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Journal of Tropical Marine Ecosystem

Journal of Tropical Marine Ecosystem 1(2012):15-23

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Metal concentrations in Sungai Sedili Kecil, Johor, Peninsular Malaysia

(Kepekatanlogam di Sungai Sedili Kecil, Johor, Semenanjung Malaysia)

Shuhaimi-Othman M., Ahmad A.K., Nadzifah Y., Azmah M.

School of Environmental and Natural Resource Science, Faculty of Science and Technology, UniversitiKebangsaan Malaysia,43600 Bangi, Selangor, Malaysia.

Received 1 Mac 2012; accepted 15 April 2012

ABSTRACT

Water and sediment from five sampling stations in Sungai Sedili Kecil were sampled in October 2010 and analyzed for 11 metals including cadmium (Cd), copper (Cu), manganese (Mn), iron (Fe), lead (Pb), aluminium (Al), zinc (Zn), nickel (Ni), cobalt (Co), arsenic (As) and argentum (Ar). Results showed that the mean dissolved metal concentrations (in µg/L) in Sungai Sedili waters based on 5 sampling stations (in descending order) for Fe, Al, Zn, Cu, As, Mn, Ni, Pb, Co, Cd and Ag were 443.7, 52.7, 50.2, 34.2, 25.9, 20.3, 6.8, 1.4, 0.77, 0.67 and 0.10 µg/L, respectively. Mean metal concentrations (in µg/g dry weight) for sediments (in descending order) for Fe, Al, Mn, Zn, Pb, Cu, As, Ni, Co, Cd and Ag were 33389.4, 17118.7, 190.5, 55.1, 29.1, 26.3, 19.3, 10.9, 4.7, 0.18 and 0.12 µg/g, respectively. A comparison with various water and sediment quality standards showed that the mean metal concentrations in surface water and sediment of Sungai Sedili Kecil were low and within the range of natural background except for Cu and Fe in water.

Keywords: Metals, water, sediment, river, dissolve metal

ABSTRAK

Air dan sedimen dari lima stesen persampelan telah diambil di Sungai Sedili Kecil pada Oktober 2010 dan dianalisa 11 logam iaitu kadmium (Cd), kuprum (Cu), mangan (Mn), besi (Fe), plumbum (Pb), aluminium (Al), zink (Zn), nikel (Ni), kobalt (Co), arsenik (As) dan argentum (Ar). Hasil menunjukkan purata kepekatan logam terlarut (µg/L) dalam air di Sungai Sedili berdasarkan 5 stesen persampelan (dalam turutan menurun) bagi logam Fe, Al, Zn, Cu, As, Mn, Ni, Pb, Co, Cd dan Ag masing-masing adalah 443.7, 52.7, 50.2, 34.2, 25.9, 20.3, 6.8, 1.4, 0.77, 0.67 and 0.10 µg/L. Purata kepekatan logam (µg/g berat kering) dalam sedimen (dalam turutan menurun) bagi Fe, Al, Mn, Zn, Pb, Cu, As, Ni, Co, Cd dan Ag masing-masing adalah 33389.4, 17118.7, 190.5, 55.1, 29.1, 26.3, 19.3, 10.9, 4.7, 0.18 and 0.12 µg/g. Perbandingan dengan piawaian air dan sedimen menunjukkan kepekatan logam dalam air permukaan dan sedimen di Sungai Sedili Kecil adalah rendah dan dalam julat kepekatan semulajadi kecuali bagi logam Cu dan Fe dalam air.

Katakunci: Logam, air, sedimen, sungai, logam terlarut

*Corresponding author: shuhaimi@ukm.my

INTRODUCTION

Heavy metals are of particular concern due to their environmental persistence and biogeochemical recycling and ecological risks. Under certain environmental conditions, metals may accumulate to toxic concentrations and cause ecological damage. Major sources of metal pollution in marine and freshwater systems come from domestic wastewater effluents (especially As, Cr, Cu, Mn and Ni), coal-burning power plants (especially As, Hg and Se), non-ferrous metal smelters (Cd, Ni, Pb and Se), iron and steel plants (Cr, Mo, Sb and Zn) and the dumping of sewage sludge (As, Mn and Pb). The assessment of metal contamination in the field such as in water and sediment can provide information on the presence of such metals, as well as describe adverse effects in organisms and is therefore of great significance to environmental management and conservation (Graney et al. 1995).

