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The Evaluation of Water Quality and Metal Concentrations of Titiwangsa Lake, Selangor, Peninsular Malaysia

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Abstract: A study of water quality parameters (temperature, conductivity, total dissolved solid, dissolved oxygen, pH and water hardness) in Titiwangsa Lake was conducted in January, April, July and October 2010. The water quality parameters were tested and recorded at different sampling stations chosen randomly using hydrolab data sonde 4[®] and surveyor 4[®] a water quality multi probe (USA). Six metals i.e., cadmium, chromium, lead, nickel, zinc and copper were determined in five different compartments of the lake namely water, total suspended solids, plankton, sediment and fish. The metals concentration were determined by Inductively Coupled Plasma Mass Spectrometer (ICP-MS), perkin elmer elan, model 9000. The water quality parameters were compared with National Water Quality Standard (NWQS Malaysia) while metal concentrations were compared with Malaysian and international standards. The study shows that water quality parameters are of class 2. This condition is suitable for recreational activities where body contact is allowed and suitable for sensitive fishing activities. Furthermore, metal concentrations were found to be lower than the international standards, therefore toxic effects for these metals would be rarely observed and the adverse effects to aquatic organisms would not frequently occur.

Key words: Metals concentration, water quality, sediment, total suspended solids, plankton, fish, Titiwangsa lake

INTRODUCTION

Heavy metal pollution of water systems is one of the main causes of environmental hazards due to their high level of toxicity. Toxic metals from various sources namely discharge of industrial or sewage influents, domestic wastewater, periodic precipitation contaminated with airborne pollutants, transport, burning of fossil fuels and fertilizers containing trace metals could affect fish healthy (Handy, 1994; Jent *et al.*, 1998). Metals have been used in various human activities since thousands of years ago and metal pollution in the aquatic environment has been an issue. Malaysia as a developing country, finds it inevitable avoiding this problem. The existence of metals concentration in the environment could be of natural causes or anthropogenic. The natural causes could be weathering; climate changes (wind and temperature) inflicted on igneous and metamorphic rocks. However, the burning of fossil fuels, mining, melting minerals, industrial wastes, the use of fertilizers and pesticides in the agriculture are the main contribution of anthropogenic sources (Kendrick *et al.*, 1992). In the context of

environmental pollution, the existence of metal pollution and the existence of metal concentration could be categorized into 3 important types; non-critical, undiluted toxic metals which hardly exist and toxic metal concentrations which are widely used (Forstner and Wittman, 1992). Unlike organic pollution, toxic metals could be not eliminated through biodegradable process and the impact of toxic metals could remain permanently in the environment. In some heavy metals such as mercury and cadmium, are known to have toxic effect although they have low concentrations (Forstner and Wittman, 1992). Heavy metal concentrations in aquatic ecosystems are usually monitored by measuring its concentration in water and biota (Camusso *et al.*, 1995), which generally exist in low levels in water and attain considerable concentrations in biota. Essential and non essential metals are of equal importance to ecotoxicology due to their persistence as well as lethal effects on live organisms (Storelli *et al.*, 2005). Heavy metals do not exist in soluble forms for a long time in waters; they are present mainly as suspended colloids or are fixed by organic and mineral substances

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(Kabata-Pendias and Pendias, 2001). In aquatic ecosystems, water contamination by heavy metals is one of the main types of pollution that may stress the biotic community (Baldantoni *et al.*, 2004).

The objective of this research is to identify the status of the metal concentrations in water, plankton, total suspended solids, sediment and fish of a recreational Titiwangsa lake, Selangor, Peninsular Malaysia.

MATERIALS AND METHODS

Study area: Titiwangsa lake is a man-made freshwater lake and it is a recreational park north of downtown Kuala Lumpur adjacent to Istana Budaya, an arts and culture centre with depth of 10 meters. It is geographically located at 03°10'40" N and at 101°42'20" E. The main source of water was the rain water and drainage through one drainage pipe to the surrounding areas. Titiwangsa lake gardens cover average of 415 acres and the lake covering 1.85 acres (DOE, 2003) (Fig. 1).

Water samples for water quality parameters: Water samples were collected just below the water surface randomly at different locations representing the open water bodies in the lake using a 1000 mL bottles (acid washed, distilled water rinsed polyethylene bottles). The triplicates water samples from the lake were pooled together. The samples were collected at monthly intervals during January, April, July and October 2010. The samples were used to analyze physico-chemical parameters such as Temperature (T), Electrical Conductivity (EC), Total Dissolved Solid (TDS), Dissolved Oxygen (DO) and pH. The water quality parameters were tested and recorded at each sampling station using Hydrolab Data Sonde 4[®] and Surveyor[®]4 a water quality multi probe (USA). Calibration of hydrolab data sonde 4[®] and surveyor[®]4 a was conducted in the laboratory before field sampling. For water hardness concentrations of calcium (Ca²⁺) and magnesium (Mg²⁺) were determined using Inductively Coupled Plasma Mass Spectrometer (ICP-MS), perkin elmer elan, model 9000.

Water samples for heavy metals concentration: The samples were immediately filtered using 0.45 µM membrane filters (American Public Health Associations (APHA), 1992). For metal concentrations, 10 mL filtrate was acidified with 0.5 mL of concentrated HNO₃ (70%) to pH <2 and kept in the cool storage at 4°C. The filtrated water was dried at 70°C and then digested with 5 mL concentrated HNO₃ (Smith *et al.*, 1996). The metals concentration were determined by Inductively Coupled Plasma Mass Spectrometer (ICP-MS), perkin elmer elan, model 9000.

