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Full Length Article

Water Quality Monitoring in Upper Ping River, Thailand

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ABSTRACT

Concentrations of heavy metals (Cd, Hg, Pb & Fe) were measured in the water and bottom sediment of the Ping River in Chiang Mai and Lumphun Provinces collected from six different sites. Since water quality is influenced by the metal content in water, measurements of the physical (temperature & conductivity) and chemical (pH, dissolved oxygen, total Kjehldahl nitrogen and total phosphorus parameters were also taken at each site. Results for the levels in the tested water were compared to the national water quality guidelines. The concentrations of heavy metals in the water were below the detectable limit, while the concentration in the sediments were < 0.01 – 0.07, 0.32 – 5.95, 0.18 – 1.10 and 0.09 – 1.16 mg kg^{-1} for Cd, Hg, Pb and Fe, respectively. These data will be used as a reference for future studies in monitoring heavy metals and their impact on the water quality in the Upper Ping River. In addition, the heavy metals accumulation in sediment can be implied as basic information for further study on the bioaccumulation and biomagnification of heavy metals in different trophic levels are highly recommended.

Key Words: Heavy metal; Cd; Hg; Pb; Fe; Ping river

INTRODUCTION

Ping River, approximately 600 km long, is one of the most important rivers in Thailand. People along this river use water for many purposes. However, the surface water quality is deteriorating due to anthropogenic activities, industrialization, farming activities, transportation, urbanization, animal and human excretions and domestic wastes. Some effluents are directly discharged into this river without treatment. Urban areas can cause aquatic contamination by multiple sources such as road runoff (Sansalone & Buchberger, 1997; Legret & Pagotto, 1999) and roof runoff (Good, 1993; Förster, 1996) probably resulting in high metal loads in urban storm water (Boller, 1997). An urban sewer, which generally collects industrial wastewaters is a major metal contamination source in densely populated area (Bergbäck *et al*., 2001; Sörme & Lagerkvist, 2002). As a result, the municipal treatment plants must be efficient in removing these contaminants. Currently, the fish die-off phenomenon occurs more often while some aquatic organisms have migrated. For this reason, it is very important to routinely monitor the water quality in the Ping River in order to get the data which can be used for effective management policies.

In addition to affecting water quality, sediments usually serve as a pool for pollutants (Fatoki & Mathabatha, 2001; McCready *et al*., 2006). The distribution of metals in sediments adjacent to human settlement and industrial areas can provide researchers with evidence of the anthropogenic impact on ecosystems and therefore, aid in assessing the risks associated with discharged human waste (Demirak *et al*., 2006). These trace metals are able to move towards the water column or accumulate in plants and consequently enter the food chain. Of major concern about the presence of some metal ions in the environment are potential adverse health effects to humans, animals, plants and ecosystems in general.

The objectives of this research were: (1) to assess the physicochemical properties and the distribution of heavy metals such as Cd, Hg, Pb and Fe of water and sediment in the Upper Ping River in Chiang Mai and Lamphun provinces and (2) to compare these data with the former report data of the Ping River.

MATERIALS AND METHODS

Water and surface sediment samples were collected in the Upper Ping River in Chiangmai and Lamphun provinces. A map of the six sampling locations is shown in Fig. 1. The sampling locations were upstream from Chiangmai Municipality (station 1), inside the Chiangmai Municipality (station 2), below from Chiangmai Municipality (station 3), upstream from Lamphun Municipality (station 4), inside the Lamphun Municipality

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(station 5) and below from Lamphun Municipality (station 6). The sampling stations were chosen from the locations of the Ping River exposed to rapid growing metropolitan cities.

Temperature, pH, conductivity, transparency and dissolved oxygen were measured at the time of sample collection. Surface water samples were collected in clean acid-washed polyethylene bottles. Samples were acidified with 10% HNO3, placed in an ice box and brought to the laboratory. The samples were filtered through a Whatman filter paper and analyzed within 24 h. Other parameters such as BOD, COD, nitrates and phosphate were immediately analyzed upon laboratory arrival. Azide modification method was used to determine BOD. Closed reflux method was used to determine COD. Total phosphorus (Total-P) was measured by acid digestion followed by titration (APHA). In Total Kjehldahl Nitrogen (TKN) analysis, the digestion and titration method was carried out according to the procedures by APHA, AWWA and WEA (1998).