The impact of metals on the environment is an increasing problem worldwide. Malaysia, as a developing country, is no exception and faces metal pollution such as As, Ag, Cd, Cu, Pb, and Zn in the water and sediment of some rivers and coastal areas caused primarily by anthropogenic activities such as manufacturing, agriculture, sewage, mining, and motor vehicle emissions (DOE 2009, Zulkifli et al. 2010, Yap & Pang 2011). In aquatic ecosystems, sediment plays a useful role in the assessment of metal contamination because in unperturbed environments, metals are preferentially transferred from the dissolved to the particulate phase and as a result, metal concentrations in sediment are generally much higher than in the overlaying water, and can reflect contamination loads over a long period of time (Forstner & Wittmann 1981, Bryan & Langston 1992). Data on metal contamination in a natural environment (lake or river) is very useful. Information on the occurrence (spatial and temporal distribution) of metals in the ecosystem furthersthe understanding of the role human activities play in discharging these chemicals to the environment. This information serves as a benchmark for assessing contaminant discharge-reduction strategies. The assessment of metal contamination in the field can provide information on this metal's availability and describe adverse effects in organisms and is therefore of great significance as a tool for environmental management and conservation.

This study was conducted in October 2010 and a total of 11 metals were measured in the surface water and sediment of Sungai Sedili Kecil. The aim of this study is to determine the metal concentrations in the water and sediment from five sampling stations in Sungai Sedili Kecil in Johor, Peninsular Malaysia.

MATERIAL AND METHODS

Sungai Sedili Kecil is located in TanjungSedili, east of the state of Johor in Malaysia. There are two Sedili rivers in this area, i.e. Sungai Sedili Kecil and Sungai Sedili Besar. The extent of the freshwater swamp forest in and around Sungai Sedili Kecil and Sedili Besar has reduced agriculture and village settlements. The riverine vegetation is in good condition with a distinct gradation of vegetation zones in the river i.e. mangrove belt – *nypa* belt – *Barringtoniaconoidea* belt – *pandanus* belt to freshwater tidal belt. Both Sungai Sedili Besar and Sungai Sedili Kecil have ecotourism potential as boat rides along the river are extremely pleasant and have both aesthetic and recreational values (Wetland International Malaysia). In this study, five sampling stations were selected in Sungai Sedili Kecil; the locations are shown in Figure 1.

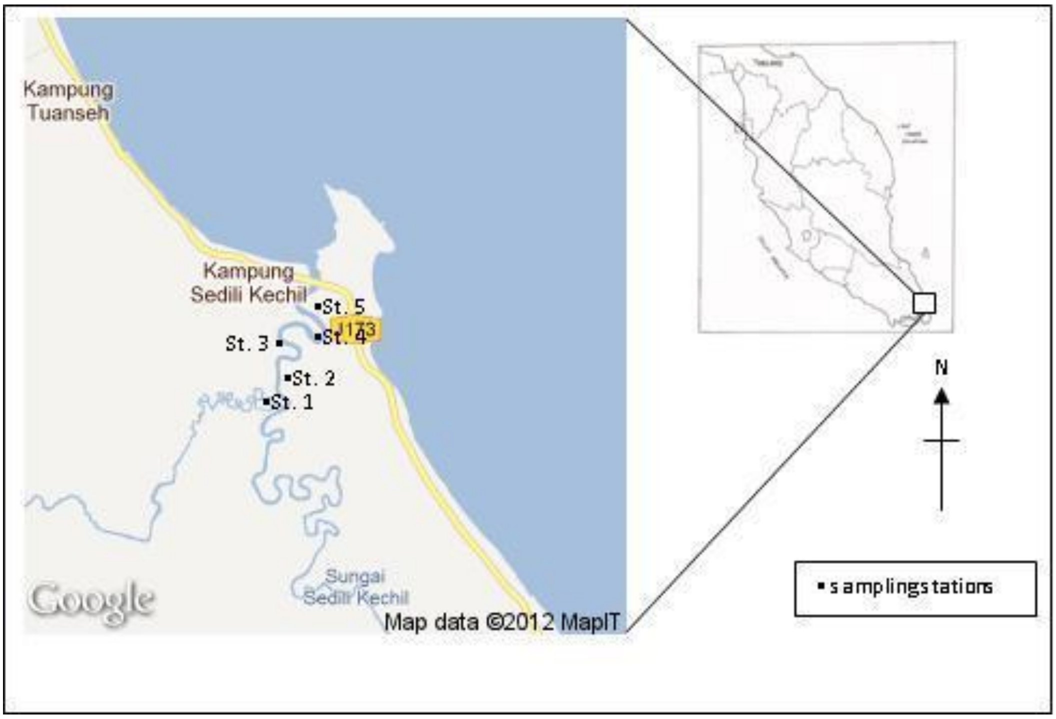

Figure 1: Five sampling stations at Sungai Sedili Kecil.

