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Trace Metal Concentration in the Surface Sediments of Paka Mangrove Forests, Terengganu, Malaysia

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ABSTRACT Surface sediment samples from 2 transects (20 stations) of mangrove forest of Paka were analyzed for the concentrations of Mn, Cu, Zn and Pb. In this study, the average concentrations of Mn, Cu, Zn and Pb were 112.4 ± 3.6 µg/g dry weight, 18.1 ± 0.91 µg/g dry weight, 44.9 ± 0.22 µg/g dry weight and 24.1 ± 0.36 µg/g dry weight, respectively. The calculated enrichment factors (EF) obtained for Cu, Zn and Pb can be considered to have the terigeneous in sources while Mn, which has slightly higher value, was probably influenced by anthropogenic input. The concentration of metal especially for Mn and Pb, increased with the decrease of mean size particle, suggesting their association with the fine fraction of the sediments.

ABSTRAK Sedimen permukaan daripada 2 transet (20 stesyen) di hutan paya bakau Paka dianalisa kepekatan Mn, Cu, Zn dan Pb. Didalam kajian ini, purata kepekatan Mn, Cu, Zn dan Pb adalah masing-masing 112.4 µg/g berat kering, 18.1 µg/g µg/g berat kering, 44.9 µg/g µg/g berat kering and 24.1 µg/g µg/g berat kering. Faktor pengkayaan (EF) yang dikira bagi Cu, Zn dan Pb adalah didapati menghampiri 1 dan boleh dianggap terhasil daripada sumber semulajadi, manakala Mn yang mempunyai nilai EF yang lebih tinggi memberikan gambaran bahawa sumber Mn mempunyai sedikit pengaruh daripada antropogenik. Kepekatan logam terutamanya Mn dan Pb didapati meningkat dengan pengecilan saiz butiran, dan ini mengesyorkan ada terdapat hubungan langsung logam dengan saiz butiran yang halus.

(surface sediments, Paka mangrove forest, EF)

INTRODUCTION

Mangrove systems are ecosystems at the land–sea margin whose area has been largely reduced in the past decades due to man's activities [1]. In the tropics and subtropics, mangroves cover 100,000km^2 to 230,000km^2 and are the major ecosystems fringing the continental margins. Mangrove sediments are anaerobic, rich in sulphide and organic matter, thus favoring the retention of the water-borne heavy metals [2]. Previous studies have reported that mangrove sediments have a large capacity to retain heavy metals from tidal water, freshwater rivers and storm water runoff, and mangrove sediments often act as sinks for heavy metals [3]. Heavy metals are commonly retained within mangrove sediments and several studies indicate that the anoxic, fine–grained, and organic–rich mangrove sediments can reduce the potentially deleterious effects of metal contamination because the low availability of metals accumulated within the sediments for remobilization and biotic uptake [4]. In addition to contamination, the degree of heavy metal retained in sediment is also affected by sediment characteristics, in particular, type and quantities of organic matter, grain size, cation exchange capacity and mineral constituents [5]. It has been shown that large amounts of heavy metals are bound in the fine–grained fraction (<63µm) of the sediment, mainly because of its high surface area to grain size ratio and humid substance content [6]. The metals in this fine–grained fraction are more likely to be biologically available than those in the bulk sediments [7]. Traditionally, the fine–grained fraction of the sediment has been used to examine metal contamination in sediments [8]. In Malaysia, studies relating to mangrove to the productivity of the coastal waters and fisheries are well documented and are mostly biological and ecological in nature [9]. Few studies have been done regarding their role in process of sedimentation [10] In view of the potential importance of the mangroves to various aspects of the environment, research on the concentration of Mn, Cu, Zn, and Pb as well as their distribution pattern in the sediments was carried out.

EXPERIMENTAL

Sampling sites

The Paka River is located in the Dungun district, which is situated near the Paka town, south of Kuala Terengganu, the capital state of Terengganu (Figure 1). The study area lies in the wet tropics where high rainfall is recorded in the monsoon season in the month of November up to January. In this study, two transect lines (TR 1 and TR 2) were set up with 10 sampling stations fixed along each transect. The transects line with no physical signs of active bioturbation were selected, thus avoiding the complication of biological disturbance. Transect 1 was set up near the estuary while transect 2 was set up near upstream (Figure 1). Surface sediments for trace metals and physical characteristics were collected at all sampling points by gently scraping the sediment surface.