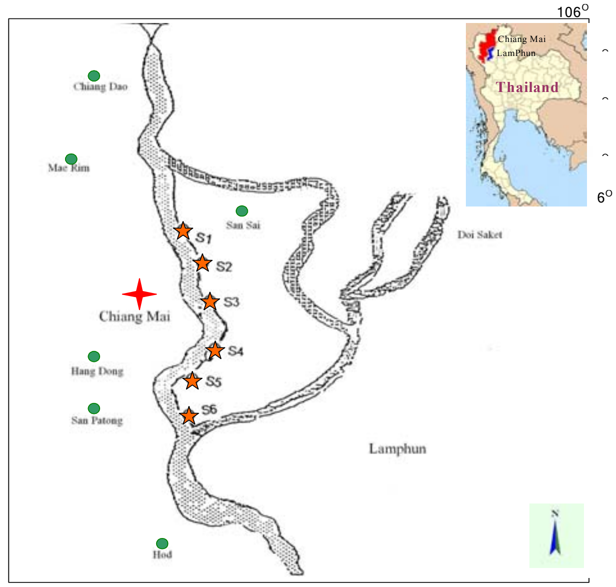
The surface sediment samples (to a depth of 10 cm) were taken with an Ekman grab sampler. All of the sediment samples were stored in plastic bags at 4°C immediately after collection and prior to undergoing processing in a laboratory. Samples were collected monthly and dried in an oven at 65°C for at least 24 h. The dried sediments were ground to powder using an agate mortar and pestle. The particles with size less than 63 µm were collected and used for the heavy metal analysis. The sediment samples were digested in concentrated nitric and perchloric acids to dissolve heavy metals and major elements in solution. A 0.250 g of ground sediment samples was weighed and placed into acid-washed Pyrex test tubes. A 10 mL of nitric acid and 2.5 mL of perchloric acid were added to each tube. Each mixture was gently shaken using a vortex and then placed in an aluminum-heating block completely dry. After cooling, 10 mL of 5% nitric acid was added to the residue and heated at 70°C for 1 h. The mixture was shaken gently, poured into polyethylene tubes, and centrifuged prior to undergoing metal concentration analyses. The Cd, Hg, Pb and Fe concentrations were measured by Atomic Absorption Spectroscopy. Blanks were included in each batch of analysis. Calibration standards were regularly performed to evaluate the accuracy of the analytical method.

Statistical analysis. Data analysis (mean & standard deviation) using statistical methods were performed in this study. Differences in each water quality variable and heavy metals between sampling sites were tested using analysis of variance (ANOVA) followed by a Duncan's Multiple Rang Test (DMRT), processed by the SPSS 11.5 computer package. Results of testing were considered significant if calculated P-values were < 0.05.

RESULTS AND DISCUSSION

Mean temperature, pH, conductivity, DO, BOD, COD, TKN and Total-P in water in winter, summer and rainy seasons are presented in Table I. There were no differences

Fig. 1. Six sampling sites of Ping River at Chiang Mai and Lamphun Province Site 1 Chiangmai Municipality, Site 2 Inside the Chiangmai Municipality, Site 3 Below from Chiangmai Municipality, Site 4 Upstream from Lamphun Municipality, Site 5 Inside the Lamphun Municipality, Site 6 Below from Lamphun Municipality



in the stations for all parameters (P > 0.05), which implied that the municipal wastewater treatments in both provinces were equally effective. In addition, the water qualities in those sites were acceptable at that time. The pH did not vary much. However, seasonal variation in conductivity, DO, TKN and Total-P was found.

