Bull Environ Contam Toxicol (2012) 89:507–511
DOI 10.1007/s00128-012-0698-4

Assessment of Metals Distribution and Microbial Contamination at Selected Lake Waters in and Around Miri City, East Malaysia

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Received: 28 January 2012 / Accepted: 1 June 2012 / Published online: 10 June 2012

Abstract A baseline study was carried out to assess the metal concentrations and microbial contamination at selected Lake waters in and around Miri City, East Malaysia. Sixteen surface water samples were collected at specific Lakes in the environs of major settlement areas and recreational centers in Miri City. The Physico-chemical parameters [pH, Electrical Conductivity (EC) and Dissolved Oxygen (DO)], metals (Fe, Mn, Cu, Cd, Ni and Zn) and *Escherichia coli* (*E. coli*) were analysed. The concentrations of Fe, Mn and Ni have been found to be above the permissible limits of drinking water quality standards. The metals data have also been used for the calculation of heavy metal pollution index. Higher values of *E. coli* indicate microbial contamination in the Lake waters.

Keywords Metals · Lake waters · Pollution index · Contamination

Surface water bodies (Lakes, reservoirs and rivers) are the essential component of the environment for the fresh water sources. The main cause of the water pollution is human activities such as land use, release of domestic waste from cities or villages in the close vicinity of the lakes (Zinabu 1998, 2002; Zinabu and Dadebo 1989; Prasanna et al. 2012). Monitoring of metal pollution in ground and surface waters assumes significance in the context of human health. Trace metals are dangerous because they tend to bio-accumulate resulting in metal poisoning. Many trace metals are regarded as serious pollutants of aquatic ecosystems because of their environmental persistence, toxicity and ability to be incorporated into food chains (Abolude et al. 2009). Various metals from agricultural, industrial, domestic and urban wastes may enter river and lake waters through leaching, runoff, effluents and dry deposition (Biney and Christopher 1991; Okoye et al. 1991). Microbiological quality can be assessed by monitoring the abundance of indicator bacteria that are associated with recent faecal contamination. The most frequent types of contamination in surface water at rural areas is fecal pollution from different sources includes livestock and inadequate on-site human waste disposal systems (Conboy and Goss 2001; Barnes and Gordon 2004). Several investigators selected coliform bacteria and faecal streptococci to assess the pollution in marine environment (Mancini 1978; Garcia-Lara et al. 1991; El-Naggar et al. 2003; El-Shenawy and Farag 2005). High levels of faecal indicator bacteria in aquatic environment might indicate the presence of pathogenic microorganisms. The purpose of the present study was to analyze the physico-chemical and microbial parameters in surface water from the selected Lakes and to assess the metal concentrations and microbial contamination in the water.

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Materials and Methods

The proposed study area is located in Miri City, Sarawak State of East Malaysia (Fig. 1). Miri City is surrounded by