Determination of heavy metals concentration in total suspended solid (TSS): Water samples were collected using acid washed, distilled water rinsed polyethylene bottles. The triplicates water samples were pooled together. The water samples were immediately filtered using 0.45 µM membrane filters (American Public Health Associations (APHA), 1992). The filtered samples were put in petri dishes and dried at 103-105°C for 48 h by oven (Mettler/F503.022 model). The dried samples were put in test tubes and digested with 5 mL of a mixture of concentrated tri-acid HNO₃:HClO₄:H₂SO₄ (10:4:1) at 100°C in a hot plate (COD Reactor sastec/ST-DBMK200-4 Model) for 2 h. The cooled residue was dissolved completely by adding 1 mL HCl (35%) and the volume was completed to 25 mL with distilled water in conical flasks (FAO,1975). The solution was filtered by vacuum (Gast/DOA-P504-BN). The metals concentration were determined by Inductively Coupled Plasma Mass Spectrometer (ICP-MS), perkin elmer elan, model 9000.

Determination of heavy metals concentration in plankton: Mixed plankton (phytoplankton and zooplankton) was collected randomly at different locations from the water lake by using 240 µM plankton net and these samples were pooled together. The pooled samples were kept in plastic bottles. After cleaning the plankton samples were washed with tap water followed by distilled water and filtered by 0.45 µM membrane filters. The filtered samples were put in Petri dishes and dried at (60°C for 24 h) by oven (Mettler/F503.022 model). The dried plankton samples were put in test tubes and digested with 5 mL of a mixture of concentrated tri-acid HNO₃:HClO₄:H₂SO₄ (10:4:1) at 100°C in a hot plate (COD Reactor Sastec/ST-DBMK200-4 Model) for 2 h. The cooled residue was dissolved completely by adding 1mL HCl (35%) and the volume was completed to 25 mL with distilled water in conical flasks (FAO, 1975). The solution was filtered by vacuum (Gast/DOA-P504-BN). The metals concentration were determined by Inductively Coupled Plasma Mass Spectrometer (ICP-MS), perkin elmer elan, model 9000.

Determination of heavy metals concentration in sediments: Core sampler (Wild Co[®] Instruments) was used to collect sediment samples from the surface down to a depth of 5-7 cm randomly at different locations. All the sediment samples were sealed in polyethylene bags embedded in ice during transportation to the laboratory. They were then dried at 110°C for 2 h and passed through a 1 mm size test sieve (Endecotts LTD England) to separate the stones, leaves and dead invertebrates. The sediment was then ground into powder of the particle size less than 63 µM using a mortar and a pestle. The sieved

