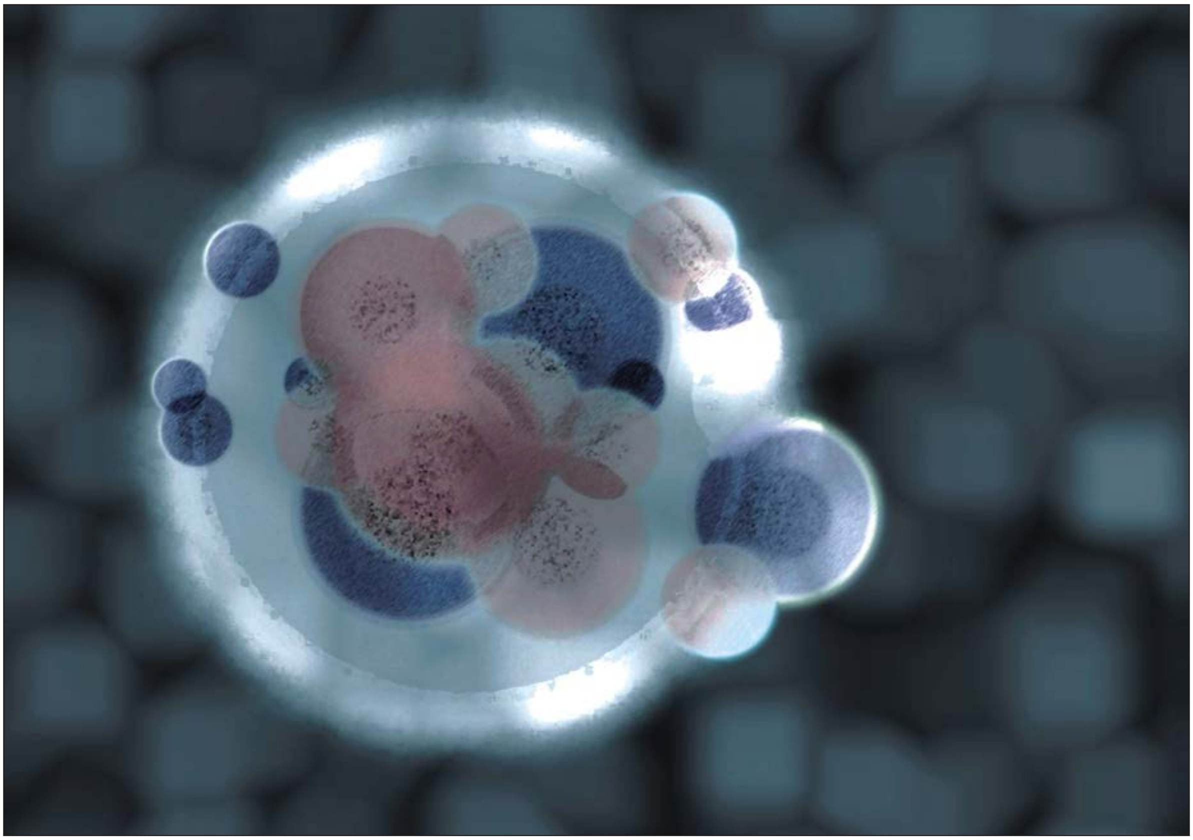

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Metals Concentration in Water and Sediment of Bebar Peat Swampy Forest River, Malaysia

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Abstract: A study was conducted in Bebar River, Pahang, a peat swamp river in 2005 to determine metals concentration in the water and sediment and some physical-chemical parameters. Eleven sampling stations were selected along the river. Water quality parameters were recorded at each station using a Hydrolab® Surveyor 4a system. Water and sediment samples were brought back to laboratory for metals analysis. Results show that the physical-chemical parameters of water in Bebar River were in normal range/class I (good) according to Malaysian Interim Water Quality Standard (INWQS) except for pH (class III - moderate) and dissolved oxygen in the water (class IV-V - bad). However, low values of these parameters are normal for peat water (blackwater). Metals concentration (dissolved metal) in the water (Cu, Cd, Pb, Cr and Ni) was in the range of natural concentrations. Zinc, Fe and Mn concentration were higher than recommended concentrations at some stations. Cadmium, Pb, Zn and Ni concentrations in sediment were low and in the range of natural concentrations while Cu and Cr was high at some stations. Correlation analysis show that only Cu and Cr have significant positive correlation ($p<0.05$) between metal concentration in the sediment and water. The importance of this sensitive ecosystem is discussed further in this study.

Key words: Metal, Bebar River, peat swamp forest, sediment, water

INTRODUCTION

Peat swamp forests are ancient and unique ecosystem. It is a forested area characterized by water-logging with low nutrient and dissolved oxygen levels in acidic water regimes (FRIM-UNDP/GEF, 2004). Tropical peat land covers about 38 million ha or 8.72% of the world's total of 436 million ha, including about 25 million ha in tropical Asia. In Southeast Asia much of the peat swamp forest is found in Indonesia with a smaller percentage in Malaysia including about 300,000 ha in Peninsular Malaysia where it is found in the lowlands of the states of Perak, Selangor, Johor and Southeast of Pahang. Peat swamp forest is important not only for the production of timber, but also for its role in hydrology functions of the ecosystem such as its role in flood mitigation, maintenance of river base flow, providing habitats and breeding ground for many restricted flora and fauna, prevention of saline water intrusion, sediment and nutrient removal and serving as a vital carbon sink. Southeast Pahang peat swamp forest covering a total of 200,000 ha is believed to be mainland Asia's largest and least disturbed tropical peat swamp forest. However it's surrounded by developed lands on all sides and continues to face tremendous pressures from development such as timber harvesting, agriculture and other human activities. This area has been identified as one of the most critical environmentally sensitive areas in Peninsular Malaysia (FRIM-UNDP/GEF, 2004). Human activities such as industrial processes (e.g., mining, smelting, finishing and plating of metals, paints and dye manufacture) and other unsustainable land use activities such as timber harvesting, aquaculture and agriculture could contributed to metals contamination in the aquatic environment (Kendrick *et al.*, 1992; Rand *et al.*, 1995; Hoffman *et al.*, 2003). Therefore, it is important to conduct studies to gather information on the status of metals concentration in this sensitive peat swamp forest river ecosystem.