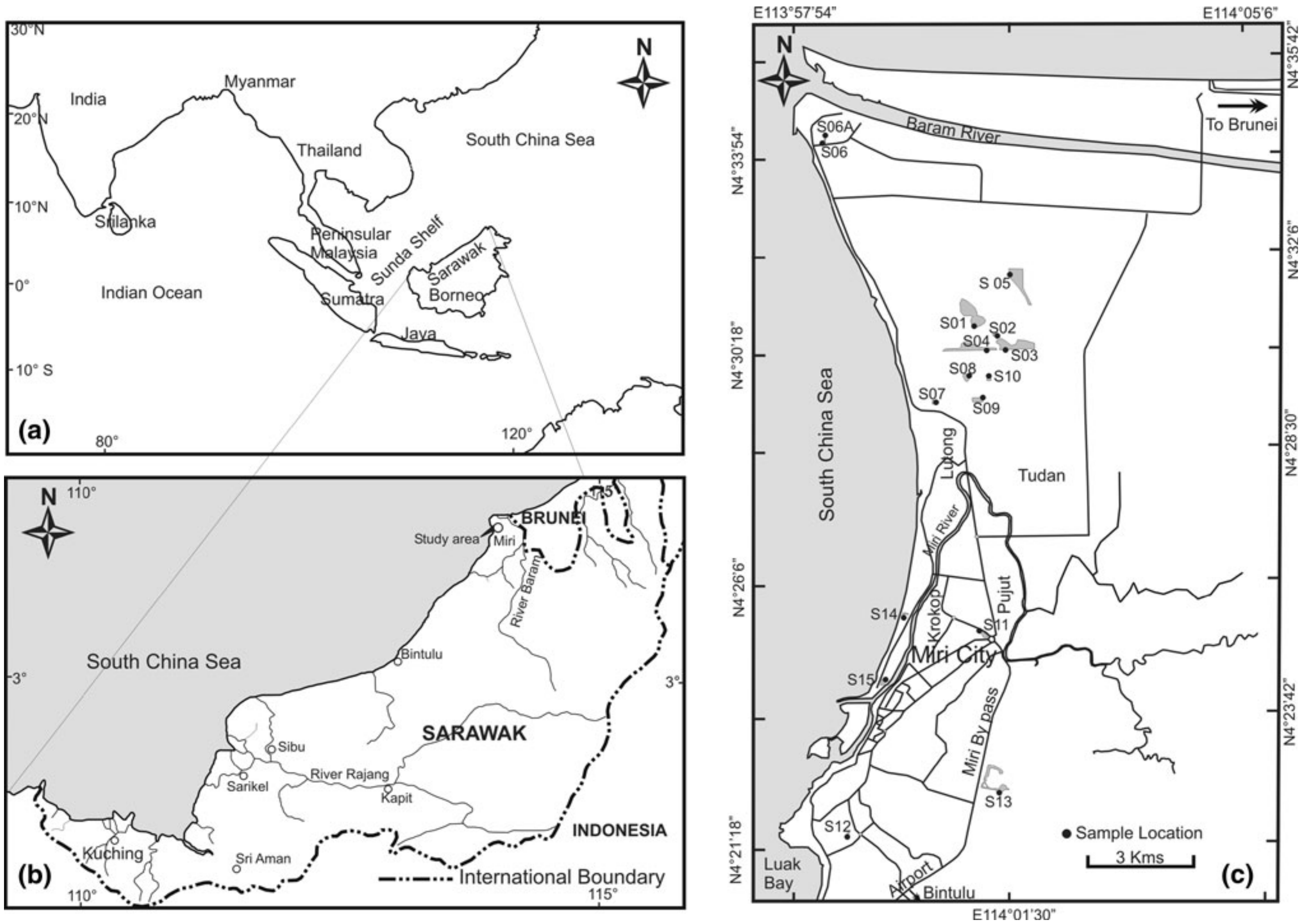

Fig. 1 Location map of the study area

coastal region, agricultural and industrial areas, settlements and commercial areas. The surface water in Miri City is available throughout the year and mainly utilized for irrigation and domestic purposes. Demand for large scale supplies of fresh water has increased in this region due to the increase of population and economic activities. Sixteen lake water samples were collected (Fig. 1) below the water surface using 200 mL polyethylene bottles. Prior to sampling the bottles were rinsed with the water to be sampled and the samples were preserved by acidifying to pH $\sim$ 2 with HNO_3 and keep at a temperature of 4°C until analysis. pH, EC and DO measurements were performed insitu with portable meter. The collected water samples were filtered using a pre-conditioned plastic Millipore filter unit equipped with a 0.45 µm filter membrane for further elemental analysis. Metals (Fe, Mn, Cu, Cd, Ni and Zn) were analyzed using inductively coupled plasma-optical emission spectrometer (ICP-OES) Optima 5000 DV Series (Perkin Elmer). It comes with WinLab32 Software which optimizes the work flow and accuracy. Appropriate quality control/quality assurance samples were collected to provide confidence in the data regarding bias and variability. Equipment blank was used to test for bias from possible contamination of blank water, which consists of distilled water. This is to verify that decontamination procedures and laboratory protocols are adequate (Koterba et al. 1995). *E. coli* was analyzed by membrane filtration method.

The HPI method was developed by assigning a rating or weightage (W_i) for each chosen parameter. The rating is an arbitrary value between zero and one and its selection reflects the relative importance of individual quality considerations. It can be defined as inversely proportional to the standard permissible value (S_i) for each parameter (Horton 1965; Mohan et al. 1996; Reddy 1995). In this study, the concentration limits (i.e., the standard permissible value (S_i) and highest desirable value (I_i) for each parameter) were taken from the WHO standard. The uppermost permissive value for drinking water (S_i) refers to the maximum allowable concentration in drinking water in absence of any alternate water source. The desirable maximum value (I_i) indicates the standard limits for the same parameters in drinking water.