Sampling was conducted in October 2010. Prior to any analysis, all equipment and containers were soaked in 10% HNO_3 (overnight) and rinsed thoroughly with deionized water before use. At each sampling station, water samples (surface water) were taken and stored in polypropylene bottles (60 mL x 3 replicates); filtered with 0.45 µm membrane filters and acidified to pH < 2 with nitric acid (70%). Sediment samples were collected using a sediment sampler (Ponar grab) and samples were taken from the upper 0-5 cm, mixed together, stored in polyethylene plastic bags (3 replicates) and kept in the dark at 4^oC. Sediment samples were dried in the oven at 80^oC for 48 hours (constant weight) and sieved through a 63-µm mesh. Dried sediment samples were digested (0.2 g) in 0.9 mL nitric acid (70 %) and 0.2 mL hydrochloric acid (35 %) in a block thermostat (80 ^oC) for 3 to 4 hours until the solutions were clear, filtered with Whatman® filter paper (no. 1) then made up to 25 mL with deionized water in 25 mL volumetric flasks (Sinex et al. 1980). Metal analysis in all samples was carried out by Inductively Coupled Plasma – Mass Spectrophotometry (ICP-MS, model Perkin-Elmer Elan 9000, Massachusetts, USA). Eleven metals were analysed in water and sediment samples which were cadmium (Cd), copper (Cu), manganese (Mn), iron (Fe), lead (Pb), aluminium (Al), zinc (Zn), nickel (Ni), cobalt (Co), arsenic (As) and argentum (Ar). The accuracy of the analysis was checked against blanks. Procedural blanks and quality control samples made from standard solutions for all metals were analyzed for every ten samples in order to check for sample accuracy. Percentage recoveries for metals analyses were between 85-105%.

RESULTS AND DISCUSSION

Mean metal concentrations in water (dissolved metal) and sediment from the 5 sampling stations in Sungai Sedili Kecil are summarized in Table 1. Results show that mean dissolved Cu in the water (µg/L) ranged from 18.01 to 58.30, Cd 0.09 to 2.25, Pb 0.38 to 1.29, Zn 37.11 to 55.91, Ni 5.81 to 8.90, Fe 312 to 609, Mn 4.22 to 26.58, Al 31.35 to 71.04, Co 0.51 to 1.21, As 15.19 to 41.34 and Ag 0.03 to 0.27 µg/L. Statistical analyses show that there were significant differences of Cu, Pb, Ni, Fe, Mn, Al, Co, As and Ag (but not Cd and Zn) in the water between stations (ANOVA, $p<0.05$, Tukey-Kramer, $p<0.05$). In sediment, Cu (µg/g dry weight) was found in the range of 19.12 to 40.38, Cd 0.14 to 0.22, Pb 22.96 to 32.26, Zn 50.86 to 65.99, Ni 8.83 to 11.52, Fe 22835 to 45027, Mn 102.82 to 239.47, Al 9668 to 31921, Co 4.20 to 5.48, As 13.56 to 30.33 and Ag 0.10 to 0.14 µg/g. Statistical analyses show that there were significant differences of Cu, Pb, Ni, Fe, Mn, Al, Co and As (but not Cd, Ag and Zn) in the sediment between stations (ANOVA, $p<0.05$, Tukey-Kramer, $p<0.05$). Generally, metal concentrations in the river water was found in a decreasing sequence of Fe>Al>Zn>Cu>As>Mn>Ni>Pb>Co>Cd>Ag, and metal concentrations in the sediment Fe>Al>Mn>Zn>Pb>Cu>As>Ni>Co>Cd>Ag.

Metal concentrations in the water and sediment are good indicators of the degree of river contamination. Metal concentrations in the water were compared with the Canadian Environmental Quality Guidelines for protection of aquatic life (CCME 1999), National Recommended Water Quality Criteria by U.S. Environmental Protection Agency (EPA 2004) i.e. for Criteria Maximum Concentration (CMC) and Criterion Continuous Concentration (CCC) and Malaysian Water Quality Standard (NWQS) (DOE 2010) (Table 2). Results show that for Cd, Pb, Ni, Mn, Al, Co, As and Ag, concentrations in the water were low and within the range of natural concentrations. Copper concentrations were higher than all the standards and further studies are needed to examine this situation. Zinc concentrations were higher than CCME guidelines (< 30 µg/L) at all stations, however they are still lower than EPA guidelines (<120 µg/L). Iron concentrations were higher than 300 µg/L at all stations and exceeded CCME guidelines, however they were still lower than most of the other standards (<1000 µg/L).

