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A Preliminary Study of the Distribution of Selected Trace Metals in the Besut River Basin, Terengganu, Malaysia

S. Suratman · H. C. Hang · N. A. M. Shazili · N. Mohd Tahir

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Abstract This paper presents a preliminary result carried out in the Besut River basin, Terengganu, Malaysia to determine the selected trace metal concentrations. Concentrations of dissolved Pb, Cu, and Fe during the present study were in the range of 3.3–8.3 µg/L Pb, 0.1–0.3 µg/L Cu, and 1.1–12.3 µg/L Fe. For the particulate fraction concentrations of Pb, Cu, and Fe ranged from 1.0 to 3.6 µg/L, 0.3 to 2.8 µg/L, and 114 to 1,537 µg/L, respectively. The concentrations of metals in this study area, in general, were lower than those reported for other study areas. Higher metal concentrations measured in the wet monsoon season suggest that the input was mainly due to terrestrial runoff.

Keywords Dissolved metals · Particulate metals · Distribution · Besut River

The Besut River is located in the northern part of Terengganu, Malaysia and discharges into South China Sea (Fig. 1). This river is approximately 40 km in length and receives input from its main tributaries mainly the La, Keruak, Angga, Tadau, and Jertih Rivers. Land use within this basin is predominantly rural with agricultural activities dominant at the upper reaches of the river. There are no major industrial activities within the basin. Population density is concentrated at the middle and lower reaches of the river at the towns of Jertih, Kg. Raja, and Kuala Besut. This river basin is important for the area as a source of water for irrigation as well for aquaculture, municipal water supply, and wastewater dilution.

This river basin is strongly influenced by the wet Northeast monsoon from late November to February and dry Southwest monsoon from March to early September, thus generating two well-marked seasons (Malaysia Meteorological Department 2008). The months of September and October, preceding the Northeast in November, is called the intermonsoon season or transition period. The annual rainfall within the basin ranges from 1,800 to 2,000 mm and November–December usually has maximum rainfall.

In recent years, many land areas within the basin have been developed for housing, agricultural, and aquaculture activities especially from the middle to lower reaches of the river. It is likely that levels of pollutants will increase in line with the scale of development as wastes discharges increase, particularly for domestic sewage, especially since these sources are not currently regulated and hence effectively controlled. A study has shown that the nutrient concentrations in some areas of this river have increased due to the domestic sewage (Suratman et al. 2006). This study was therefore carried out to establish the distributions and current levels of trace metals (Pb, Cu, Fe) both in dissolved and particulate forms in the river basin and to study the effects of monsoon on the concentrations of these metals and should provide an effective reference study as discharges increase in the future.

Materials and Methods

Eight sampling stations were chosen within the river basin. These sampling stations (B1, B2, B3, B4, B5, B6, B7, and

S. Suratman (✉) · H. C. Hang · N. Mohd Tahir
Environmental Research Group (ERG), Department of Chemical Sciences, University Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia
e-mail: miman@umt.edu.my

N. A. M. Shazili
Institute of Oceanography (INOS), University Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia

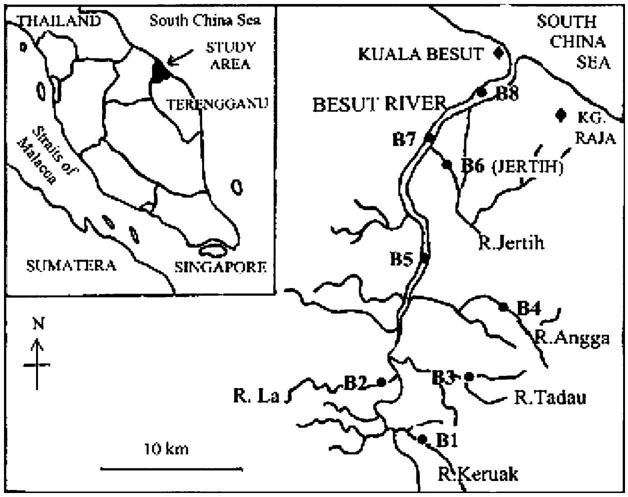


Fig. 1 Map of Besut river basin showing location of sampling stations

B8) are shown in Fig. 1, which covered the downstream and upstream of the Besut River basin. Due to the inaccessibility of some sub-basins, sampling stations were located only as shown in the figure. In this study, all the solutions were prepared using analytical grade chemicals from the Merck Chemical Company. Ultrapure water from the Milli-Q water system (18.2 MΩ) was used to prepare all the solutions.