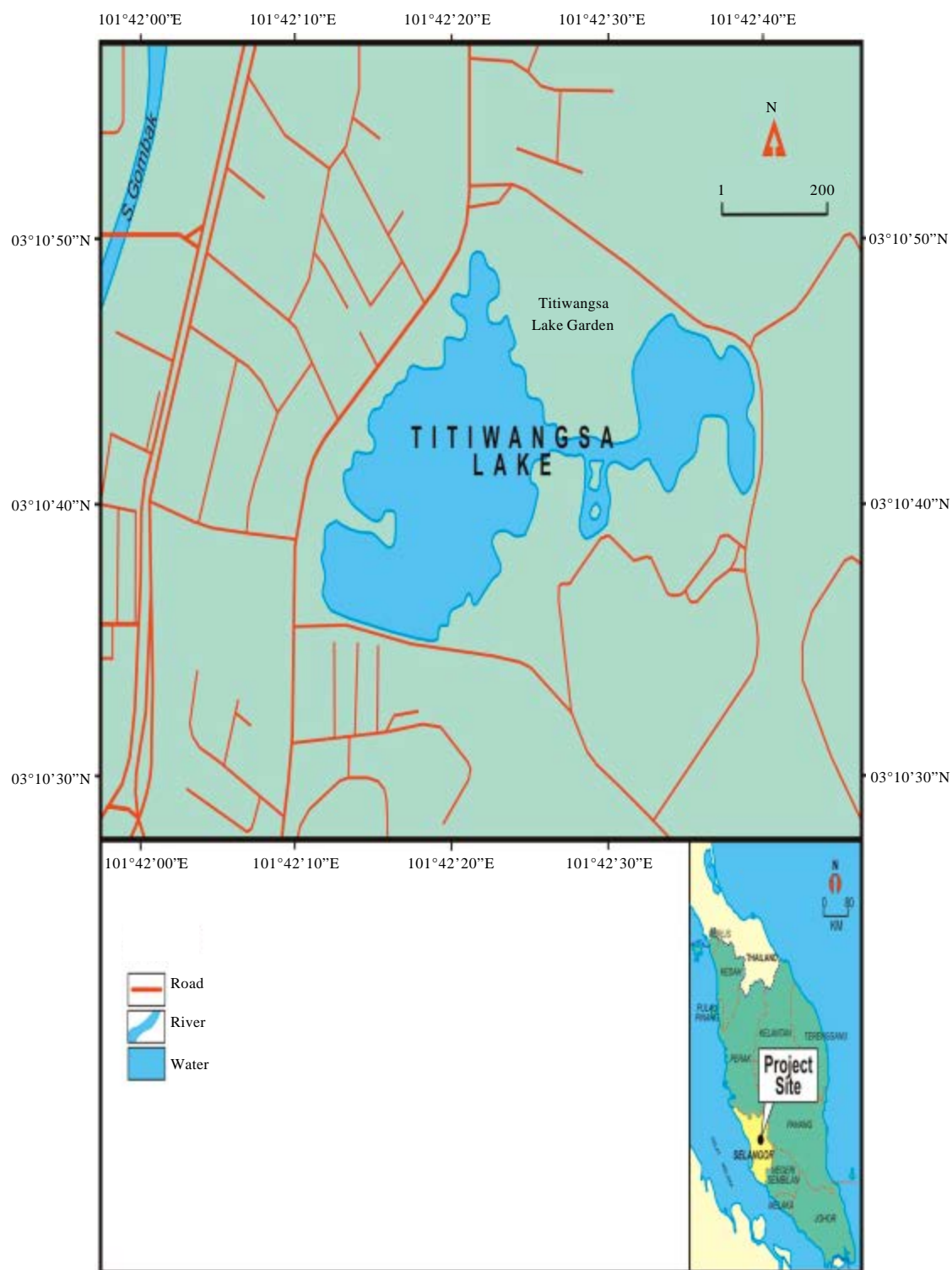


Fig. 1: Geographical location of Titiwangsa Lake, Selangor, Peninsular Malaysia

samples were used for physico-chemical parameters of sediment such as particle size, pH and organic matter that were determined according to Bascomb (1982). For trace metal analysis, 250 mg of sediment was digested with a mixture of concentrated tri-acid HNO₃:HClO₄:H₂SO₄ (10:4:1) at 100°C in a hot plate (COD Reactor Sastec/ST-DBMK200-4 Model) for 2 h. The cooled residue was dissolved completely by adding 1 mL HCl (35%) and the volume was completed to 25 mL with distilled water in conical flasks (Zhou *et al.*, 1998). The solution was filtered by vacuum (Gast/DOA-P504-BN). The metals concentration were determined by Inductively Coupled Plasma Mass Spectrometer (ICP-MS), perkin elmer elan, model 9000.

Determination of heavy metals concentration in fish:

Three fresh fish of Tilapia (*Oreochromis niloticus*) were collected by plastic net from fresh water lake monthly. The mean wet weight of these fish species were from 150 g to 180 g. The fish samples were sealed in polyethylene bags and kept in the freeze at 20°C in the laboratory. The fish samples were given about 2 h of defrosting before analysis. After the fish were rinsed with de-ionized water, each fish was dissected with the help of stainless-steel knife and scissors on a clean Petri dish to extract gill, liver and muscle tissues. Polyethylene gloves were worn during dissection of fish tissues to reduce surface contamination of samples. After dissection, 2 g samples of each tissue were dried by oven (Memmert/F503.022 model) at 80°C over night (24 h) to a constant weight. Dried tissues were ground, sieved (1 mm size) and transferred to a porcelain basin. One gram powdered samples was kept in 30 mL crucible and placed in the muffle furnace (Carbolite.ELF 11/14) at 50, 150 and 450°C for 10 min, 1 and 8 h, respectively by raising the temperature for complete ashing. Then they were transported to 25 mL erlenmeyer flask for digestion. Each tissue was digested separately with tri-acid mixture (HNO₃:HClO₄:H₂SO₄ = 10:4:1) at 5 mL per 0.5 g of sample and was placed on a hot plate at 120°C for 2 h. Digestion was continued until the liquor was clear (AOAC, 1990). All the digested liquors were filtered through Quantitative whatman 541 filter paper and diluted to 25 mL in the volumetric flask with distilled water. They were stored in acid rinsed polyethylene bottles at 4°C prior to analysis. The metals concentration were determined by Inductively Coupled Plasma Mass Spectrometer (ICP-MS), perkin elmer elan, model 9000 (AOAC, 1990).

Statistical analysis: One-way analysis of variance (ANOVA) was conducted to see the variation of water parameters and heavy metal concentration among the different months and different compartments. The statistical significance level was set at p>0.05. All test procedures were performed in a computer program SPSS version 20.

RESULTS

Physicochemical parameters of water: The physico-chemical parameters of water of Titiwangsa lake are summarized in Table 1. The physico-chemical parameters of water of Titiwangsa lake were analyzed during January, April, July and October 2010. Temperature, SPC, TDS, DO, pH and hardness of water varied from 28.65-29.49°C, 1325.3-1364 µS cm⁻¹, 810-990 mg L⁻¹, 5.43-6.37, 8.14-8.64 and 37.13-37.63 mg L⁻¹ as CaCO₃, respectively. For all physico-chemical parameters, values shows no significant differences (p>0.05) among all months.

Physicochemical parameters of sediment: The physicochemical parameters of Titiwangsa lake sediment such as pH, organic matter and texture are summarized in Table 2. pH and organic matter ranged from 6.10-8.23 and from 0.21-2.11%, respectively and the texture of the sediment was sandy clay.

Metal concentration in water: The metal concentrations in water of Titiwangsa lake are presented in Table 3. Titiwangsa Lake contained only detectable amounts of cadmium, chromium, copper, lead, zinc and nickel in water. For all six metals concentration, study shows no significant differences (p>0.05) among all months. Zinc

Table 1: Monthly water quality parameters of Titiwangsa lake during 2010

Parameter	Jan.	Apr.	Jul.	Oct.	Mean±SD	NWQS Malaysia (class 1)
Temperature (C°)	29.49	28.67	29.26	28.65	29.02±0.43	
SPC (µS cm ⁻¹)	1333.3	1352	1364	1325.3	1343.7±1.76	1000
TDS (mg L ⁻¹)	990	930	940	810	920±0.08	500
DO (mg L ⁻¹)	5.43	6.27	6.37	5.60	5.92±0.47	7
pH	8.17	8.22	8.14	8.64	8.29±0.24	6.5-8.5
Hardness CaCO ₃ (mg L ⁻¹)	37.20	37.63	37.13	37.44	37.35±0.23	50

NWQS (Malaysia)-National water quality standards of Malaysia, 2008, SPC: Specific conductivity, TDS: Total dissolved solids, DO: Dissolved oxygen

Table 2: Monthly sediment parameters of Titiwangsa lake during 2010

Parameter	Jan.	Apr.	Jul.	Oct.	Mean±SD
pH	6.10	7.83	7.98	8.23	7.54±0.97
Organic Matter (%)	2.11	1.87	1.54	0.21	1.43±0.85