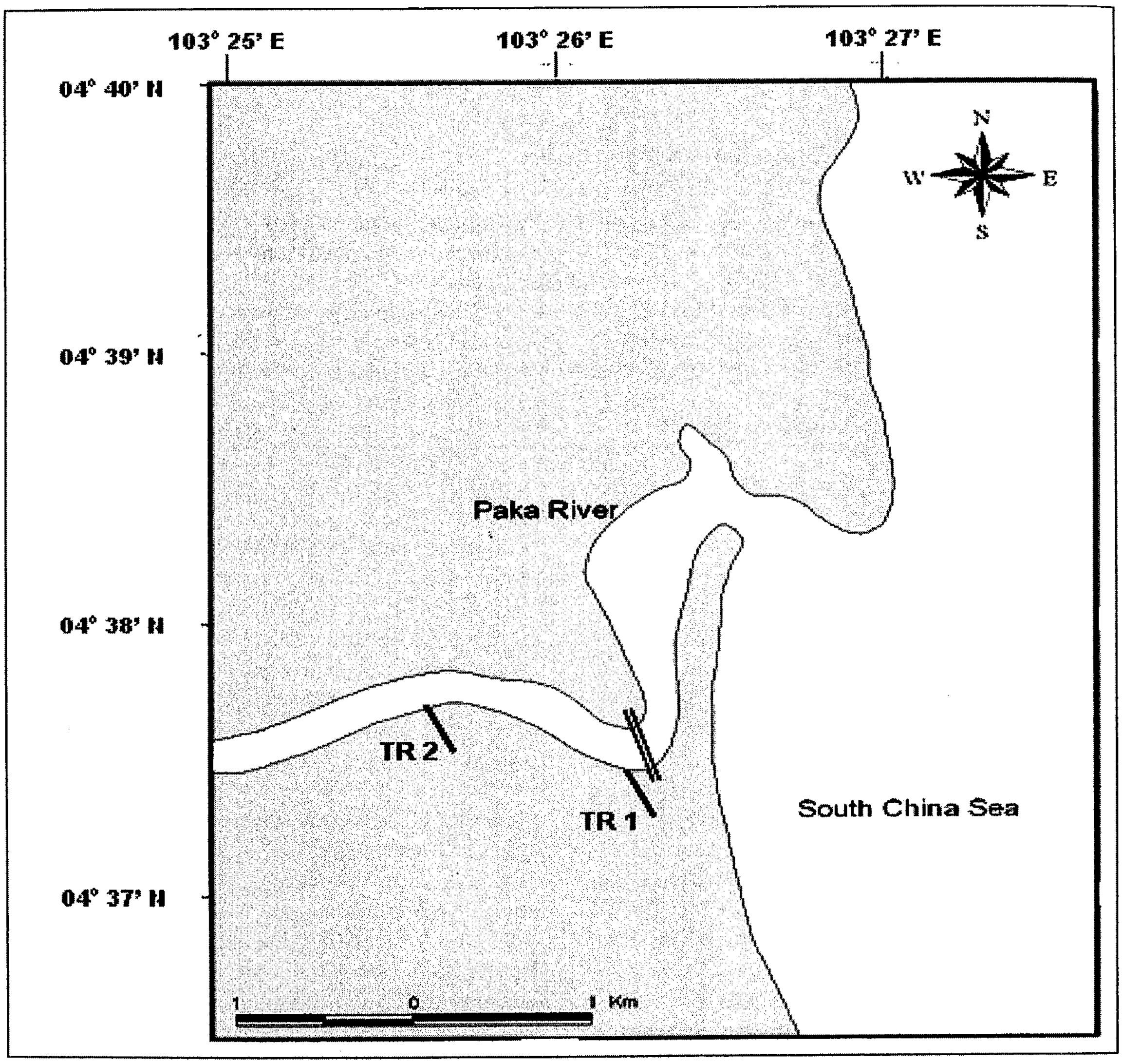

Figure 1. Location of the study area showing 2 transects (with 10 sampling stations at each transect) near the Paka mangrove forests.

