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SPATIAL DISTRIBUTION OF TRACE METALS (Pb, Cr, Cu and Zn) IN SEDIMENTS OF THE BERAU DELTA, EAST KALIMANTAN AND THEIR ACCUMULATION IN BENTHIC BIOTA

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ABSTRACT

Berau delta is a coastal ecosystem where man-made activities are relatively low. The present study has investigated spatial distribution of Pb, Cr, Cu and Zn in sediments and their implication to benthic biota. The result of our study showed that metal concentrations varied from undetected to 55.53 mg kg^{-1} for Pb and from 3.28 to 22.9 mg kg^{-1} for Cu, while for Cr and Zn vary from 9.65 to 64.67 mg kg^{-1} and 10.00 to 1,200 mg kg^{-1}, respectively. The concentrations of Pb, Cu, Cr and Zn in *Anadara* sp were 7.53 ± 2.06, 4.92 ± 0.55, 1.44 ± 0.12 and 97.87 ± 9.12 mg kg^{-1} dry weight (dw), respectively. On the other hand, the Pb, Cr, Cu and Zn in *Telescopium mauritsi* were 4.49 ± 0.03, 0.87 ± 0.05, 259.0 ± 0.01 and 64.78 ± 0.01 mg kg^{-1} dw, respectively. In conclusion, spatial distribution of trace metals (Pb, Cu, Cr and Zn) in sediments showed that higher concentrations were found in the southern part of the delta, and the accumulation of the metals by mollusk might reflect natural concentrations in biota.

Keywords: *Trace metals, Spatial distribution mollusk, Berau Delta*

INTRODUCTION

Berau Delta is a large and shallow (< 20 m) embayment on the east coast of Kalimantan, Indonesia. Industrialization is planned for the area of the delta. Hence, it is expected that significant changes in the levels of trace metals and organic contaminants will occur in the near future. There are at least four driving forces that will affect the Berau delta system *i.e.*, fishery, marine-culture, tourism and industry. The industry currently operates are among others coal mining, pulp paper and forest logging, while fishery sector is mostly catch fishery and traditional shrimp culture (Arifin *et al.,* 2007). The main potential issues in the future will be increasing sediment load to the delta because of extensive forest clearing and opening area for tourist development, shrimp culture and coal mining.

As the forest clearing and industrial activities increased in inland area, hazardous contaminants that associated with sediment load especially trace metals will be of concern. Sediment quantitatively represents the major compartment for metal storage in aquatic environment. Concentration of metals in sediment is the first step to indicate the condition of environment and provides a base line information on a possibility of metal contaminants bioavailability to benthic biota. The ecological risk posed by contaminated sediments will depend on metal mobility to overlaying water, and the ability of benthic biota to assimilate metals from ingested sedimentary particles (Amiard *et al.,* 2007). Moreover, trace metals' mobility will depend on various processes including physical (diffusion, aggregation and burying), chemical (adsorption, complexation, precipitation and adsorption) and biological ones (degradation, transformation and accumulation) (Luoma, 1983). Therefore, the objective of the present study is to determine spatial distribution of Pb, Cr, Cu and Zn in sediments and their bioavailability to benthic biota.

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MATERIALS AND METHODS

The Berau delta is located at 118 °E and 2 °N. Tropical climate is found on Kalimantan, dry season during May to October with two rainfalls maxima (April – May and Dec – January). The study was conducted in May 2006 to represent rainfall maxima and September 2006 to represent dry season. Sixteen sediment samples were collected from Berau delta (Fig. 1). A composite of three-replicate of sediments were collected using Smith McIntyre grab. From three grabs of sediment, the superficial sediments (< 5 cm depth) were scraped using stainless steel scope, and mixed thoroughly, then placed them in a plastic bottle. The bottle was filled to the brim to eliminate air. Samples were put on ice-box and transported to the laboratory with icepacks in an isothermal container. The main characteristics of these sediments are shown in Figure 2.