Table 3: Metal concentrations in water of Titiwangsa Lake during 2010

Metal ($\mu\text{g L}^{-1}$)	Jan.	Apr.	Jul.	Oct.	Mean \pm SD	USEPA (2004) (CMC) ($\mu\text{g L}^{-1}$)	USEPA-(CCC) ($\mu\text{g L}^{-1}$)	CCME (1999)-protection of aquatic life ($\mu\text{g L}^{-1}$)	NWQS (2008) Class 2 ($\mu\text{g L}^{-1}$)
Cd	0.08	0.08	0.08	0.08	0.08 \pm 0.000	2	0.25	0.017	10
Cu	5.93	4.93	5.26	5.31	5.36 \pm 0.420	13	9.00	2-4	20
Pb	0.71	0.73	0.73	0.73	0.73 \pm 0.010	65	2.50	1-7	50
Zn	10.14	9.92	10.02	10.01	10.02 \pm 0.090	120	12.00	30	5000
Cr	2.87	2.82	2.94	2.93	2.89 \pm 0.060	570	74.00	8.9	2500
Ni	2.59	2.51	2.63	2.49	2.55 \pm 0.070	470	52.00	25-150	50

USEPA: United states environment protection agency, CMC: Criteria maximum concentration, CCC: Criteria continuous concentration, CCME: Canadian council of ministers of environment, NWQS: National water quality standards Malaysia

Table 4: Metal concentrations in sediment of Titiwangsa Lake during 2010

Metal ($\mu\text{g g}^{-1}$)	Jan.	Apr.	Jul.	Oct.	Mean \pm SD	EPA guidelines, TEL values ($\mu\text{g g}^{-1}$)	EPA guidelines, PEL values ($\mu\text{g g}^{-1}$)
Cd	0.97	0.94	0.91	0.91	0.93 \pm 0.03	1.2	9.60
Cu	9.48	9.50	9.55	9.48	9.50 \pm 0.03	34.0	2.70
Pb	3.19	3.19	3.16	3.19	3.18 \pm 0.02	46.7	2.18
Zn	11.52	11.41	11.57	11.43	11.48 \pm 0.08	150.0	4.10
Cr	3.73	3.72	3.71	3.73	3.72 \pm 0.01	81.0	3.70
Ni	2.58	2.56	2.55	2.60	2.57 \pm 0.02	-	-

EPA: Environment protection agency, 1999, TEL: Threshold effect level, PEL: Probable effect level

values recorded the lower value on April ($9.92 \mu\text{g L}^{-1}$) and the higher value on January ($10.14 \mu\text{g L}^{-1}$) and the average was $10.02\pm 0.09 \mu\text{g L}^{-1}$. Copper values proved the lower value on April ($4.93 \mu\text{g L}^{-1}$) and the higher value on January ($5.93 \mu\text{g L}^{-1}$) and the average was $5.36\pm 0.42 \mu\text{g L}^{-1}$. Nickel values recorded the lower value on October ($2.49 \mu\text{g L}^{-1}$) and the higher values on July ($2.63 \mu\text{g L}^{-1}$) and the average was $2.55\pm 0.07 \mu\text{g L}^{-1}$. Chromium values explained the lower value on April ($2.82 \mu\text{g L}^{-1}$) and the higher value on July ($2.94 \mu\text{g L}^{-1}$) and the average was $2.89\pm 0.06 \mu\text{g L}^{-1}$. Lead values proved the lower value on January ($0.71 \mu\text{g L}^{-1}$) and the higher value on October ($0.73 \mu\text{g L}^{-1}$) and the average was $0.73\pm 0.01 \mu\text{g L}^{-1}$. Cadmium values confirmed the lower value on January, April, July and October ($0.08 \mu\text{g L}^{-1}$) and the average was $0.08\pm 0.00 \mu\text{g L}^{-1}$. Zinc had the highest concentration while cadmium had the lowest concentration and the accumulation order was $\text{Zn} > \text{Cu} > \text{Cr} > \text{Ni} > \text{Pb} > \text{Cd}$.

Metal concentration in sediment: The metal concentrations in sediment of Titiwangsa Lake are given in Table 4. The sediment of Titiwangsa Lake contained detectable amounts of heavy metals. Among the detected heavy metals in sediment, copper had the highest concentration while cadmium had the lowest concentration. Study shows no statistically significant ($p > 0.05$) among all months for six metals concentration. Zinc values recorded the lower value on April ($11.41 \mu\text{g g}^{-1}$) and the higher value on July ($11.57 \mu\text{g g}^{-1}$) and the average was $11.48\pm 0.08 \mu\text{g g}^{-1}$. Copper values proved the lower value on January and October ($9.48 \mu\text{g g}^{-1}$) and the higher value on July ($9.55 \mu\text{g g}^{-1}$) and the average was $9.50\pm 0.03 \mu\text{g g}^{-1}$. Nickel values recorded the lower value on July ($2.55 \mu\text{g g}^{-1}$) and the

higher values on October ($2.60 \mu\text{g g}^{-1}$) and the average was $2.57\pm 0.02 \mu\text{g g}^{-1}$. Chromium values explained the lower value on July ($3.71 \mu\text{g g}^{-1}$) and the higher value on January and October ($3.73 \mu\text{g g}^{-1}$) and the average was $3.72\pm 0.01 \mu\text{g g}^{-1}$. Lead values proved the lower value on July ($3.16 \mu\text{g g}^{-1}$) and the higher value on April, July and October ($3.19 \mu\text{g g}^{-1}$) and the average was $3.18\pm 0.02 \mu\text{g g}^{-1}$. Cadmium values confirmed the lower value on July and October ($0.91 \mu\text{g g}^{-1}$) and the higher value on January ($0.97 \mu\text{g g}^{-1}$) and the average was $0.93\pm 0.03 \mu\text{g g}^{-1}$. Sediments samples contained high levels of metals and the accumulation order was $\text{Zn} > \text{Cu} > \text{Cr} > \text{Pb} > \text{Ni} > \text{Cd}$.