Analytical method for metals

The sediment samples were digested according to the methods [11-13] with some modifications. An inductively-coupled plasma mass spectrometer (ICP-MS) was used for the quick and precise determinations of Mn, Cu, Zn, Pb and Th in the digested marine sediment. Briefly, the digestion method involved the heating of 50 mg of a < 63 μm size sample in a sealed teflon vessel with mixed concentrated acids of HF, HNO_3 and HCl in the ratio of 2.5: 3.5: 3.5. The teflon vessels were kept at 150 ^{0}C for three to five hours. After cooling, a mixed solution of boric acid and EDTA was added, and the vessel was again heated at 150 ^{0}C for at least five hours. After cooling to room temperature, the content of the vessel was thoroughly transferred into a 10 ml polypropylene test tube and was diluted to 10 ml with deionized water. A clear solution with no residue should be obtained at this stage. The precision assessed by replicate analyses was within 3%. The accuracy was also examined by analyzing, in duplicate a Canadian Certified Reference Materials Project standard (DL-1a) and the results coincided with the certified values with a difference of ± 3%.

RESULTS AND DISCUSSION

Horizontal distribution of Mn, Pb, Cu and Zn for two transects are given in the bar graph (Figure 2). The concentrations of Mn for both transects generally decreased with the distance from the riverside. Mn ranged from 56.1 μg/g dry weight to 221.7 μg/g dry weights and averaged at 112.38 μg/dry weight. Meanwhile, concentrations of Pb were observed to be almost constant and ranged from 10.5 μg/g dry weight to 44.9 μg/dry weights. Their average concentration of 26.21 μg/g dry weight is close to the values of the average shales and the mean crustal material. Cu concentrations ranged from 7.51 μg/g dry weight to 38.59 μg/g dry weights and averaged 19.02 μg/g dry weights. However, their mean value was lower when compared with their average shales. Zn has a similar trend with Pb where their metal concentration was almost constant except for station 1 to station 3 in transect 1. The average concentration of Zn was 51.7 μg/g dry weights, and ranged from 18.8 μg/g dry weight to 168.6 μg/g dry weight. The relatively high values at some stations probably are the result of a combination of factors including industrial discharges to the river, inputs from weathering and the effects of local activities nearby such as fishing and industrial activities.

In this study, the concentration of all elements was found to have relatively higher values near the front mangroves. This phenomena was also reported by [14] in the Kemaman mangroves. In the front mangrove areas, enormous amounts of fine sediments are transported by the river, increasing the adsorbing surface of trace metals. Kamaruzzaman *et al.* [14] also reported that there is a positive correlation between grain size and the concentrations of Cu, Zn and Pb, suggesting the influence of the fine fraction in their incorporation into the sediments. The silt clay type of sediment near the riverside or the front mangroves which are rich in organic content [15] have higher cation exchange capacities and larger surface areas [16]. Fine sediments are able to trap metal rich sediment, while sandy type sediments, organically poor sediments have little ability to retain metal ions.

For a better estimation of anthropogenic input, an enrichment factor was calculated for each metal by dividing its ratio to the normalizing element by the same ratio found in the chosen baseline. Table 1 shows the calculated EFs of the analysed elements with respect to those determined in the crustal abundance [17], employing the equation:

$$EF = (E/Al)_{sed}/(E/Al)_{crust},$$

where $(E/Al)_{sed}$ and $(E/Al)_{crust}$ are the relative concentrations of the respective element E and Al in the sediment and in the crustal material, respectively [18, 19]. An enrichment factor close to 1 would indicate a crustal origin, while those with factors greater than 10 are considered to have non-crustal sources. It is clear from Table 1 that only Pb has EF values close to unity and may therefore be considered to be predominantly terrigenous in origin. On the contrary, the higher EF values found for Mn, Cu and Zn indicate that these metals can be considered to be predominantly anthropogenic in origin.