Metals in Sediments

All laboratory ware was soaked in 10% hydrochloric acid, rinsed three times with deionized water and dried in a desiccator sheltered from atmospheric dust. Bulk sediments were analyzed for metals (Pb, Cr, Cu and Zn). The sediments were dried using oven at 60 °C for 24 h and ground them with mortar. The sediments (0.5 – 1 g dry weight) were digested with 1:3 (v:v) 33% HCl and 65% HNO_3 (Edgell, 1996). In these acid solutions and after dilution with deionized water, metals were analyzed by flame AAS (Varians Spectr AAS 20 plus). The calibration was carried out using in house standards for all of the four metals.

Metals in Benthic Biota

As we could not find a large quantity of benthic fauna from the stations where we sampled sediments, two mollusks (*Anadara* sp. and *Telescopium mauritsi*) were collected from fishermen who fished around the delta. The mollusks were transported to the field laboratory, and boiled before finally transported to laboratory in Jakarta. The gastropod *T. mauritsi* (average of 8.0 cm in shell height) and three sizes of bivalve *Anadara* sp. (<2.5 cm, 2.5 – 3.0 cm and 3.1 – 4.0 cm in shell length) were analyzed. Soft tissues of the biota were digested with concentrated HNO_3 and added H_2O_2. After digestion, metal levels in