Metal concentration in total suspended solids: The metal concentrations in total suspended solids of Titiwangsa Lake are given in Table 5. In the present study, copper had the highest concentration while cadmium had the lowest concentration. Zinc values recorded the lower value on October ($3.78 \mu\text{g g}^{-1}$) and the higher value on January, April and July ($3.79 \mu\text{g g}^{-1}$) and the average was $3.79\pm 0.01 \mu\text{g g}^{-1}$. Copper values proved the lower value on April ($3.68 \mu\text{g g}^{-1}$) and the higher value on July ($9.55 \mu\text{g g}^{-1}$) and the average was $6.60\pm 3.37 \mu\text{g g}^{-1}$. Nickel values recorded the lower value on January and April ($1.59 \mu\text{g g}^{-1}$) and the higher values on October ($2.60 \mu\text{g g}^{-1}$) and the average was $2.08\pm 0.57 \mu\text{g g}^{-1}$. Chromium values explained the lower value on April ($2.31 \mu\text{g g}^{-1}$) and the higher value on October ($3.73 \mu\text{g g}^{-1}$) and the average was $3.02\pm 0.81 \mu\text{g g}^{-1}$. Lead values proved the lower value on January and April ($0.29 \mu\text{g g}^{-1}$) and the higher value on October ($3.19 \mu\text{g g}^{-1}$) and the average was $1.73\pm 1.67 \mu\text{g g}^{-1}$. Cadmium values confirmed the lower values on January and April ($0.05 \mu\text{g g}^{-1}$) and the higher values on July

and October ($0.91 \mu\text{g g}^{-1}$) and the average was $0.48 \pm 0.50 \mu\text{g g}^{-1}$. The order of concentration of these elements in total suspended solids was $\text{Cu} > \text{Zn} > \text{Cr} > \text{Ni} > \text{Pb} > \text{Cd}$. In addition, study shows no significant differences ($p > 0.05$) among all months.

Metal concentration in plankton: The metal concentrations in plankton of Titiwangsa Lake are summarized in Table 6. Zinc values recorded the lower value on April and July ($6.23 \mu\text{g g}^{-1}$) and the higher value on January ($6.8 \mu\text{g g}^{-1}$) and the average was $6.30 \pm 0.08 \mu\text{g g}^{-1}$. Copper values proved the lower value on April ($4.52 \mu\text{g g}^{-1}$) and the higher value on January ($4.85 \mu\text{g g}^{-1}$) and the average was $4.70 \pm 0.17 \mu\text{g g}^{-1}$. Nickel values recorded the lower value on July ($2.36 \mu\text{g g}^{-1}$) and the higher values on April ($2.43 \mu\text{g g}^{-1}$) and the average was $2.40 \pm 0.03 \mu\text{g g}^{-1}$. Chromium values explained the lower value on October ($2.27 \mu\text{g g}^{-1}$) and the higher value on January and April ($2.60 \mu\text{g g}^{-1}$) and the average was $2.47 \pm 0.16 \mu\text{g g}^{-1}$. Lead values proved the lower value on April and October ($0.51 \mu\text{g g}^{-1}$) and the higher value on July ($0.54 \mu\text{g g}^{-1}$) and the average was $0.52 \pm 0.02 \mu\text{g g}^{-1}$. Cadmium values confirmed the lower on October ($0.05 \mu\text{g g}^{-1}$) and higher value on January ($0.08 \mu\text{g g}^{-1}$) and the average was $0.06 \pm 0.01 \mu\text{g g}^{-1}$. The order of accumulation of these elements in plankton was

$\text{Zn} > \text{Cu} > \text{Cr} > \text{Ni} > \text{Pb} > \text{Cd}$. Moreover, study shows that values were not significantly different ($p > 0.05$) among all months.

Metal concentration in fish: The metal concentrations in fish tissues of Titiwangsa Lake are summarized in Table 7. In the present study, tilapia fish (*Oreochromis niloticus*) contained variable levels of different metals. The order of concentration of these elements in fish was $\text{Cu} > \text{Zn} > \text{Cr} > \text{Ni} > \text{Pb} > \text{Cd}$. Metals accumulated at variable levels in different tissues of fish and followed the order of Gills > liver > muscles Table 7. Study shows that values were not significantly different ($p > 0.05$) among all fish tissues. Zinc values recorded the lower value for gills on January ($4.00 \mu\text{g g}^{-1}$) and the higher value on July ($3.31 \mu\text{g g}^{-1}$) and on October ($3.34 \mu\text{g g}^{-1}$) for liver, whereas on January ($2.50 \mu\text{g g}^{-1}$) and on July ($2.60 \mu\text{g g}^{-1}$) for muscles tissues. Copper values recorded the lower value for gills on January ($5.20 \mu\text{g g}^{-1}$) and the higher value on July ($5.32 \mu\text{g g}^{-1}$), while on January ($4.70 \mu\text{g g}^{-1}$) and on October ($4.88 \mu\text{g g}^{-1}$) for liver, whereas on July ($4.08 \mu\text{g g}^{-1}$) and on October ($4.18 \mu\text{g g}^{-1}$) for muscles tissues. Nickel values recorded the lower value for gills on January ($2.30 \mu\text{g g}^{-1}$) and the higher value on July ($2.36 \mu\text{g g}^{-1}$), while on January ($2.00 \mu\text{g g}^{-1}$) and on April ($2.08 \mu\text{g g}^{-1}$) for liver, whereas on January ($1.40 \mu\text{g g}^{-1}$) and on April ($1.49 \mu\text{g g}^{-1}$) for muscles tissues. Chromium values recorded the lower value for gills on January ($2.80 \mu\text{g g}^{-1}$) and the higher value on July ($2.88 \mu\text{g g}^{-1}$), while on October ($2.27 \mu\text{g g}^{-1}$) and on July ($2.30 \mu\text{g g}^{-1}$) for liver, whereas on January ($2.01 \mu\text{g g}^{-1}$) and on October ($2.07 \mu\text{g g}^{-1}$) for muscles tissues. Lead values recorded the lower value for gills on January ($1.60 \mu\text{g g}^{-1}$) and the higher value on October ($1.80 \mu\text{g g}^{-1}$), while on January ($1.20 \mu\text{g g}^{-1}$) and on October ($1.37 \mu\text{g g}^{-1}$) for liver, whereas on January ($1.00 \mu\text{g g}^{-1}$) and on October ($1.13 \mu\text{g g}^{-1}$) for muscles tissues. Cadmium values recorded the lower value for gills on January and April ($0.30 \mu\text{g g}^{-1}$) and the higher value on July ($0.32 \mu\text{g g}^{-1}$), while on January and April ($0.24 \mu\text{g g}^{-1}$) and on July ($0.26 \mu\text{g g}^{-1}$) for liver, whereas on October ($0.17 \mu\text{g g}^{-1}$)