Sampling was carried out at respective sampling stations during dry pre-monsoon (4/8/2002 and 26/10/2002) and wet monsoon (23/11/2002) periods. Only one sampling event was carried out in wet monsoon period due to the flood preventing sampling at most stations. Water samples were collected at 1 m depth from the surface using a Van Dorn sampler. Samples were immediately transferred from the sampler into pre-nitric acid-cleaned 1 L high-density polyethylene (HDPE) bottles. The bottles were stored in an ice filled cool box for transport to the laboratory. Trace metals analyses were undertaken for both dissolved and particulate fractions within 1 month after sampling.

At the laboratory, samples were vacuum-filtered through cellulose acetate membrane filters (47 mm diameter; 0.45 μm pore size) in a class 100 laminar flow hood on the day of the sampling. The filtrates for dissolved metals analyses were then acidified with concentrated HNO_3 to pH 2–3 as a preservative. Dissolved metals were determined after pre-concentration-complexation treatment (Magnusson and Westerlund 1981). The metals were complexed with 1% ammonium pyrrolidine dithiocarbamate (APDC) and extracted into methyl isobutylketone (MIBK) in Teflon separatory funnels. After phase separation, the water was discarded and the complexes in the MIBK were back extracted into 2 M HNO_3 and stored in polypropylene test tubes. Spikes were added to ~20% of samples to determine the extraction efficiency, which was better than 90% for all metals investigated. This method provided a 40 fold pre-concentration factor. The particulate metals remaining on the filter and blanks were digested with a mixture of HNO_3–HCl–HF in a microwave digester at 210°C for 30 min (Chen and Ma 2001). After cooling, H_3BO_3 was added to neutralize the HF. The digested samples were then brought up to 25 mL in a volumetric flask with ultrapure water and stored in polypropylene test tubes. Trace metal analysis for both dissolved and particulate metals was then performed by inductively coupled plasma optical emission spectrometry (ICP–OES) (Varian Vista-Pro). The detection limits during the analysis for Pb, Cu, and Fe were 0.6, 0.6, and 0.5 μg/L, respectively.

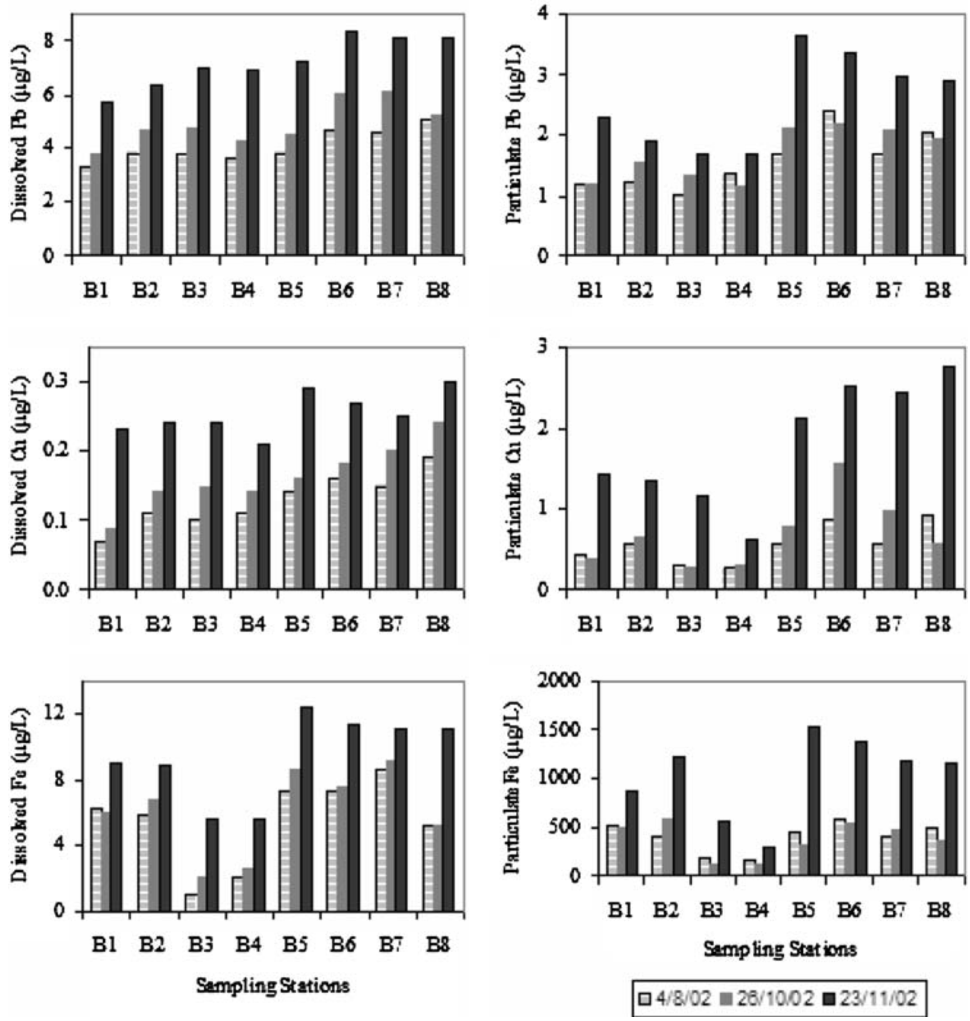
The data were then tested by one-way analysis of variance (ANOVA) at 95% significance level to show differences between sampling stations. No statistical analysis was made between seasons due to the limitations of data set size.