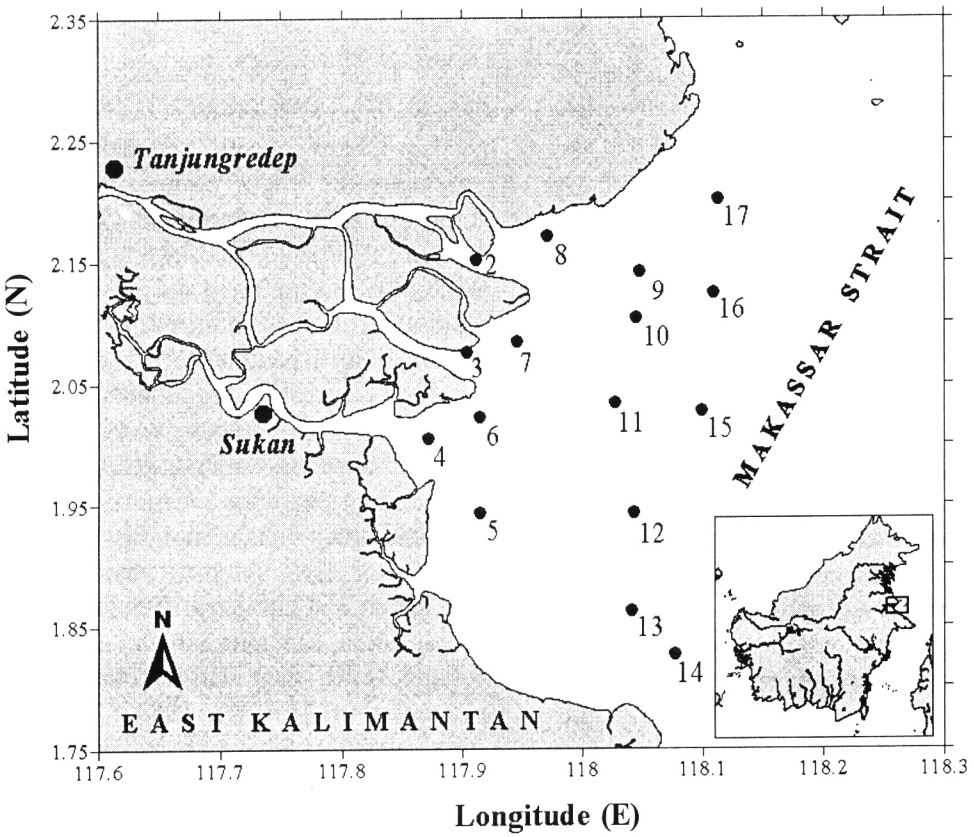

Figure 1. Study area and sampling stations of Berau Delta, East Kalimantan

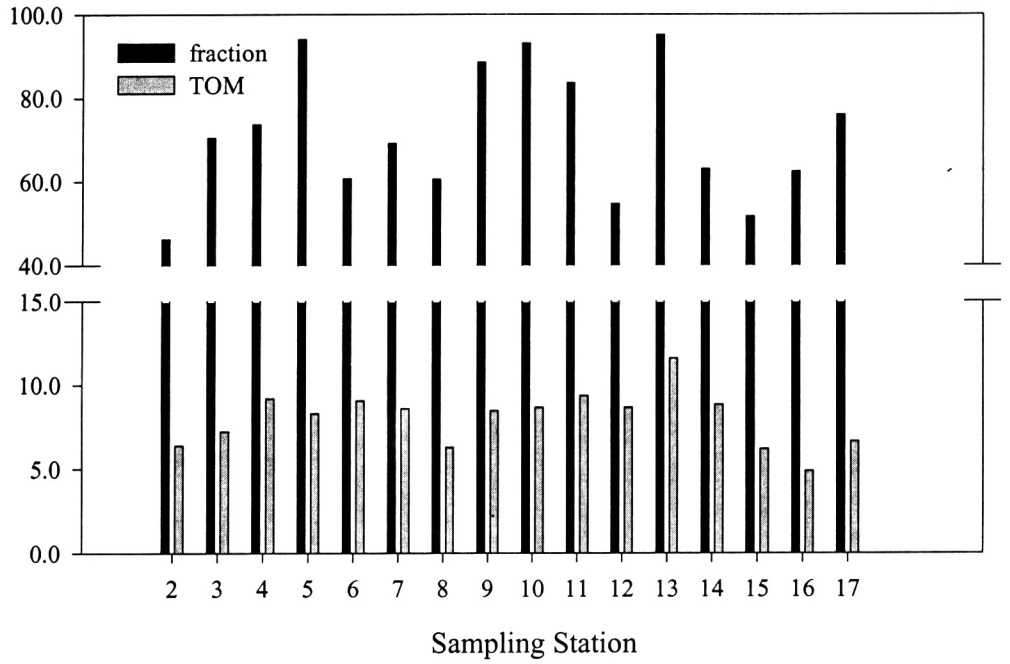

Figure 2. Main characteristics of sediments in 16 sampling stations. Fraction of sediment particle with size < 63 μm (%) and organic content (%, at 450 °C).

the solutions were diluted using deionized water, then determined by flame AAS (Varian SpectrAAS 20 plus). The results were expressed in mg Cd, Cu, Pb and Zn per kilogram dry weight.

RESULTS

Spatial Distribution of Trace Metals in Sediment

Concentrations of Pb and Cr were generally two to three times higher during September than that during May. Pb concentration varied between 6.0 and 26.0 mg kg^{-1} in May, and between 20 and 52 mg kg^{-1} in September. Moreover, Cr varied 6.0 – 48.0 mg kg^{-1} in May, and 30.0 – 84.0 mg kg^{-1} in September. In contrast concentrations of Cu and Zn were higher in May.

Concentrations of Pb and Cr were relatively higher in the southern part of the delta in May (Fig. 3a,c) and move toward northern part of the delta in September (Fig. 3b,d). High concentrations of Pb and Cr might relate to higher organic content of sediments in southern part of the delta. On the other hand, Cu concentration did not reflect any specific distribution within delta with its concentration was almost double in May than that in September (Fig. 3 e,f).