Table 5: Metal concentrations in total suspended solids of Titiwangsa lake during 2010

Metal ($\mu\text{g g}^{-1}$)	Jan.	Apr.	Jul.	Oct.	Mean \pm SD
Cd	0.05	0.05	0.91	0.91	0.48 ± 0.50
Cu	3.69	3.68	9.55	9.48	6.60 ± 3.37
Pb	0.29	0.29	3.16	3.19	1.73 ± 1.67
Zn	3.79	3.79	3.79	3.78	3.79 ± 0.01
Cr	2.32	2.31	3.71	3.73	3.02 ± 0.81
Ni	1.59	1.59	2.55	2.60	2.08 ± 0.57

Table 6: Metal concentrations in plankton of Titiwangsa lake during 2010

Metal ($\mu\text{g g}^{-1}$)	Jan.	Apr.	Jul.	Oct.	Mean \pm SD
Cd	0.08	0.06	0.06	0.05	0.06 ± 0.010
Cu	4.85	4.52	4.58	4.83	4.70 ± 0.170
Pb	0.53	0.51	0.54	0.51	0.52 ± 0.020
Zn	6.38	6.23	6.23	6.36	6.30 ± 0.080
Cr	2.60	2.60	2.42	2.27	2.47 ± 0.160
Ni	2.41	2.43	2.36	2.41	2.40 ± 0.030

Table 7: Metal concentrations of different fish tissues in Titiwangsa lake during 2010

Metal ($\mu\text{g g}^{-1}$)	Jan.			Apr.			Jul.			Oct.		
	Gills	Liver	Muscles	Gills	Liver	Muscles	Gills	Liver	Muscles	Gills	Liver	Muscles
Cd	0.30	0.24	0.19	0.30	0.24	0.18	0.32	0.26	0.20	0.31	0.25	0.17
Cu	5.20	4.70	4.09	5.25	4.73	4.09	5.32	4.80	4.08	5.30	4.88	4.18
Pb	1.60	1.20	1.00	1.62	1.28	1.02	1.70	1.26	1.04	1.80	1.37	1.13
Zn	4.00	3.20	2.50	4.09	3.30	2.58	4.20	3.31	2.60	4.08	3.34	2.58
Cr	2.80	2.28	2.01	2.83	2.29	2.03	2.88	2.30	2.06	2.82	2.27	2.07
Ni	2.30	2.00	1.40	2.33	2.08	1.49	2.36	2.06	1.44	2.33	2.06	1.47

and on July ($0.20 \mu\text{g g}^{-1}$) for muscles tissues. The order of concentration of these elements in fish was $\text{Cu} > \text{Zn} > \text{Cr} > \text{Ni} > \text{Pb} > \text{Cd}$. In the present study, the averages of Cu, Zn, Cr, Ni, Pb and Cd in gills, liver and muscles were ($5.27, 4.78$ and $4.11 \mu\text{g g}^{-1}$) ($4.09, 3.29$ and $2.57 \mu\text{g g}^{-1}$) ($2.83, 2.29$ and $2.04 \mu\text{g g}^{-1}$) ($2.33, 2.05$ and $1.45 \mu\text{g g}^{-1}$) ($1.68, 1.28$ and $1.05 \mu\text{g g}^{-1}$), ($0.31, 0.25$ and $0.19 \mu\text{g g}^{-1}$), respectively.