Metal accumulation is potentially one of the most valuable tools for identifying and quantifying the impact of metals in aquatic environments (Borgmann and Norwood, 1995). The assessment of metal contamination in the field such as in water and sediment can provide information on this metal's availability and describe adverse effects in organisms and is therefore of great

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significance for environmental management and conservation (Graney *et al*., 1995). Sediment can play 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 load over long period of time (Förstner and Wittmann, 1981; Bryan and Langston, 1992). Physical and chemical parameters of water and sediment are also important in determine the suitability of habitat for living organism. Its can also influenced the bioavailability of toxic materials such as heavy metals, the toxicity and accumulation by aquatic organisms (Bradley and Morris, 1986; Zhou *et al*., 2008). Individuals, populations, species and ecosystems can take up, accumulate and bioconcentrate manmade and natural toxicants are well documented and are influenced by physical and chemical characteristics of the water and sediment (EPA, 2004; Wang and Rainbow, 2008). This study was conducted in Bebar River where 11 sampling stations were sampled. The aim of this study is to determine status of metals concentration in the water and sediment and the influence of some physical-chemical parameters.

MATERIALS AND METHODS

Study area: Peat swamp in the Southeast Pahang can be divided into three blocks i.e. Pekan forest reserve which is bounded by Pahang River to the North and Bebar River to the South, Kedondong and Nenasi Forest Reserve which are bounded by Bebar River to the North and Resak Forest Reserve which forms the most Southerly block. In this study, sampling stations were selected in Pekan Forest Reserve area where Bebar River is located. Bebar River is located at South-East Pahang in the area of peat swamp forest within latitude 03°17'03" to 03°21'10"N and longitude 103°13'51" to 103°15'32"E. Its lies within the boundaries of the Pekan District (Fig. 1). A limited extent of freshwater alluvial swamp forest dominated by *Campnosperma macrophylla* and *Durio carinatus* (Kamaruzzaman *et al*., 2007). It is characterized by blackwater draining from the peat swamp, with a very low pH and low dissolved oxygen (FRIM-UNDP/GEF, 2004). Eleven sampling stations were selected along the river from station 1 (St. 1) at the down stream to station 11 (St. 11) at the upper stream and station 2 (St. 2) was located at the mouth of Serai River (Fig. 1).