There is a trend in increasing order from station 1 (upstream) to station 5 (downstream) of metal distribution in the water especially for Cu, Ni, Fe and As. High concentrations of these metals at some stations could not be explained and further studies are needed. Other studies have shown that Fe concentrations were high in other natural water areas in Peninsular Malaysia such as Lake Chini (794.84 µg/L) and Lake Bera (180-1950 µg/L) (Ikusima et al. 1982, Shuhaimi-Othman et al. 2008). No published data was found in the literature on metal concentrations in water and sediment for the present study area. However, a comparison of metal concentrations in a number of Malaysian rivers, such as the Langat, Mamut and Linggi rivers showed the Cu concentration to be between 0.02-0.04 mg/L, 0.014 mg/L and 0.24-0.26 mg/L respectively (Sukiman Sarmani 1985, Hamzah et al. 1997, Shuhaimi-Othman & Nurlailawati 2004, Ali et al. 2004), which were higher than many international standards (Table 2).

Table 1: Metal concentrations (mean with S.D) in water (μg/L) and surface sediment (μg/g dry weight) at 5 stations in Sungai Sedili Kecil, Johor.

Station		Cu	Cd	Pb	Zn	Ni	Fe	Mn	Al	Co	As	Ag
1	Wat	18.01 ± 0.18	1.30 ± 0.98	1.29 ± 0.61	54.99 ± 5.35	5.81 ± 0.78	312.47 ± 21.52	25.78 ± 0.73	50.74 ± 12.17	0.51 ± 0.04	15.19 ± 0.95	0.27 ± 0.17
	Sed	19.69 ± 4.11	0.22 ± 0.06	29.16 ± 1.21	65.99 ± 2.52	8.83 ± 1.00	40520.22 ± 1370.87	102.82 ± 2.64	31921.51 ± 1626.68	4.24 ± 0.19	21.06 ± 0.71	0.13 ± 0.02
2	Wat	23.47 ± 1.39	0.39 ± 0.13	0.56 ± 0.06	54.72 ± 8.17	5.81 ± 0.49	356.70 ± 20.28	26.58 ± 1.35	46.16 ± 4.01	0.57 ± 0.06	19.08 ± 1.12	0.09 ± 0.03
	Sed	19.12 ± 1.29	0.17 ± 0.01	32.26 ± 1.00	54.63 ± 4.35	11.28 ± 1.86	45027.20 ± 2435.47	180.55 ± 14.99	18039.97 ± 1190.74	5.48 ± 0.37	30.33 ± 2.47	0.14 ± 0.02
3	Wat	29.53 ± 0.75	0.25 ± 0.04	0.57 ± 0.13	55.91 ± 4.74	6.16 ± 0.16	429.48 ± 13.33	25.61 ± 1.33	64.05 ± 3.05	0.70 ± 0.03	23.47 ± 0.37	0.06 ± 0.01
	Sed	40.38 ± 12.16	0.21 ± 0.05	33.89 ± 5.80	50.86 ± 6.30	9.55 ± 1.83	32102.10 ± 5514.37	200.80 ± 30.85	14077.01 ± 2845.16	5.18 ± 0.82	15.96 ± 3.05	0.11 ± 0.03
4	Wat	41.67 ± 3.43	0.28 ± 0.06	0.60 ± 0.25	48.47 ± 11.39	7.52 ± 0.41	510.51 ± 24.36	19.27 ± 1.02	71.04 ± 18.02	0.88 ± 0.07	30.62 ± 1.49	0.05 ± 0.01
	Sed	14.60 ± 0.20	0.16 ± 0.02	27.01 ± 1.35	52.61 ± 9.90	13.37 ± 1.54	26462.36 ± 892.71	228.96 ± 3.04	11887.08 ± 527.97	4.56 ± 0.20	15.64 ± 0.44	0.11 ± 0.02
5	Wat	58.30 ± 2.06	0.087 ± 0.037	0.38 ± 0.18	37.11 ± 6.87	8.90 ± 0.11	609.46 ± 35.26	4.22 ± 1.89	31.35 ± 14.50	1.21 ± 0.05	41.34 ± 1.05	0.03 ± 0.01
	Sed	38.00 ± 0.84	0.14 ± 0.02	22.96 ± 2.59	51.49 ± 2.93	11.52 ± 1.52	22835.30 ± 1337.70	239.47 ± 18.61	9668.085 ± 956.89	4.20 ± 0.23	13.56 ± 0.77	0.10 ± 0.03

Wat – Water; Sed – Sediment

Table 2: Metal concentration standards in freshwater ecosystems.