The HPI, assigning a rating or weightage (W_i) for each selected parameter, is determined using the expression below (Mohan et al. 1996):

$$HPI = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i}$$

where Q_i and W_i are the sub-index and unit weight of the ith parameter, respectively, and n is the number of parameters considered. The sub-index (Q_i) is calculated by

$$Q_i = \sum_{i=1}^{n} \frac{\{M_i(-)I_i\}}{S_i - I_i} \times 100$$

where M_i, I_i and S_i are the monitored metal, ideal and standard values of the ith parameter, respectively. The sign (−) indicates numerical difference of the two values, ignoring the algebraic sign.

Results and Discussion

The range and mean concentrations of pH, EC, metals (Cd, Cu, Fe, Mn, Ni and Zn), *E. coli* and DO in the surface waters are given in Table 1. The analytical results indicate that pH of surface waters varies from 4.20 to 8.72 and most of the samples are neutral to alkaline in nature. The EC vary from 49.50 to 13,770 µS/cm, shows wide variations in the values. The mean metal concentrations in surface water is follows a descending order as: Fe > Mn > Zn > Ni > Cu > Cd. The concentrations of Cd, Cu and Zn are below the maximum allowable concentration (MAC) (Siegel 2002; Edet and Offiong 2002) and maximum permissible limit (MPL) prescribed by Malaysia drinking water standard.

Table 1 Summary of physico-chemical water quality of Lake waters

Parameters	Lake waters	MDS	MAC
pH	4.20–8.72 (7.24)	6.5–8.5	6.5–8.5
EC (µS/cm)	49.50–13,770 (1,208.44)	NS	1,400[a]
Cd (µg/L)	0.53–2.74 (1.13)	5	3
Cu (µg/L)	5.42–55.39 (11.10)	1,000	1,000
Fe (µg/L)	60.65–1,508.37 (637.43)	300	200
Mn (µg/L)	2.56–400.41 (61.42)	1	50
Ni (µg/L)	1.63–77.08 (10.38)	NS	20
Zn (µg/L)	7.38–298.10 (59.16)	5,000	5,000
E. coli (MPN/100 mL)	1–55 (15.63)	NS	0[b]
DO (mg/L)	2.80–3.40 (3.14)	NS	NS

MDS Malaysian Drinking Standards, *MAC* Maximum Acceptable Concentration (adopted from Siegel 2002), [a] WHO (1993), [b] WHO (2006), *NS* not specified

The results show that Fe varies from 60.65 to 1,508.37 µg/L with an average concentration of 637.43 µg/L. The Fe concentration shows that 31 % of samples exceed the MAC of 200 µg/L and 63 % of samples exceed the MPL of Malaysia drinking water standard (300 µg/L). Mn varies from 2.56 to 400.41 µg/L with an average value of 61.42 µg/L. 81 % of samples show Mn in excess of MAC value (50 µg/L) and all the samples exceeds the MPL of Malaysia standard. Ni concentration varies from 1.63 to 77.08 µg/L with an average value of 10.38 % and 13 % of samples show Ni in excess of MAC (20 µg/L).

Quality indices are useful in obtaining a composite influence of all parameters of overall pollution. The Heavy metal pollution index (HPI) represents the total quality of water with respect to metals. The critical pollution index of HPI value for drinking water as given by Prasad and Bose (2001) is 100. The heavy metal pollution index was calculated with mean concentration values of all the analyzed metals, including all sampling points. It was found to be 92, which is just below the critical index value of 100 (Prasad and Bose 2001). This value suggests that currently the surface water is not contaminated with respect to metal pollution.