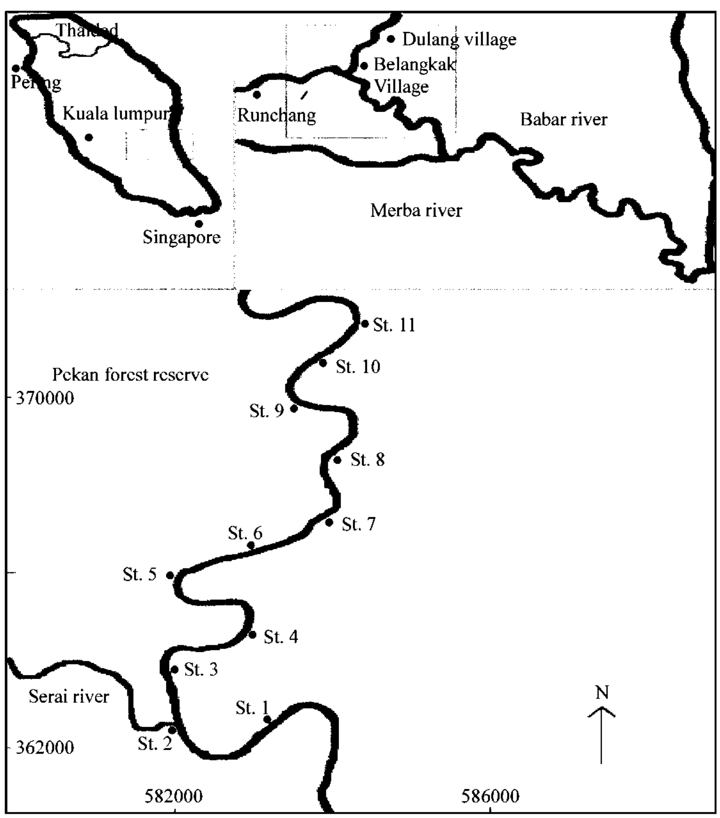

Fig. 1: Map of the study area showing 11 sampling stations along Bebar River

Water and sediment sampling: Sampling was conducted from 3 to 4 March 2005. Prior to any analysis, all equipment and container were soaked in 10% HNO_3 and rinsed thoroughly with deionized water before use. At each sampling station, water samples (surface water) were taken and stored in polypropylene bottles (30 mL×3 replicates); filtered with 0.45 μm membrane filters and acidified to pH<2 with nitric acid (70%). Sediment samples were collected using hand corer (Wildco®) and samples were taken from the upper 0-5 cm, mixed together, stored in polyethylene plastic bag (3 replicates) and kept in the dark at 4°C. Sediment samples were dried in the oven at 80°C for 48 h (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 acid hydrochloric (35%) in a block thermostat (80°C) for 3 to 4 h 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 Atomic Absorbance Spectrophotometry (AAS, model Perkin-Elmer Analyst 800) by flame or graphite furnace methods depending on the concentration. Standard and blank samples were analyzed every 20 samples. Eight elements (Cu, Cd, Pb, Zn, Cr, Ni, Fe and Mn) were measured in water samples and sediments samples. Metal concentrations in reference soil material (SRM 2711) were determined using the same analytical procedures and values obtained were within 10% range of the reference values. Water quality parameters (temperature, pH, conductivity, turbidity, total dissolved solid and dissolved oxygen) of the water were recorded at each station using a Hydrolab® Surveyor 4a system. Water hardness samples (Ca^{2+} and Mg^{+2}) were fixed with Aristar® nitric acid and measured by flame Atomic Absorbance Spectrophotometry (AAS). Total Organic Carbon (TOC) and pH of the sediment were determined in the laboratory according to method by Baize (1993).

Statistical analysis: Statistical analysis was conducted by oneway ANOVA and Tukey-Kramer multiple comparison tests using the statistical package Minitab (Ver. 12). Data were tested for normality (Shapiro-Wilk test) and homogeneity (Barlett's χ^2) and to meet these requirements, data were log10 or square root transformed. For non-parametric data, Kruskal-Wallis test were used (Fry, 1994). Correlation analyses (Pearson) were used to test the relationship between metal concentrations in the water and sediment and between water quality and sediment parameters.

RESULTS AND DISCUSSION

Water quality parameters for the 11 sampling stations in Bebar River are summarized in Table 1. Result shows that the mean temperature in Bebar River ranged from 26.08 to 29.22°C, conductivity 38.23 to 50.70 μS cm^{-1}, Total Dissolved Solid (TDS) 24.50 to 32.43 mg L^{-1}, Dissolved Oxygen (DO) 0.54 to 2.72 mg L^{-1}, water hardness 2.19 to 9.21 mg L^{-1} $CaCO_3$, pH 4.06 to 5.13 and turbidity 0 to 9.47 NTU. Statistical analyses show that all water quality parameter were significantly different between stations (ANOVA, p<0.001, Tukey-Kramer, p<0.05). However, no trend was found in physical-chemical parameters of water distribution along 11 sampling stations in Bebar River except for station 2 at the mouth of Serai River (Fig. 1) where the readings for conductivity, TDS, DO, water hardness, pH and turbidity were significantly higher (ANOVA, p<0.05; Tukey-Kramer, p<0.05) compare to other stations in Bebar River (Table 1).

Data show that the mean Total Organic Carbon (TOC) in sediment ranged from 17.76 to 68.78% and pH 3.32 to 4.21. Statistical analyses showed that there were significant differences (ANOVA, p<0.001; Kruskal-Wallis, p<0.05) for the TOC and pH for sediment between sampling stations (Table 1).

Table 1: Physico-chemical parameters (mean with SD) of surface water and sediment at 11 sampling stations in Bebar River

Station	Temperature (°C)	Conductivity (μS cm^{-1})	Total dissolved solid-TDS (mg L^{-1})	Dissolved oxygen -DO (%)	Dissolved oxygen (mg L^{-1})	Water hardness (mg L^{-1} $CaCO_3$)	pH	Turbidity (NTU)	Total organic carbon (TOC) -sediment (%)	pH (sediment)
1	28.55±0.01	39.60±0.17	25.33±0.12	10.47±0.40	0.81±0.04	4.343±0.047	4.24±0.01	0	17.76±0.28	3.50±0.04
2	29.22±0.01	50.70±0.17	32.43±0.12	35.50±0.35	2.72±0.03	9.210±0.030	5.13±0.02	9.47±0.25	20.66±0.25	3.96±0.04
3	28.68±0.05	39.53±0.06	25.33±0.06	7.03±1.01	0.55±0.08	2.610±0.010	4.08±0.01	0	51.26±10.09	3.84±0.02
4	28.40±0.02	39.03±0.25	24.93±0.15	7.70±0.66	0.60±0.05	2.357±0.025	4.06±0.02	0	34.95±0.13	3.32±0.04
5	29.14±0.18	38.23±0.15	24.50±0.10	12.90±2.08	0.99±0.16	2.493±0.025	4.22±0.01	0	56.32±0.06	3.68±0.01
6	28.88±0.04	38.57±0.15	24.70±0.10	11.10±0.69	0.85±0.06	2.413±0.021	4.17±0.03	0	62.65±0.07	4.21±0.03
7	28.56±0.04	39.20±0.00	25.10±0.00	10.83±2.97	0.84±0.23	2.463±0.012	4.09±0.00	0	57.68±0.28	3.73±0.00
8	27.77±0.02	38.77±0.15	24.80±0.10	8.67±0.57	0.68±0.04	2.393±0.012	4.21±0.01	0	40.63±4.61	3.77±0.01
9	26.72±0.01	38.93±0.06	24.93±0.06	6.73±1.93	0.54±0.15	2.403±0.021	4.17±0.02	0	68.78±0.00	3.92±0.02
10	27.30±0.16	41.23±0.12	26.37±0.06	14.03±1.78	1.11±0.14	2.187±0.012	4.24±0.00	0	44.10±0.49	3.91±0.03
11	26.08±0.06	41.53±0.25	26.60±0.10	9.53±0.64	0.77±0.06	2.317±0.025	4.26±0.01	0	64.57±3.00	3.76±0.01