Metals in Benthic Biota

Based on shell length, a concentration of Pb was highest in small size of *Anadara* sp, but the value was not reflected in other trace metals (Cr, Cu and Zn), (Fig. 4a, b). An overall average of Pb, Cu, Cr and Zn concentrations in *Anadara* sp were 7.53 ± 2.06, 1.44 ± 0.12, 4.92 ± 0.55, and 97.87 ± 9.12 mg kg^{-1} dry weight (dw), respectively. On the other hand, the Pb, Cr, Cu and Zn in *Telescopium mauritsi* were 4.49 ± 0.03, 0.87 ± 0.05, 259.0 ± 0.01 and 64.78 ± 0.01 mg kg^{-1}, respectively.

DISCUSSION

Rivers in East Kalimantan discharge large quantity suspended sediments from the hinterland into the coastal waters. This factor affects metal-bound sediments in the delta system. The present study has investigated metal contaminants (Pb, Cr, Cu and Zn) at 16 sites within Berau delta. It is well understood that sediment-metal bound is mainly influenced by physico-chemical characteristics of the sediment especially grain size and organic content of sediments. In the present study, the < 63 μm fraction of sediment was very dominant (>65 %) and the organic content (TOM)

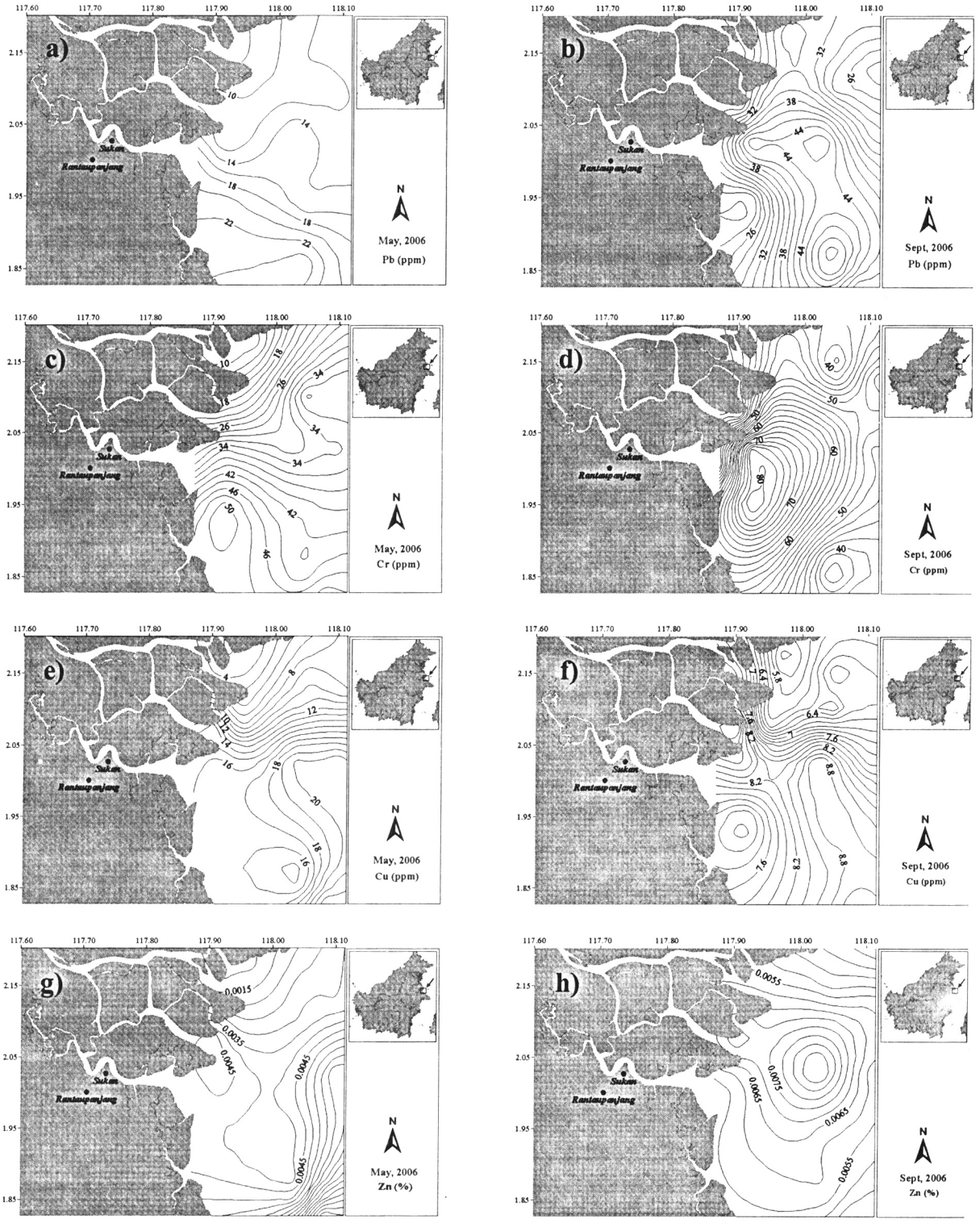

Figure 3. Spatial distribution of trace metals Pb (a, b), Cr (c, d), Cu (e,f) and Zn (g, h) in sediments of Berau Delta in May and September 2006.

varied between 5.0 and 12 % (Fig. 2). Total organic content in sediments was significantly correlated with Pb, Cr and Cu concentrations (r = 0.64 – 0.70) during May, however this strong correlation was not shown during the month of September.

Spatial distribution of metals especially Pb and Cr in the southern part of the delta were slightly elevated compared to the northern part of the delta, which might be attributed to the higher sedimentation in the southern part as a result of