The HPI of all the surface waters has also been calculated separately (Table 2) using WHO standards (Siegel 2002). In each calculation, all the six metals were considered. This helps us to assess the surface water quality in each sampling points, which can be used to compare the index of each sample. The range and mean values of HPI were 34–162 and 92. The calculated values of HPI showed that 31 % of the samples were above the critical index value. The mean deviation and percentage deviation were

Table 2 Heavy metal pollution index (HPI) of Lake waters

Sample number	HPI	Mean deviation	% Deviation
S1	97.79	6.06	6.61
S2	81.42	−10.31	−11.24
S3	33.80	−57.93	−63.16
S4	107.65	15.92	17.36
S5	60.79	−30.94	−33.73
S6	81.19	−10.54	−11.49
S6A	78.91	−12.82	−13.98
S7	97.74	6.01	6.55
S8	80.05	−11.68	−12.73
S9	94.97	3.24	3.53
S10	96.45	4.72	5.14
S11	88.85	−2.88	−3.14
S12	102.44	10.71	11.67
S13	100.59	8.86	9.66
S14	162.13	70.40	76.75
S15	102.85	11.12	12.13

calculated for all the samples (Table 2). Seven sampling points (S2, S3, S5, S6, S6A, S8 and S11) showed that the index values are lower than the mean value and the percentage deviation is also in the negative sign, which indicates a free pollution status of water with respect to metals (Prasad and Bose 2001). The remaining sampling points (S1, S4, S7, S9, S10, S12–S15) with index values more than the mean HPI value were considered as polluted water.

Different HPI criteria values have been developed for the samples, guided by their respective mean values, and the different levels of contamination were demarcated by a multiple of the mean values (Edet and Offiong 2002). Therefore, the proposed HPI criteria for the samples in the present study are as follows: low (HPI < 90), medium (HPI = 90–180) and high (>180) (Table 3). The present level shows that 44 % of samples are within the low HPI zone, while 56 % fall within the medium zone of pollution.

Escherichia coli is a type of faecal coliform bacteria commonly found in the intestines of animals and humans. The presence of *E. coli* in water is a strong indication of recent sewage or animal waste contamination. Sewage may contain many types of disease-causing organisms. *E. coli* in the study area varied from 1 to 55/100 mL and the mean concentration is 15.63/100 mL. The WHO (2006) standard value is 0 in 100 mL, but all the samples analyzed had over 1/100 mL except at S6, which is an indication of faecal pollution from the domestic sewage, waste disposal and landfill (Akinbile and Yusoff 2011). Significant higher values were noted in the locations; S1, S4, S6A, S10, S12 and S13. These sample points are located in the vicinity of residential sites, recreational centres and animal farm, where the presence of sewage system and open waste disposal sites. Large volume of waste water is being discharged from these areas to the nearby surface water bodies (Lakes), which gives direct impact on the surface water quality of the study area. The presence of such high *E. coli* may cause dysentery, diarrhea, vomiting and other waterborne diseases on consumption. The DO concentrations in the Lake waters were lower than the minimum requirement for aquatic organisms that is 4 mg/L (Baker 1980). The mean concentration of DO in the Lake waters was 3.14, and classified into class III according to Malaysian interim water quality standard (Ahmad et al. 2009). The depletion of oxygen infers the presence of pollutants that consume the oxygen in water (Akinbile and Yusoff 2011).

Table 3 Evaluation of Lake waters quality based on HPI criteria

Index method	Category	Degree of pollution	No. of samples	%	Samples
HPI	<90	Low	7	44.00	S2, S3, S5, S6, S6A, S8, S11
	90–180	Medium	9	56.00	S1, S4, S7, S9, S10, S12–S15
	>180	High	0	0.00	Nil

The present study reveals that the metals concentration (Fe, Mn and Ni) were higher and above the permissible limits in certain Lake waters of the study area. The calculated values of HPI showed that 31 % of the samples were above the critical index value (100). The proposed HPI criteria shows that 44 % of samples are within the low HPI zone and remaining samples fall within the medium zone of pollution. Higher values of *E. coli* indicate faecal contamination of Lake waters, substantiated by low DO concentrations in the water. Hence, the physico-chemical and microbiological results show that they have adversely affected the quality of Lake waters, which is likely to arise from a variety of sources, including domestic sewage, open dumping of waste materials and landfills.

Acknowledgments The authors wish to express thanks to Curtin Sarawak Research Fund (CSRF) for providing necessary financial support to carry out this study. They also thankful to the School of Science and Technology, Universiti Malaysia Sabah, Kota Kinabalu, Malaysia for helping in the metals analysis for the water samples.

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