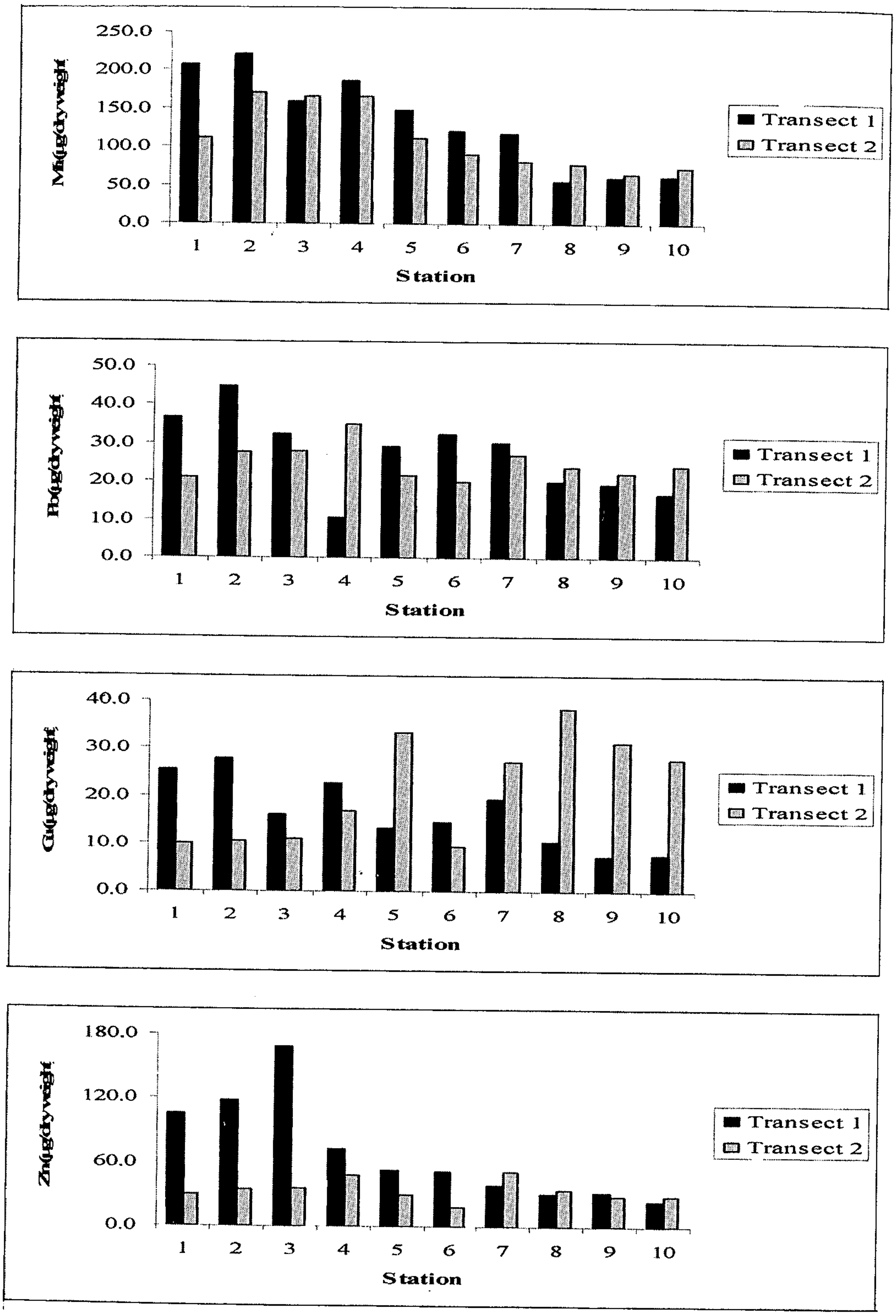

Figure 2. Concentration of the Mn, Pb, Cu and Zn in the surface sediments for both transects. Station 1 is located in the front mangrove areas and close to the river bank.

Table 1. Calculated average values of enrichment factor (EF) for Mn, Pb, Cu and Zn in the study area for both transects.

Element	EF values
Mn	3.27 ± 0.91
Pb	0.46 ± 0.02
Cu	1.61 ± 0.55
Zn	2.71 ± 0.89

CONCLUSION

Generally metals concentrations in the sediment were much influenced by the natural processes. Their regional distribution of all elements show relative enrichment near the river bank compared too much further areas inside the mangroves. The concentration of metals increased with the decreasing mean grain size, suggesting their association with the fine fraction of the sediments. The calculated EFs for all elements indicates their occurrences in both lithogenous and non-lithogenous fractions. In conclusion, even though the the Paka mangroves and nearby areas are rapidly developing, the activities at present are not widespread enough as to have much influence on pollution in the area.

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