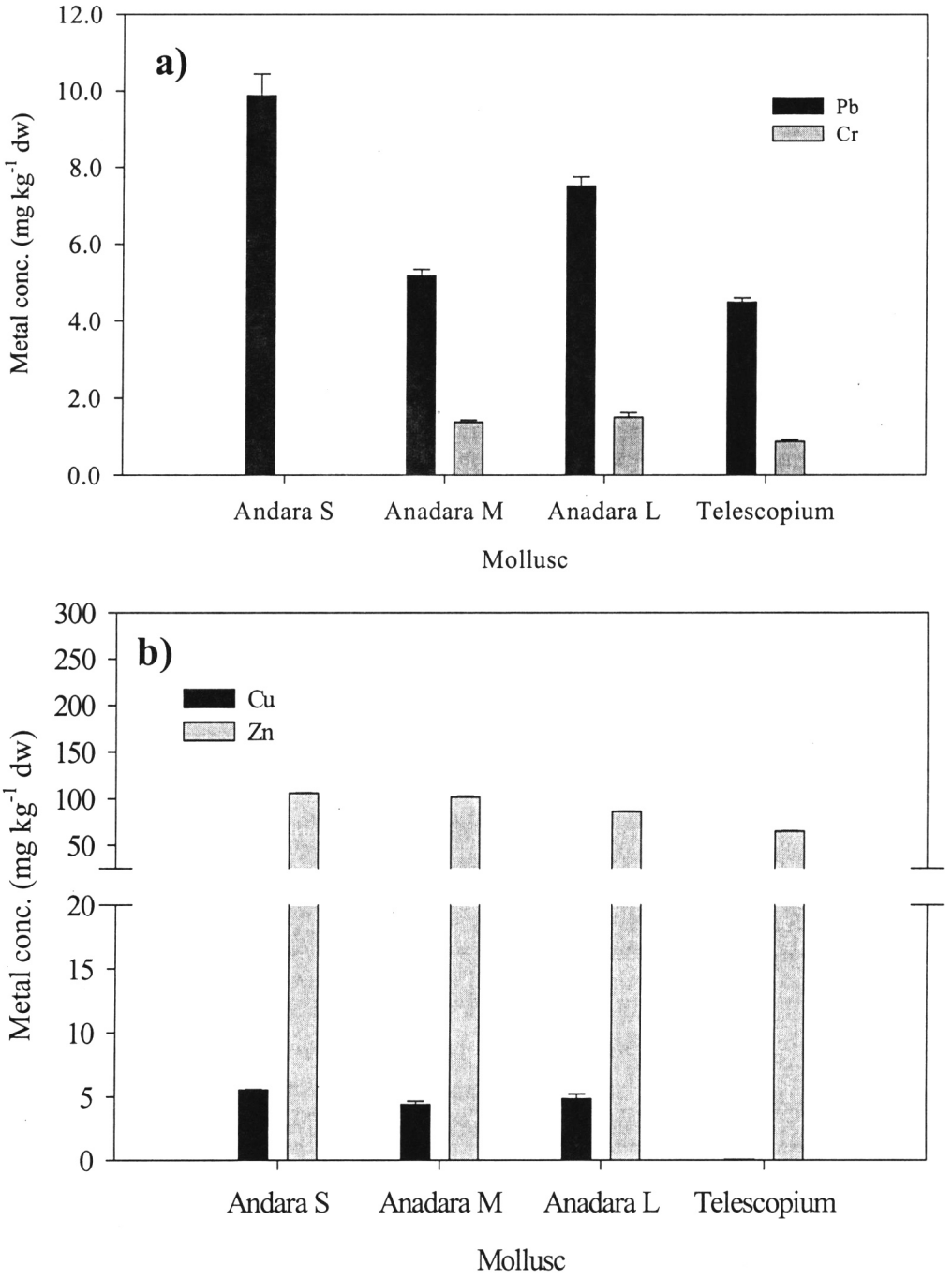

Figure 4. Concentrations of Pb and Cr (a) and Cu and Zn (b) in bivalve (*Anadara* sp) and gastropod (*Telescopium*) of Berau Delta. *Anadara* was divided into 3 sizes: S- small (< 2.5 cm), M - medium (2.5 – 3.0 cm), and L- large (3.1 – 4.0 cm) in shell length.

erosion from upland area via the southern channel (Muara Pantai). Moreover, it seems that trace metals of Pb and Cr had different behavior than that of Cu and Zn. Concentrations of Pb and Cr in September 2006 were two to five times higher than that in May 2006 (Fig. 3 a,b). In contrast, concentrations of Cu in May were double compared to that in September (Fig. 3 e,f), and concentrations of Zn (Fig. 3 g,h) were relatively the same during the study (May and September). This different behavior among four trace metals would determine their distribution and transport as well as their bioavailability to the benthic biota.

Deposit-feeders such as *Anadara* and *Telescopium* are directly exposed to sediment-bound metals, and are capable of accumulating

metals from interstitial metals and/or from ingested sediment. Because of their limited mobility, mollusks have been used for biological monitors of metal pollution. In the present study, we consider results from field surveys in which superficial sediment samples and benthic invertebrates were collected within the bay. The concentration of Pb maximum (9.88 ± 0.56 mg kg^{-1}) was found in medium size of *Anadara* sp, and the accumulation of Pb by this species was significantly higher compared to *T. mauritsi* (7.53 ± 2.06 vs. 4.49 ± 0.03, Fig. 4a). On the other hand, Cr accumulation by both mollusks was relatively low (1.44 ± 0.12 in *Anadara* sp vs. 0.87 ± 0.05 for *T. mauritsi*), (Fig. 4a).

Comparing to other coastal ecosystems, concentrations of trace metals (Pb, Cr, Cu and Zn) in sediments were relatively lower compared to the values found in Banten Bay and Jakarta Bay (Booij *et al.*, 2001; Arifin, 2004). To some extents, the accumulation was not as high as it is expected. Based on the present data (May and September), Berau delta can be considered relatively pristine delta from the view of concentrations of trace metals. In summary, trace metals (Pb, Cu, Cr and Zn) in sediments were relatively low and reflected an undisturbed benthic system. Moreover, *Anadara* sp and *Telescopium mauritsi* accumulated very low level of Pb and Cr, and the accumulation of the metals might reflect natural concentrations in biota.

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