Metal	Present Study-water (µg/L)	CCME-Protection of Aquatic Life (µg/L)	EPA-Criteria Maximum Concentration (CMC) µg/L	EPA-Criterion Continuous Concentration (CCC) µg/L	NWQS Class II (µg/L)	Present Study-Sediment (µg/g)	CCME-Freshwater sediment (µg/g)[c]	
							ISQG[a]	PEL[b]
Copper (Cu)	34.2	2-4	13	9.0	20	26.4	35.7	197
Cadmium (Cd)	0.5	0.017	2.0	0.25	10	0.18	0.6	3.5
Lead (Pb)	0.7	1-7	65	2.5	50	29.1	35	91.3
Zinc (Zn)	50.2	30	120	120	5000	55.1	123	315
Nickel (Ni)	6.8	25-150	470	52	50	10.9	22.7[c]	48.6[c]
Iron (Fe)	443.7	300	-	1000	1000	33389.4	-	-
Manganese (Mn)	20.3	-	-	-	100	190.5	-	-
Aluminum (Al)	52.7	5-100	750	87	-	17118.7	-	-
Cobalt (Co)	0.8	-	-	-	-	4.7	-	-
Arsenic (As)	25.9	5	340	150	50	19.3	5.9	17
Argentum (Ag)	0.1	-	-	-	50	0.12	-	-

Sources: CCME 1999; NWQS (DOE 2010); EPA 2004

[a]ISQG-Interim sediment quality guideline

[b]PEL-Probable effect level

[c]Source from MacDonald et al. (2000)

Table 3: Person correlation coefficients (r) between metal concentrations in the water and sediment.

Metal	Cu (w)	Cd (w)	Zn (w)	Pb (w)	Ni (w)	Fe (w)	Mn (w)	Al (w)	Co (w)	As (w)	Ag (w)
Cu (s)	0.377										
Cd (s)		0.545*									
Zn (s)			0.272								
Pb (s)				0.088							
Ni (s)					0.441						
Fe (s)						-0.881***					
Mn(s)							-0.551*				
Al (s)								-0.092			
Co (s)									-0.400		
As (s)										-0.671**	
Ag (s)											0.102

(w)-metal in water; (s) metal in sediment

* indicates a significant relationship ($p<0.05$) ** indicates a significant relationship ($p<0.01$)

*** indicates a significant relationship ($p<0.001$

Metal concentrations in the sediment were compared to Canadian Environmental Quality Guidelines (Table 2) for freshwater sediment i.e. for interim sediment quality guidelines (ISQG) and the probable effect level (PEL) (CCME, 1999). Results show that all metals in the sediment were low and within the range of natural concentrations (CCME, 1999; MacDonald *et al.*, 2000). A correlation analysis (Table 3) showed that only Cd has a significant positive relationship between concentrations in the sediment and water (0.545, $p<0.05$), however this correlation is weak and Cd concentration in the water and sediment were low. Negative significant correlation ($p<0.01$) were shown between Fe and As concentration in the water and sediment.Comparison with other rivers in Malaysia, Abbas et al. (2009) showed that sediments from the Juru and Jejawi Estuaries were highly polluted with Fe, Zn and Cd, and that electroplating, pulp and paper, textile, food and beverages and auto-workshop industries were closely linked to industrial pollution in these areas. Yap and Pang (2011) reported that metal in surface sediments from 5 river drainage systems in west Peninsular Malaysia were 10.24–119.6 µg/g dry weight for Cu, 26.7–125.7 µg/g dry weight for Pb and 88.7–484.1 µg/g dry weight for Zn which were higher than the CCME standard (ISQG, Table 2).

CONCLUSION

This study shows that in general, metal concentrations in the water and sediment of Sungai Sedili Kecil were still low and in agreement with national and international standards except for Cu, and to a lesser extent Fe and Zn concentrations in water.

ACKNOWLEDGEMENTS

Authors would like to thank the Marine Ecosystem Research Center (EKOMAR) of Universiti Kebangsaan Malaysia for organizing the scientific expedition.

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