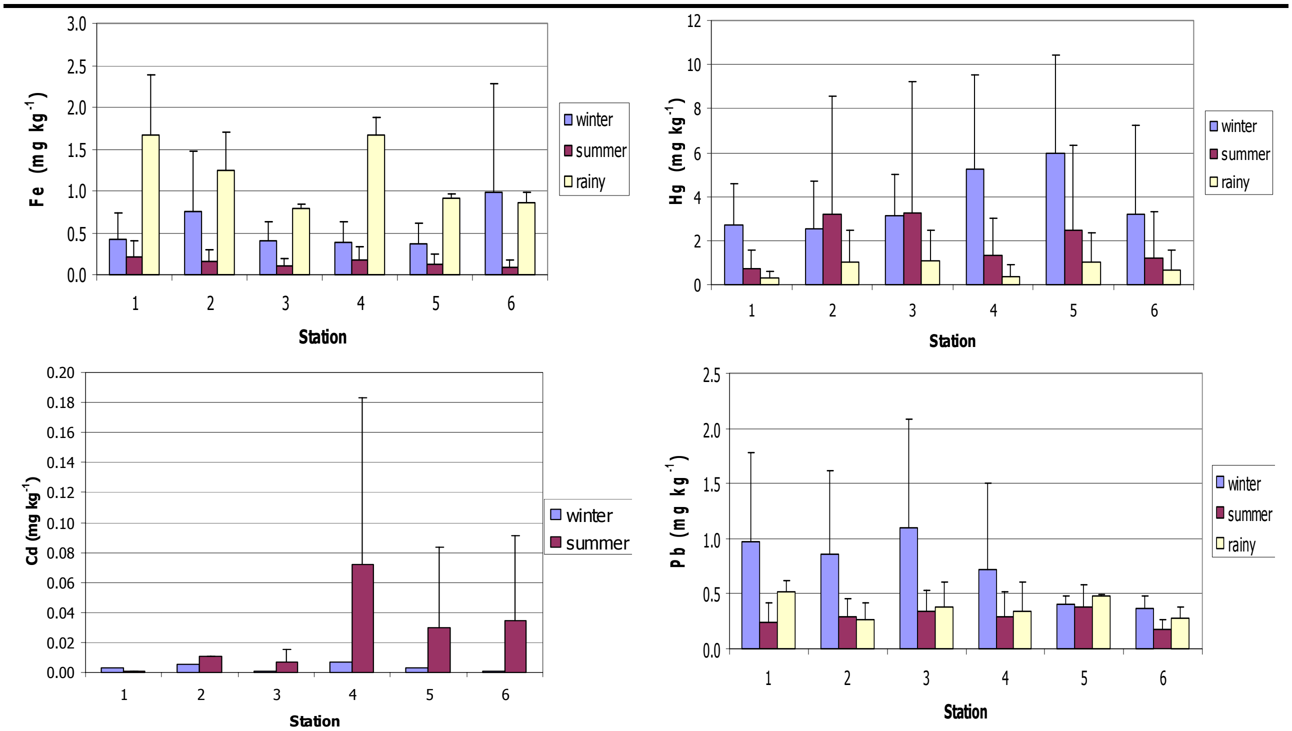
Water quality regulations in Thailand divide inland surface waters into five classes. Class I refers to clean water that can be used for domestic purposes after simple disinfection, for recreational purposes or for irrigation. Class II refers to fairly clean water that can be used as domestic water after treatment, for recreational purposes or for fishing, farming, etc. Class III includes polluted water, which can be used after water improvement. This water can also be used for agricultural purpose. Class IV includes polluted water, which can only be used as industrial water after treatment. Class IV refers to heavily polluted water that can only be used for transportation and should not be used for other purposes at all. Referring to pH, BOD and DO parameters, the water in the Upper Ping River was classified as class III. One of the serious problems in the water deterioration of the Upper Ping River is caused by soil erosion because of highland agriculture and deforestation. This affects the aquatic organisms and increases the cost of tap water preparation. Conductivity tests were in the range of 170 – 286 µs cm^{-1}. Conductivity can be used as a tool to classify according to grain size distribution of sediments; higher electric conductivity is representative of fine grained sediments, such as silt or clay, while sand is characterized by distinctly lower electric conductivity (Segura *et al*., 2006).