Table 2: Metals concentration (Mean with SD) in the water (μg L^{-1}) and surface sediment (μg g^{-1} dry weight) at 11 stations in Bebar River, Pahang

Station	Cu	Cd	Pb	Zn	Cr	Ni	Fe	Mn	Ca	Mg
1										
Wat	0.481±0.148	0.235±0.037	0.655±0.332	40.120±4.43	2.60±0.03	1.48±0.97	1462±28	42.00±13	833±16	550±5
Sed	5.310±0.007	0.405±0.042	3.104±0.150	37.070±0.404	51.23±1.85	14.16±1.74	13 867±175	107.23±2.29	-	-
2										
Wat	0.503±0.01	0.231±0.045	0.167±0.021	39.250±0.80	5.71±0.39	1.79±0.82	1270±143	153.00±60	1413±6	1380±4
Sed	9.972±0.17	0.110±0.003	4.988±0.101	26.900±0.917	93.27±4.05	12.66±0.11	13 627±203	33.23±4.19	-	-
3										
Wat	0.399±0.042	0.194±0.006	0.331±0.119	30.960±6.07	2.61±0.11	1.25±0.52	1550±149	89.00±32	409±2	386±4
Sed	8.700±0.652	0.105±0.010	5.712±0.142	11.500±1.323	25.77±0.87	7.25±0.05	1515±135	22.57±6.74	-	-
4										
Wat	0.364±0.066	0.096±0.004	0.274±0.056	30.150±0.76	2.93±0.53	0.54±0.23	1471±137	98.00±52	375±6	345±3
Sed	261.170±1.861	0.645±0.019	1.885±0.005	53.930±0.493	31.87±1.54	4.59±0.18	3169±3859	23.50±2.80	-	-
5										
Wat	0.457±0.011	0.087±0.037	0.387±0.039	18.790±0.70	7.40±0.27	1.47±0.61	1638±53	76.00±48	379±5	376±3
Sed	338.500±1.900	0.279±0.003	3.275±0.223	55.770±0.153	37.37±6.37	9.95±1.71	4601±53	67.57±4.11	-	-
6										
Wat	0.313±0.036	0.104±0.074	0.363±0.014	40.650±0.52	6.59±0.05	0.98±0.61	1534±44	72.00±11	369±7	362±1
Sed	369.430±3.07	0.233±0.027	1.975±0.072	67.400±0.656	45.47±4.75	5.84±0.001	14329±202	182.73±3.67	-	-
7										
Wat	0.264±0.043	0.051±0.066	0.329±0.011	24.390±2.69	5.57±0.08	1.05±0.53	1465±99	108.00±4	395±4	359±3
Sed	287.900±2.05	0.777±0.078	17.530±3.523	72.970±1.332	31.80±3.21	5.64±0.007	2245±168	24.20±3.92	-	-
8										
Wat	0.302±0.064	0.059±0.011	0.308±0.013	42.120±1.97	6.64±0.05	3.85±0.56	1580±111	81.00±34	373±3	355±3
Sed	9.910±0.88	0.258±0.019	4.678±0.007	20.900±0.608	56.00±3.99	5.21±0.97	1547±189	15.20±1.57	-	-
9										
Wat	0.165±0.03	0.080±0.063	0.400±0.105	74.870±0.14	6.78±0.09	1.82±1.04	1451±96	91.00±10	374±12	356±2
Sed	353.030±2.81	0.214±0.002	1.323±0.017	91.800±1.868	71.60±3.82	5.25±1.39	10573±202	117.20±2.50	-	-
10										
Wat	0.772±0.06	0.122±0.008	0.409±0.054	41.950±1.10	5.65±0.04	1.08±0.41	1450±208	120.00±15	349±5	320±1
Sed	8.504±0.26	0.070±0.011	2.085±0.095	12.770±1.328	76.77±2.21	4.52±0.12	11831±207	191.03±4.87	-	-
11										
Wat	0.679±0.13	0.180±0.148	0.338±0.021	53.070±5.15	5.46±0.02	0.97±0.19	1409±21	90.00±40	389±6	327±2
Sed	8.384±0.78	0.070±0.018	1.172±0.021	9.833±0.833	73.37±2.90	9.92±0.80	15681±227	259.63±4.94	-	-

Wat: Water; Sed: Sediment; - Ca and Mg in sediment samples were not measured

Table 3: Criteria of metal concentrations in freshwater ecosystems

Metal	CCME- protection of Aquatic Life (μg L^{-1})	EPA- criteria Maximum Concentration (CMC) μg L^{-1}	EPA- criterion Continuous concentration (CCC) μg L^{-1}	INWQS class II (μg L^{-1})	CCME-Freshwater sediment (μg g^{-1}) ISQG[b]	PEL[c]
Copper (Cu)	2-4	13	9.0	20	35.7	197
Cadmium (Cd)	0.017	2.0	0.25	10	0.6	3.5
Lead (Pb)	1-7	65	2.5	50	35	91.3
Zinc (Zn)	30	120	120	5000	123	315
Chromium[a] (Cr)	8.9	570	74	50[e]	37	90
Nickel (Ni)	25-150	470	52	50	22.7[d]	48.6[d]
Iron (Fe)	300	-	1000	1000	-	-
Manganese (Mn)	-	-	-	100	-	-