Results and Discussion

The results for the trace metals obtained during the present study are summarized in Fig. 2. The concentrations for the dissolved fractions were in the range of 3.3–8.3 μg/L Pb, 0.1–0.3 μg/L Cu, and 1.1–12.3 μg/L Fe. The levels for particulate Pb, Cu, and Fe varied from 1.0 to 3.6 μg/L, 0.3 to 2.8 μg/L, and 114 to 1,537 μg/L, respectively. Statistical tests showed that the metal concentrations were significantly different ($p < 0.05$) between sampling stations. It was also observed that for all the three metals studied, there was a trend of increasing concentrations going from the upstream stations to the downstream stations. The high concentrations of Pb and Cu found at the downstream stations could be attributed to sewage effluents from domestic sources. It is the general practice in the area to discharge wastes, in particular domestic sewage, without prior treatment due to lack of proper treatment facilities. Studies by other researchers also found that domestic sewage effluents act as an important source of trace metals (Neal et al. 2000; Bordalo et al. 2001). Fe is naturally abundant due to the geology of the Besut River basin and therefore likely to be derived from the surrounding soil. Furthermore, the extremely high concentration of particulate Fe is consistent with Fe as the main component of trace metals in the soil.

The dissolved and particulate trace metals showed markedly high concentrations during the wet monsoon period than that of the dry pre-monsoon period. Other studies also recorded the same observation in their study area (Satyanarayana et al. 1985; Bordalo et al. 2001). An observed increase in trace metals studied during the wet

Fig. 2 Variations of Pb, Cu, and Fe during the period of study



monsoon period can be explained due to the impact of terrestrial runoff during the heavy rainfall and hence led to high concentrations of trace metals in the rivers. Runoff from land is a major source of addition of trace metals to the river (Rajendran et al. 1982). River waters bring the trace metals both as dissolved and particulate species, the concentration of which is controlled by the nature of the rocks and activities within the basin. It must be conceded that the assessment of the role of wet monsoon period on the concentrations of trace metals using one sampling trip was not sufficiently representative. However, this data provides some indicative trend and we recommend further studies to be carried out to build on the current observations.

Comparison of the data obtained during the present study has been made with other study area (Table 1). In general, the average concentrations of trace metals in Besut River basin were lower than those recorded at Wear River, England (Neal et al. 2000) and Bangpakong River, Thailand (Bordalo et al. 2001). This is probably due to the fact that there is no major industrial activity in the Besut River basin as compared with those two studies area. However,

Table 1 Comparison of average trace metals concentrations

Concentration (µg/L)	Besut River, Malaysia	Wear River, England	Bangpakong River, Thailand	World River water
Dissolved Pb	5.4	2.8	na	670
Dissolved Cu	0.2	2.4	50	5
Dissolved Fe	6.9	142	2,710	3
Particulate Pb	1.9	5.4	na	na
Particulate Cu	1.0	1.2	na	na
Particulate Fe	602	159	na	na

na = not available

dissolved Pb and particulate Fe were higher compared with Wear River, England. Comparison of the concentrations of dissolved metals with those given for world average river water (Riley and Chester 1971) indicated that, with the exception of Fe, the trace metals studied showed lower concentrations.

In conclusion, the present study suggests that Pb, Cu, and Fe concentrations were still relatively low compared with other study areas. However, continuous inputs from the expanding domestic sector, which results in continuous discharge into the water bodies without proper treatment, will increasingly impact on the Besut River basin and its tributaries. The high concentrations of the metals observed during the wet monsoon period may suggest a significant input from the land through the runoff process.

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