Table I. The distribution of mean temperature, pH, conductivity, DO, BOD, COD, Total Kjehldahl Nitrogen (TKN) and Total Phosphorus (Total-P) in water from six stations* in winter, summer and rainy seasons**

			Winter			
Parameter	**Station 1**	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**
water-temp °C	24.14 ± 1.38	24.58 ± 1.51	24.88 ± 1.03	24.10 ± 1.25	24.63 ± 0.85	25.10 ± 2.08
pH	6.95 ± 0.42	6.93 ± 0.48	6.99 ± 0.40	6.84 ± 0.31	6.94 ± 0.38	6.99 ± 0.36
Cond. 2000 us cm^{-1}	242.75 ± 48.05a	239.50 ± 52.94a	238.67 ± 33.42a	286.17 ± 75.50a	258.08 ± 48.88a	267.50 ± 52.75a
DO (mg L^{-1})	6.78 ± 0.34df	6.44 ± 0.36df	6.30 ± 0.52df	5.75 ± 1.23df	6.25 ± 1.11df	6.25 ± 0.88df
BOD (mg L^{-1})	2.41 ± 1.27	2.36 ± 0.44	2.52 ± 0.27	2.06 ± 0.28	2.58 ± 0.34	2.21 ± 0.50
COD (mg L^{-1})	8.01 ± 1.83	8.01 ± 1.83	9.62 ± 0.04	8.82 ± 1.61	8.01 ± 1.83	7.21 ± 1.59
TKN (mg L^{-1})	1.29 ± 0.21gi	1.23 ± 0.24gi	1.17 ± 0.12gi	1.33 ± 0.36gi	1.39 ± 0.34gi	1.51 ± 0.35gi
Total-P (mg L^{-1})	0.18 ± 0.06j	0.22 ± 0.09j	0.22 ± 0.06j	0.23 ± 0.13j	0.20 ± 0.15j	0.14 ± 0.16j
			Summer			
Parameter	**Station 1**	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**
water-temp °C	29.47 ± 1.47	30.12 ± 1.45	30.53 ± 1.47	30.25 ± 2.28	30.43 ± 1.80	31.15 ± 1.84
pH	6.82 ± 0.25	7.10 ± 0.29	7.17 ± 0.25	6.92 ± 0.24	7.09 ± 0.32	7.06 ± 0.31
Cond. 2000 us cm^{-1}	208.20 ± 22.60b	213.27 ± 31.30b	216.07 ± 30.10b	237.40 ± 33.69b	233.60 ± 31.84b	242.00 ± 34.28b
DO (mg L^{-1})	5.95 ± 0.24ef	5.63 ± 0.26ef	5.65 ± 0.29ef	5.54 ± 0.56ef	6.01 ± 0.21ef	5.47 ± 0.29ef
BOD (mg L^{-1})	3.08 ± 0.76	2.17 ± 0.58	2.21 ± 0.81	2.07 ± 0.36	2.83 ± 0.70	2.43 ± 0.47
COD (mg L^{-1})	9.60 ± 0.01	8.96 ± 1.43	8.32 ± 1.75	7.68 ± 1.75	9.60 ± 0.00	8.96 ± 1.43
TKN (mg L^{-1})	1.06 ± 0.11hi	1.20 ± 0.16hi	1.12 ± 0.15hi	1.23 ± 0.25hi	1.23 ± 0.35hi	1.33 ± 0.37hi
Total-P (mg L^{-1})	0.31 ± 0.10k	0.34 ± 0.12k	0.34 ± 0.17k	0.29 ± 0.14k	0.27 ± 0.16k	0.29 ± 0.20k
			Rainy Season			
Parameter	**Station 1**	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**
water-temp °C	27.28 ± 0.82	27.65 ± 1.30	27.82 ± 1.15	27.20 ± 1.32	28.15 ± 0.21	29.10 ± 0.24
pH	7.13 ± 0.31	6.91 ± 0.09	6.99 ± 0.05	6.51 ± 0.25	6.86 ± 0.06	6.86 ± 0.13
Cond. 2000 us cm^{-1}	170.33 ± 0.00c	171.00 ± 0.94c	170.83 ± 0.24c	188.00 ± 2.36c	184.83 ± 14.38c	184.33 ± 11.31c
DO (mg L^{-1})	5.88 ± 0.35f	6.28 ± 0.07f	5.98 ± 0.12f	5.78 ± 0.78f	6.32 ± 0.12f	6.02 ± 0.45f
BOD (mg L^{-1})	2.37 ± 0.19	2.33 ± 0.28	2.30 ± 0.05	2.37 ± 0.24	2.28 ± 0.26	2.53 ± 0.00
COD (mg L^{-1})	8.03 ± 2.23	8.03 ± 2.23	6.43 ± 0.04	8.04 ± 2.32	8.04 ± 2.32	8.04 ± 2.32
TKN (mg L^{-1})	1.07 ± 0.02i	1.03 ± 0.01i	1.03 ± 0.03i	1.05 ± 0.02i	1.05 ± 0.03i	1.10 ± 0.04i
Total-P (mg L^{-1})	0.42 ± 0.02l	0.38 ± 0.10l	0.44 ± 0.02l	0.43 ± 0.02l	0.43 ± 0.03l	0.42 ± 0.05l