Sources: CCME 1999; INWQS (Tong and Goh, 1997); EPA 2004, [a]Trivalent chromium (Cr(III)), [b]ISQG-Interim sediment quality guideline, [c]PEL-Probable effect level, [d]Source from MacDonald *et al.* (2000), [e]Hexavalent chromium (Cr(VI))

Results show that dissolved Cu in the water (μg L^{-1}) ranged from 0.165 to 0.772, Cd 0.051 to 0.235, Pb 0.167 to 0.655, Zn 18.79 to 74.87, Cr 2.60 to 7.40, Ni 0.54 to 3.85, Fe 1270 to 1638, Mn 42 to 153, Ca 349 to 1413 and Mg 320 to 1380. Statistical analyses show that there were significant differences of Cu, Pb, Zn, Cr, Ca and Mg (but not Cd, Ni, Fe and Mn) in the water between stations (ANOVA, $p<0.05$, Tukey-Kramer, $p<0.05$). In sediment, Cu (μg g^{-1} dry weight) was found in the ranged of 5.3 to 369.4, Cd 0.07 to 0.78, Pb 1.17 to 17.53, Zn 9.83 to 91.80, Cr 25.77 to 93.27, Ni 4.52 to 14.16, Fe 1515 to 15681 and Mn 15.20 to 259.63. Statistical analyses show that the metals differences were significant between stations (ANOVA, $p<0.001$; Tukey-Kramer, $p<0.05$). However, no trend was found for metal distribution in the water and sediment along 11 sampling stations in Bebar River (Table 2). Table 3 shows criteria of metal concentration of freshwater ecosystems.

Correlation analyses were conducted to determine the relationship between metal concentration in the water and sediment and the influence of physical-chemical parameter of water and sediment on metals concentration in water/sediment (Table 4). Results show that only Cu and Cr have significant positive relationship between metal concentration in the sediment and water (Cu $r = 0.585$, $p<0.01$; Cr $r = 0.431$, $p<0.05$). Other physical-chemical parameters such as temperature, conductivity, TDS, water hardness, pH and turbidity have significant correlation ($p<0.05$) with metals concentration in the water and sediment (Table 4).

Table 4: Person correlation coefficients (r) between metal concentration in the water, sediment and physical-chemical parameters (n = 22)

Metal and Physical-chemical parameters	Cu (w)	Cu (s)	Cd (w)	Cd (s)	Zn (w)	Zn (s)	Pb (w)	Pb (s)	Fe (w)	Fe (s)	Mn (w)	Mn (s)	Cr (w)	Cr (s)	Hard	Ni (w)	Ni (s)	T	Con	TDS	DO	pH (w)	Tur	TOC (s)
Cu (s)	0.59**																							
Cd (w)	0.39	0.48*																						
Cd (s)	0.53*	-0.58**	-0.47*																					
Zn (w)	0.15	-0.23	-0.14	0.42																				
Zn (s)	0.69***	0.86***	0.40	-0.75***	-0.14																			
Pb (w)	0.07	-0.01	0.03	0.14	-0.13	-0.09																		
Pb (s)	0.17	-0.03	0.29	-0.39	-0.58**	0.11	0.20																	
Fe (w)	0.05	0.05	0.18	0.03	-0.16	-0.06	-0.40	-0.05																
Fe (s)	-0.33	-0.05	-0.36	0.39	0.50*	0.03	-0.15	-0.61	-0.30															
Mn (w)	-0.04	0.22	-0.04	-0.36	-0.26	0.29	-0.48	-0.14	0.07	0.06														
Mn (s)	-0.32	0.02	-0.20	0.45*	0.44*	-0.07	-0.40	-0.66**	0.09	0.85***	0.09													
Cr (w)	0.18	0.37	0.35	0.17	0.13	0.24	0.15	-0.07	-0.01	0.18	-0.21	0.28												
Cr (s)	-0.25	-0.37	-0.19	0.57**	0.70***	-0.24	0.16	-0.43*	-0.31	0.68***	-0.31	0.49*	0.43*											
Hard	-0.19	-0.35	-0.39	0.11	0.02	-0.02	0.41	0.23	-0.56**	0.33	-0.06	-0.15	-0.13	0.39										
Ni (w)	-0.23	-0.17	0.03	0.23	0.09	-0.23	-0.06	-0.06	0.06	0.04	-0.12	0.11	0.11	0.22	-0.14									
Ni (s)	-0.37	-0.39	-0.39	0.17	-0.11	-0.17	-0.01	0.05	-0.26	0.38	0.27	0.17	-0.18	0.18	0.67**	-0.33								
T	0.09	0.18	0.01	-0.44*	-0.63**	0.35	0.22	0.60**	-0.08	-0.25	0.25	-0.47	-0.22	-0.45	0.43*	-0.10	0.18							
Con	-0.42*	-0.42*	-0.38	0.48*	0.13	-0.31	0.58**	0.05	-0.58**	0.40	-0.32	-0.01	0.09	0.60**	0.84***	0.02	0.50*	0.12						
TDS	0.42*	0.43*	0.38	-0.49*	-0.13	0.31	-0.58**	-0.05	0.58**	-0.40	0.33	-0.01	-0.09	-0.61**	-0.84***	-0.02	-0.50*	-0.12	-1.00					
DO	0.10	-0.22	-0.19	0.21	0.17	-0.09	0.70***	0.06	-0.44*	-0.03	-0.26	-0.42	-0.13	0.28	0.66**	-0.18	0.24	0.14	0.70***	-0.70***				
pH	-0.24	-0.33	-0.28	0.34	0.19	-0.13	0.57**	0.13	-0.64**	0.42	-0.32	-0.02	0.19	0.65**	0.89***	-0.01	0.47*	0.22	0.95***	-0.95***	0.66**			
Tur	-0.43*	-0.38	-0.31	0.53*	0.26	-0.42	0.50*	-0.16	-0.60**	0.46*	-0.35	0.20	0.15	0.57**	0.56**	-0.16	0.53	-0.23	0.79***	-0.80***	0.46*	0.74***		
TOC(s)	0.31	0.50*	0.44*	0.09	0.03	0.09	-0.12	-0.10	0.36	-0.21	-0.14	0.19	0.48*	-0.24	-0.77***	-0.03	-0.50*	-0.40	-0.52*	0.51*	-0.39	-0.54**	-0.19	
pH (s)	0.09	0.02	0.01	0.53*	0.34	-0.06	0.15	-0.03	0.07	0.30	-0.30	0.35	0.58**	0.41	0.07	0.11	-0.09	0.03	0.23	-0.23	0.04	0.33	0.17	0.33