DISCUSSION

Physico-chemical parameters of water: Study demonstrated that the water temperature values increased during the months of the study. The lower and higher values were 28.65°C and 29.49°C , respectively and the average was 29.02°C . Conductivity values increased during the study period with the averages of $1343.3 \mu\text{S cm}^{-1}$, while the lower and higher values were $1325.3 \mu\text{S cm}^{-1}$ and $1364 \mu\text{S cm}^{-1}$ respectively. Increasing water temperature values lead to increasing the evaporation from the surface area of the lake and finally increasing the content of salts and conductivity values. Moreover, the stagnant of water in some parts of the lake may affect the electrical conductivity. The total dissolved solid values increased due to increased the electrical conductivity values and the water of the lake classified as class (2) according to NWQS Malaysia with the average of 920 mg L^{-1} , while the lower and higher values were 810 and 990 mg L^{-1} , respectively. Conductivity or specific conductance is a measure of the ability of water to conduct an electrical current. It is sensitive to variations in dissolved solids, mostly mineral salts (Chapman, 1992). The degrees to which these dissociate into ions, the amount of electrical charge on each ion, ion mobility and the temperature of the solution all have an influence on conductivity. It is expressed as microsiemens per centimeter ($\mu\text{S cm}^{-1}$) or desisiemens per meter (dS m^{-1}) or milli mohos/centimeter (mM/cm) and micro mohos/centimeter ($\mu\text{M cm}^{-1}$), it is related to the concentrations of total dissolved solids and major ions. Concentrations in unpolluted waters are usually close to but less than 10 mg L^{-1} (Chapman, 1992; Gray, 1999). It was obvious that DO values were within the normal ranges with the average of 5.92 . Variations in DO can occur seasonally or even over 24 h periods in relation to temperature and biological activity (Chapman, 1992; Gray, 1999). Biological respiration including that related to decomposition processes reduces DO concentrations (Chapman, 1992). In still waters pockets of high and low concentrations of dissolved oxygen can occur depending on the rates of biological processes (Chapman, 1992). Waste discharges high in organic matter and nutrients

can lead to decreases in DO concentrations as a result of the increased microbial activity occurring during the degradation of organic matter (Chapman, 1992). In severe cases of reduced oxygen concentrations anaerobic conditions can occur (0 mg L^{-1} of oxygen) particularly close to the sediment water interface as a result of decaying sedimenting material (Chapman, 1992). Determination of DO concentrations is a fundamental part of a water quality assessment since oxygen is involved in or influences nearly all chemical and biological processes within water bodies (Chapman, 1992). Concentrations below 5 mg L^{-1} may adversely affect the functioning and survival of biological communities and below 2 mg L^{-1} may lead to the death of most fish (Chapman, 1992). The measurement of DO can be used to indicate the degree of pollution by organic matter, the destruction of organic substances and the level of self purification of the water (Chapman, 1992; Gray, 1999). It was clear that pH values were higher than the normal ranges with the average of 8.29 . The lower value was 8.14 and recorded on July but higher value was 8.64 on October. In addition, the value of hydrogen ion concentration indicated that the water of Titiwangsa Lake was alkaline medium. The pH is an important variable in water quality assessment as it influences many biological and chemical processes within a water body and all processes associated with water supply and treatment (Chapman, 1992; Gray, 1999). Change in pH can indicate the presence of certain effluents particularly when continuously measured and recorded together with the conductivity of a water body (Chapman, 1992; Droste, 1997). Diel variations in pH can be caused by the photosynthesis and respiration cycles of algae in eutrophic waters (Chapman, 1992). The pH of most natural waters is between 6.0 and 8.5 (Chapman, 1992; Gray, 1999) although, lower values can occur in dilute waters high in organic content and higher values in eutrophic waters, ground water brines and salt lakes (Chapman, 1992; Droste, 1997). It is controlled by the dissolved chemical compounds and the biochemical processes in the water (Gray, 1999). Carbon dioxide dissolves readily in water and is closely linked with the chemical processes that determine the acidity and alkalinity of water. The acidity of water is determined by the abundance or, more correctly the activity of H ions. Higher concentrations of H ions make water more acidic while lower concentrations make it more alkaline (Gray, 1999). Aquatic plants can use CO_2 or HCO_3^- . During the day uptake of CO_2 may become exhausted so that HCO_3^- is used. Hydroxide ions are secreted replacing the HCO_3^- . Some of the free CO_2 will be precipitated as CaCO_3 in hard waters and is then permanently lost. The overall result is an elevated pH ($9-10$) in water containing actively photosynthesizing

macrophytes or algal blooms. At night CO₂ is released and the process is reversed so that the pH returns to normal. In clean water pH is controlled by the balance between CO₂, HCO₃⁻ and CO₃²⁻, as well as organic acids. So HCO₃⁻ and H₂CO₃ are all inorganic forms of CO₂ and their relative contribution to the total CO₂ concentration controls the pH (Gray, 1999). Acidity and alkalinity are the base and acid neutralizing capacities of water. If the water has no buffering capacity then these are inter-related with pH. Most natural waters will contain weak acids and bases, so acidity and alkalinity should also be tested with pH. Acidity in water is controlled by the presence of strong mineral acids, weak acids (for example carbonic, humic, fulvic) and the hydrolyzing salts of metals (for example iron and aluminium). It is determined by titration with a strong base up to pH 4 (free acidity) or to pH 8.3 (total acidity) (Gray, 1999; Droste, 1997). Thus the pH values of most natural waters are in the range 4-9. Waters of low pH tend to be more corrosive and if the pH value is very low a water can have a sour or acidic taste (Droste, 1997). The hardness values were within the normal ranges during the study period with the average of 37.35 CaCO₃ mg L⁻¹ and the lower and higher values were 37.13 CaCO₃ mg L⁻¹ and 37.63 CaCO₃ mg L⁻¹, respectively. Furthermore, hardness values indicated that the water of the Titiwangsa Lake classified as soft water (Table 1). The hardness of water varies from place to place reflecting the nature of the geology with which the water has been in contact. In general surface waters are softer than ground waters, although there are many extremely soft ground waters. Hardness is caused by divalent metal cations which can react with certain anions present to form a precipitate. Only divalent cations cause hardness. In hard water Ca, Mg, SO₄, CO₃ and HCO₃⁻ ions are more abundant (Chapman, 1992; Gray, 1999).