*There were no differences in the stations for all parameters ($P > 0.05$). **Different letters in same column indicate significant differences at $P < 0.05$ (ANOVA), while there were no differences in the parameters without letters ($P > 0.05$).

Fig. 2. Heavy metal concentration distribution in sediments at six monitoring stations



Seasonal variation in water temperature has no direct effect on the solubility of metal in water (Zumdahl, 1992). However, organic matter and pH are most important factors that control the availability of heavy metals in the soil (Karaca, 2004). Cd, Hg and Pb were not detected in water at any sampling site (data was not shown here.). Fe was detected in water but in far lower amounts than the standard level. An increase of pH is generally accompanied by a decrease of the solubility of many toxic heavy metals; thus, total concentrations of heavy metals in the water body were under detection limit because a sedimental process takes place and less soluble forms are accumulated in suspended or sediment phase. The concentrations of heavy metals were higher in sediment than in water samples as expected (Fig. 2). Mean sediment concentrations of Hg were in the range of 0.32 – 5.95 mg kg^{-1}. The sediment Hg concentration of stations 4 and 5, located at the vicinity of the industrial park, were higher than other stations. Like Hg, sediment concentration of Cd at stations 4 was also higher than other stations. Results indicated that industrial wastewaters might be main sources for these two heavy metals contaminating the river. Phosphate fertilizers are additionally known for their significant content of Cd (McLauglin *et al*., 1996). Concentrations of Cd in the rainy season were below the analytical detection limit. The highest Pb concentration was found in the Chiangmai area where the combustion of fossil fuels should be taken into account in the leakage of heavy metals into the atmosphere and from there, to soils and aquatic systems. This might imply a significant Pb contribution from upstream. Generally, the highest values of heavy metals were observed during winter and the lowest during rainy season, except Fe and Cd. All heavy metals contamination in the water and the soil in the Upper Ping River were lower than the permissible limits.

Surveys of metals contents in river aquatic organisms, especially fishes residing in Upper Ping River, are limited. In addition, there is no prevention program for heavy metals contamination in this area; for this reason, impacts on human health have been poorly documented. Also the societal response to metal contamination is not developed in these communities.

CONCLUSION

Metal contamination depended to some extent upon seasonal variation in the Upper Ping River. All values were lower than the permissible limits. This seasonal variability was attributed to agricultural activities and domestic as well as industrial wastewaters, which were released, untreated or partly treated, to the river. These results can serve as a reference for future studies of chemical and biological indicators of pollution in the Upper Ping river to assess the heavy metals impact on the aquatic organisms.

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