w: Metal in water; s: Metal in sediment; Hard: Water hardness; T: Temperature; Con: Conductivity; Tur Turbidity, *indicates a significant relationship (p<0.05). **Indicates a significant relationship (p<0.01). ***Indicates a significant relationship (p<0.001)

Comparison with Malaysian Interim Water Quality Standard (INWQS) (Tong and Goh, 1997) showed that water temperature in Bebar River is in normal range, conductivity in class I (<1000 µS cm^{-1}), TDS in class I (<500 mg L^{-1}), DO in class IV (1-3 mg L^{-1}) to V (<1 mg L^{-1}), water hardness in normal range (soft water, <75 mg L^{-1} $CaCO_3$), pH in class III (3-5) and turbidity in class I (<5 NTU) to II (<50 NTU). All parameters measured were in normal range or class I (good) except for pH and DO which are the characteristic of peat swamp water (with low DO and acidic water). Gasim *et al*. (2007) reported similar results for pH and DO of Bebar River with pH range from 3.53 to 4.55 and DO 0.54 to 1.76 mg L^{-1}. Baum *et al*. (2007) reported that pH for blackwater river in central Sumatran was 4.4 to 4.7. Turbidity was not detected (zero) at all sampling stations except at station 2 where the reading was 9.47±0.25 NTU. This was contributed mainly by suspended sediment from Serai River which flow into Bebar River. Other water quality parameters such as conductivity, TDS, DO, water hardness and pH were also affected at this station by the flow in of Serai River (Table 1). Serai River is one of the main tributary that flow into Bebar River and the river flow through Runchang residential area on the south-west before joint with Bebar River (Fig. 1). Serai River is a normal freshwater river and the mixing with blackwater Bebar River at station 2 increased the reading of some water quality parameters such as DO, pH and conductivity.

This study showed that for sediment parameters in Bebar River, there was no trend in pH and TOC distribution along 11 sampling stations. TOC and pH for the sediments were found highest at station 9 (68%) and 6 (4.21) and lowest at station 1 (17%) and 4 (3.32) respectively. High organic carbon in the sediment from the sampling area is normal for peat sediment which according to FRIM-UNDP/GEF (2004) a result of peat swamp forest develops on organic soil where the organic matter content is greater than 65%. Other study also reported similar observation (Baum *et al*., 2007). Organic matter content is a critical factor influencing the metal distribution in sediments (Barroso *et al*., 2009). Doig and Liber (2006) reported that organic matter strongly influenced Ni partitioning and that Ni complexation to organic matter was significantly influenced by pH, with a complexation increase with increasing pH (from pH 6 to 8).

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 (1976) (EPA, 2004) i.e., for Criteria Maximum Concentration (CMC) and Criterion Continuous Concentration (CCC) and Malaysian Interim Water Quality Standard (INWQS) (Tong and Goh, 1997) (Table 3). Results show that Cu, Cd, Pb, Cr and Ni concentrations in the water were low and in the range of natural concentrations. Zinc concentrations were higher than CCME guideline (<30 µg L^{-1}) at all stations except stations 5 and 7, however it's still lower than EPA guideline (<120 µg L^{-1}). Iron concentration was higher than 1000 µg L^{-1} at all stations and exceeded the CCME, EPA and INWQS guidelines while Mn concentrations were higher than INWQS guideline at some stations (>100 µg L^{-1}) i.e., stations 2, 7 and 10. High concentrations of these metals at some stations are inexplicable and further studies are needed. However, iron concentrations were also reported high in natural lakes in Peninsular Malaysia such as Lake Chini (794.84 µg L^{-1}) and Lake Bera (180-1950 µg L^{-1}) about 30-50 km from Bebar River (Ikusima *et al*., 1982; Othman *et al*., 2008). This is probably due to soil composition of Peninsular Malaysia which mainly consists of laterite which is rich in iron and aluminium (Aleva, 1994). No published data were found in the literature for metals concentration in the water and sediment for the study area. Only one study has been reported on mercury (Hg) in fish sampled from Bebar River and the authors concluded that Hg concentration in several parts of fish tissues and organs were still lower than the limit for human consumption recommended by WHO (Kamaruzzaman *et al*., 2007).

