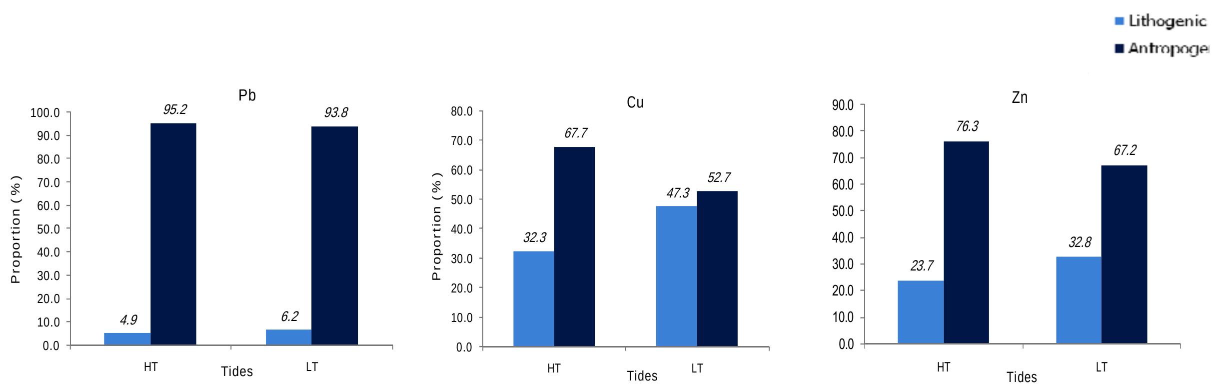

Figure 2. Copper, Lead and zinc anthropogenic and lithogenic proportions in Mengkabong mangrove sediment at high and low tides

Pekey (2006) noted similar findings to this study and elaborated that the enrichment factor of Pb is higher in locations that are located near to industrial areas, which in this case is the Kota Kinabalu Industrial Area (KKIP). KKIP is located near the Mengkabong mangrove forest.

4. Conclusion

Heavy metals dynamics by tidal effect showed relatively higher concentration at high tide compared to low tide. Tides control the water-flows that carry the sediments in the mangrove forests as well as the heavy metal dynamics. This simple explanation of conditions at high and low tides is vastly complicated by the redox conditions, oxygen condition as well as the presence of hydroxides and oxyhydroxide coating on the particles. The major source of heavy metals in Mengkabong mangrove forest is anthropogenic such as from industrial sources and construction, aquaculture, agricultural and domestic. This finding will be a foundation in the consideration of using mangrove wetlands as a sewage treatment facility.

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