Metal concentration in water: In natural aquatic ecosystem, metals occur in low concentrations, normally at the nanogram to microgram per liter level. In recent times however, the occurrence of metal contaminants especially the heavy metals in excess of natural loads has become a problem of increasing concern. This situation has arisen as a result of the rapid growth of population, increased urbanization and expansion of industrial activities, exploration and exploitation of natural resources, extension of irrigation and other modern agricultural practices as well as the lack of environmental regulations (FAO, 1992). In the present study, the mean of six metals (Zn, Cu, Cr, Ni, Pb and Cd) were lower than maximum concentrations allowed by Malaysian and international standards (Table 3). It was obvious that the mean metal concentrations (µg L⁻¹) in the water of Titiwangsa Lake based on monthly sampling for (Zn, Cu,

Cr, Ni, Pb and Cd) were 10.02, 5.36, 2.89, 2.55, 0.73 and 0.08 µg L⁻¹, respectively. The maximum concentration of the metals in the water was zinc followed by copper, chromium, nickel, lead and cadmium. The comparison of trace metals with surface water quality guidelines (USEP-Criteria Maximum Concentration (CMC), USEP-Criteria Continuous Concentration (CCC), Canadian Council of Ministers of Environment (CCME), NWQS (Malaysia)-National Water Quality Standards Malaysia) showed that all six metal concentrations below Criteria Maximum Concentration (CMC), thus toxic effects for these metals would be rarely observed and the adverse effects to aquatic organisms would not frequently occur. Furthermore, the level of heavy metals recorded in water in this study were generally low when compared with the limit of chronic reference values suggested by WHO (1985) and USEPA (1986).

Metal concentration in sediment: The study revealed that the sediment from Titiwangsa Lake contained high concentrations of heavy metals when compared with their concentration in water. Sediments act as the most important reservoir or sink of metals and other pollutants in the aquatic environment (Gupta *et al.*, 2009). Heavy metal concentrations in sediment can affect the water quality and bioaccumulation of metals in aquatic organisms, resulting in potential long-term implication on human health and ecosystem (Fernandes *et al.*, 2007). The Sediment Quality Guideline (SQGs) levels were used to determine if the concentrations reported are toxic to aquatic life (EPA, 1999) (Table 4). The comparison of metals with SQGs showed that Cu, Zn, Pb, Cr and Cd concentrations were below the TEL values. For these six metals, therefore, toxic effects would be rarely observed. Variations in levels of metals among sediments may be explained in terms of the chemical forms of the elements, physico-chemical characteristics of the sediment (organic matter, clay content, pH, etc.), microbial activity and the extent of contamination by the local environment. Heavy metal concentrations in the various matrices of the lake also depend on the geochemical structure of the lake basin that may consist of heavy metals rich metamorphic rocks.

Metal concentration in plankton: The accumulation of heavy metals in plankton depends on the factors like metal content in water, absorption properties of the plankton species and to the metal of sediment (Elmaci *et al.*, 2007). In the present study, sediment contained higher amounts of metals than that of overlying water and plankton and this probably due to the deposition of dead plankton, sedimentation of the suspended particles having trace metals content.

Metal concentration in fish: Variations in levels of metals among the fish may be explained mainly in terms of the chemical forms of the elements and their concentrations in the local environment, microbiological activity and differences in fish size. In addition, different feeding habit of fish also contributes to the variation in metal accumulation. A direct relation-ship between the trophic level of the fish and trace metals accumulation and reported that omnivorous fish had higher levels of trace metals than carnivorous and planktivorous. Trace metal accumulation in fish species was in the order of omnivorous feeder>phytoplankton>zooplankton>carnivorous>macrophyte feeder (Balasubramanian *et al.*, 1997). The difference in the accumulation of heavy metals in various organs of fishes may be attributed to the proximity to the tissues to the availability of the metals, i.e., the quantity present in the water, sediment and plankton, age and type of the fish and presence of ligands in the tissues having an affinity to the metal and/or to the role of the tissue in the detoxification process (Adhikari *et al.*, 2009). Maximum accumulation heavy metals occurred in gills and this is may be due to their capacity to accumulate heavy metals brought by blood from other parts including liver and muscles of the body and induce the production of the metal binding protein, metallothionein, that is believed to play a crucial role against the heavy metals by binding them (Kent, 1998). The highly branched structural organization of the gill and the resultant highly increased surface area, along with the large volume of water passing through the gill surface and the highly vascular physiological state and the relatively small biomass when compared to their surface area (Mayer *et al.*, 1991) make the gill a prime site for heavy metals accumulation (Jayakumar and Paul, 2006). Muscle contained the lowest concentrations of heavy metals among all the tissues investigated in the present study. Muscle does not come into direct contact with the metals as it is totally covered externally by the skin that in many ways helps the fish to ward off the penetration of the heavy metals and also it is not an active site for detoxification and therefore transport of heavy metals from other tissues to muscles (as in the case of liver) does not seems to arise. Muscles are the main edible part of fish and can directly influence human health. Therefore, most governorates have established toxicological limits for heavy metals in seafood (Agah *et al.*, 2009). According to WHO (2005), the element levels of fish muscles in this study were below the allowable concentration and have no threat to public health.

CONCLUSIONS

Water quality parameters of Titiwangsa Lake were above natural concentration range (class 2) according to National Water Quality Standard (NWQS Malaysia) which is suitable for recreational activities where body contact is allowed and suitable for sensitive fishing activities. Furthermore, heavy metals concentration in the water are described in descending order of Zn>Cu>Cr>Ni>Pb>Cd at all sampling sites but the heavy metals concentration in sediment are in order of Zn>Cu>Cr>Pb>Ni>Cd, while in total suspended solids are in order of Cu>Zn>Cr>Ni>Pb>Cd. Moreover, the heavy metals concentration in plankton are in order of Zn>Cu>Cr>Ni>Pb>Cd and in fish are in order of Cu>Zn>Cr>Ni>Pb>Cd. Finally, metal concentrations were found to be lower than the international standards, therefore toxic effects for these metals would be rarely observed and the adverse effects to aquatic organisms would not frequently occur.

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