Metal concentrations in the sediment were compared with the Canadian Environmental Quality Guidelines (Table 3) for freshwater sediment i.e. for interim sediment quality guideline (ISQG) and probable effect level (PEL) (CCME, 1999). Results show that Cd, Pb, Zn and Ni concentrations in sediment were low and in the range of natural concentrations (CCME, 1999; MacDonald *et al*., 2000). Copper concentration in the sediment has a varied range from 5.3 to 369 µg g^{-1} and no trend was observed in its distribution among stations. Stations 4, 5, 6, 7 and 9 recorded high Cu concentration that exceeded the PEL concentrations (>197 µg g^{-1}). Chromium concentration also exceeded the ISQG concentration (37 µg g^{-1}) at all stations except station 3, 4 and 7 and station 2 recorded highest concentration that exceeded PEL concentration (>90 µg g^{-1}). Correlation analysis show that there are significant positive relationship between Cu and Cr concentrations in the sediment and water (Cu $r = 0.585$, $p<0.01$; Cr $r = 0.431$, $p<0.05$) and these results are corresponding with high Cu and Cr concentrations in sediment at some stations (Table 4). Correlation analysis also showed positive significant correlation between TOC in sediment and Cu concentration in sediment ($r = 0.44$, $p<0.05$).

High organic carbon was known to influence metal bioavailability and its distribution (Aloupi and Angelidis, 2001; Liaghati *et al*., 2003; Barroso *et al*., 2009) and this might explain high Cu and Cr concentrations in the sediments at some stations in Bebar River. Water quality parameters were known to influence the availability and accumulation of metal by aquatic organisms. Other studies have shown that water quality factors such as alkalinity, pH and organic carbon might influence metal bioavailability and bioaccumulation in the natural environment (Bradley and Morris, 1986; King *et al*., 1992; Reimer and Duthie, 1993). Harter (1983) reported that soil pH appears to be important factor regulating the solubility of heavy metals. Aloupi and Angelidis (2001) and Liaghati *et al*. (2003) reported that the distribution of grain size and organic matter content were two critical factors influencing the metal distribution in sediments. The capacity of adsorption of metals is in increasing order, sand<silt<clay, due to the increase in the superficial area and to the content of minerals and organic matter and the organic matter plays a great role in binding the metals in ligands (Barroso *et al*., 2009). Low dissolved oxygen, water hardness and pH of the Bebar River could increase metals toxicity to the biota. Pascoe *et al*. (1986) reported that low Ca ion concentrations increased the acute toxicity of cadmium to rainbow trout and low dissolved oxygen increased toxicity of farm waste to macroinvertebrates (McCahon *et al*., 1991). Mackie (1989) noted that toxicity of cadmium to *H. azteca* increased with decrease in pH (pH 6 to 5). Metals complexes with organic and inorganic ligands tend to dissociate as pH decreases, resulting in increased free ion concentrations which lead to greater toxicity to biota in acidic conditions than in neutral water (Campbell and Stokes, 1985). These conditions made Bebar River water, organisms and its natural habitat sensitive to metal pollution.

CONCLUSION

This study showed that the physical-chemical parameters of water and sediment in Bebar River were in normal range/class I (good) except for pH and dissolved oxygen for the water; however it is normal for peat water (blackwater). Metals concentration in the water (Cu, Cd, Pb, Cr and Ni) was in the range of natural concentrations except for Zn, Fe and Mn concentration were higher than recommended concentrations at some stations. Cd, Pb, Zn and Ni concentrations in sediment were low and in the range of natural concentrations. However, Cu and Cr concentration in the sediment were high at some stations. This study showed that Bebar River is a vulnerable and sensitive ecosystem especially to metal pollution and care has to be taken to preserve this area from development and other indiscriminate human activities. It is important to maintain adequate riparian buffer for the Bebar River which is an important part of the riverine ecology and also its can reduce excessive runoffs into the water bodies (FRIM-UNDP/GEF, 2004).

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REFERENCES

Aleva, G.J.J., 1994. Laterites Concepts Geology Morphology and Chemistry. ISRIC, Wageningen, The Netherlands, pp: 169.

Aloupi, M. and M.O. Angelidis, 2001. Geochemistry of natural and anthropogenic metals in the coastal sediments of the island of Lesvos Aegean Sea. Environ. Pollut., 113: 211-219.

Baize, D., 1993. Soil Science Analysis-a Guide to Current Use. John Wiley and Son, Chichester, ISBN: 0471934690.

Barroso, M.R.R., J.L.G. Morales, M.D.C. Oviedo and J.M.Q. Alonso, 2009. An assessment of heavy metal contamination in surface sediment using statistical analysis. Environ. Monit. Assess., (In Press).

Baum, A., T. Rixen and J. Samiaji, 2007. Relevance of peat draining rivers in central Sumatra for the riverine input of dissolved organic carbon into the ocean. Estuarine Coastal Shelf Sci., 73: 563-570.

Borgmann, U. and W.P. Norwood, 1995. Kinetics of excess (above background) copper and zinc in *Hyalella azteca* and their relationship to chronic toxicity. Can. J. Fish. Aquat. Sci., 52: 864-874.

Bradley, R.W. and J.R. Morris, 1986. Heavy metals in fish from a series of metal contaminated lakes near sudbury ontario. Water Air Soil Pollut., 27: 341-354.

Bryan, G.W. and W.J. Langston, 1992. Bioavailability, accumulation and effects of heavy metals in sediment with special reference to United Kingdom Estuaries a review. Environ. Pollut., 76: 89-131.

Campbell, P.G.C. and P.M. Stokes, 1985. Acidification and toxicity of metals to aquatic biota. Can. J. Fish. Aquat. Sci., 42: 2034-2049.

CCME, 1999. Canadian environmental quality guidelines. Canadian Council of Ministers of the Environment, Winnipeg, pp: 61.

Doig, L.E. and K. Liber, 2006. Nickel partitioning in formulated and natural freshwater sediments. Chemosphere, 62: 968-979.

EPA (Environmental Protection Agency, United State), 2004. National Recommended Water Quality Criteria. Office of Science and Technology, Washington, DC.

FRIM-UNDP/GEF, 2004. Blackwater jewel-South-East Pahang peat swamp forest. Peat Swamp Forest Project and the Pahang Forestry Department in Collaboration with Wetland International-Malaysia, pp: 54.

Fry, J.C., 1994. Biological Data Analysis a Practical Approach. Oxford University Press, Oxford, ISBN: 0-19-963339-8, pp: 418.

Förstner, U. and G.T.W. Wittmann, 1981. Metal Pollution in the Aquatic Environment. Spring-Verlag, Berlin, New York.

Gasim, M.B., B.S. Ismail, E. Toriman, S.I. Mir and C.C. Tan, 2007. A physico-chemical assessment of the Bebar River Pahang, Malaysia. Global J. Environ. Res., 1: 7-11.

Graney, R.L., J.P. Giesy and J.R. Clark, 1995. Field Studies. In: Fundamental of Aquatic Toxicology: Effects, Environmental Fate and Risk Assessment, Rand, G.M. (Ed.). 2nd Edn., Taylor and Francis, Bristol, PA., pp: 257-304.

Harter, R.D., 1983. Effect of soil pH on adsorption of lead copper zinc and nickel. Soil Sci. Soc. Am. J., 47: 47-51.

Hoffman, D.J., A. Barnett, G. Rattner, A. Burton, and J. Cairns, 2003. Introduction. In: Handbook of Ecotoxicology, Hoffman, D.J., A. Barnett, G. Rattner, A. Burton, and J. Cairns (Eds.). 2nd Ed., Lewis Publisher, CRC Press LLC., New York, ISBN: 1-56670-546-0.

Ikusima, I., R.P. Lim and J.I. Furtado, 1982. Environmental Conditions. In: Tasek Bera the Ecology of a Freshwater Swamp, Furtado, J.I. and S. Mori (Eds.). The Hague Junk Publishers, Netherland, ISBN: 90-6193-100-2, pp: 55-148.

Kamaruzzaman, B.Y., M.C. Ong and A.H. Khali, 2007. Mercury concentration of four dominant species in Bebar peat swampy forest river Malaysia. Pak. J. Biol. Sci., 10: 1103-1107.

Kendrick, M.J., M.T. May, M.J. Plishka and K.D. Robinson, 1992. Metals in Biological Systems. Ellis Harwood Limited, New York, pp: 183.

King, S.O., C.E. Mach and P.L. Brezonik, 1992. Changes in trace metal concentrations in lake water and biota during experimental acidification of Little Rock Lake Wisconsin, USA., Environ. Pollut., 78: 9-18.

Liaghati, T., M. Preda, and M. Cox, 2003. Heavy metal distribution and controlling factors within coastal plain sediments Bells Creek catchment southeast Queensland Australia. Environ. Int., 29: 935-948.

MacDonald, D.D., C.G. Ingersoll and T.A. Berger, 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch. Environ. Contam. Toxicol., 39: 20-31.

Mackie, G.L., 1989. Tolerence of five benthic invertebrates to hydrogen ions and metals (Cd, Pb, Al). Arch. Environ. Contam. Toxicol., 18: 215-223.

McCahon, C.P., M.J. Poulton, P.C. Thomas, Q. Xu, D. Pascoe and C. Turner, 1991. Lethal and sub-lethal toxicity of field simulated farm waste episodes to several freshwater invertebrate species. Water Res., 25: 661-671.

Othman, M.S., I. Mushrifah, E.C. Lim and A. Ahmad, 2008. Trend in metals variation in tasik chini pahang peninsular Malaysia. Environ. Monit. Assess., 143: 345-354.

Pascoe, D., S.A. Evans and J. Woodworth, 1986. Heavy metal toxicity to fish and the influence of water hardness. Arch. Environ. Contam. Toxicol., 15: 481-487.

Rand, G.M, P.G. Wells and L.S. McCarty, 1995. Introduction to Aquatic Toxicology. In: Fundamentals of Aquatic Toxicology Effects Environmental Fate and Risk Assessment, Rand, G.M. (Ed.). 2nd Edn., Taylor and Francis, Washingtioc, DC.

Reimer, P. and H.C. Duthie, 1993. Concentrations of zinc and chromium in aquatic macrophytes from the Sudbury and Muskoka regions of Ontario, Canada. Environ. Pollut., 79: 261-265.

Sinex, S.A., A.Y. Cantillo and G.R. Helz, 1980. Accuracy of acid extraction methods for trace metals in sediments. Anal. Chem., 52: 2342-2346.

Tong, S.L. and S.H. Goh, 1997. Water quality criteria and standard development and river classification in Malaysia. J. Ensearch, 10: 15-26.

U.S. Environmental Protection Agency, 1976. Quality Criteria for Water. Office of Water and Hazardous Materials Rep. U.S. Environmental Protection Agency, Washington, DC.

Wang. W.X. and P.S. Rainbow, 2008. Comparative approaches to understand metal bioaccumulation in aquatic animals. Comp. Biochem. Physiol. Part C Toxicol. Pharmacol., 148: 315-323.

Zhou, Q., J. Zhang, J. Fu, J. Shi and G. Jiang, 2008. Biomonitoring an appealing tool for assessment of metal pollution in the aquatic ecosystem. Anal. Chim. Acta, 606: 135-150.