Bangladesh J. Bot. **46**(2): 691-699, 2017 (June)

CHARACTERIZATION OF CHINI LAKE WATER QUALITY WITH MALAYSIAN WQI USING MULTIVARIATE STATISTICAL ANALYSIS

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Keywords: Chini Lake, Water quality index (WQI), Waste water, Contamination

Abstract

Among the total of 16 evaluated parameters temperature, electrical conductivity (EC), total dissolve solids (TDS), dissolve oxygen (DO), biological oxygen demand (BOD_5), chemical oxygen demand (COD), depth, salinity, ammonal nitrogen (AN) and total suspended solids (TSS) had significant special variability ($p < 0.05$). According to the national standard; TSS, TDS, sulphate and nitrate were categorized as class I. Temperature, DO, BOD_5, pH, COD and turbidity were categorized as class II. Among the nutrients AN was categorized as class III. The experimental results revealed that the condition of station T3 was the worst among stations following T2 and L7. The lake water quality was classified as class II based on Water quality index (WQI), Malaysia, suggesting that., it was quite suitable for body contact and recreational purpose. This study finds prominent spatial water quality variation. The more affected water quality parameters were AN, DO, SO_4 and COD.

Introduction

Chini lake is one of the important fresh water sources in Peninsular Malaysia. Traditionally this reservoir is securing sufficient water for local's survival and ecological dependence. In recent years uncontrolled anthropogenic activities causing immediate and long-term water quality health impacts on the users and dependents. Today it's used for fishing, household and recreational purposes rather than drinking furthermore. According to the geographical location, the study area has the exceeding importance of tropical ecology as well as recreational value (Khairil *et al*. 2014). The sole UNESCO biosphere reserve in Peninsular Malaysia (Chini lake) was documented with rich diversity; some 288 species of flora, 21 species of aquatic plants, 92 species of birds, and 144 species of freshwater fish by Malaysian Nature Society (Latif *et al*. 2015). The sanctuary facilities breeding, spawning and also nursery grounds for both resident and migratory fish species. Problems started two decades ago, with the installment of a small weir (2 m) at the downstream of the lake to ease navigation for year round tourism and to boost socio-economic development (Shuhaimi-Othman *et al*. 2007).

Subsequently, the water level of the lake has risen and changed the lake ecosystem semi-lotic to lentic. The surrounding hilly and undulating catchment forest areas have been almost converted to agriculture activities of rubber, palm oil and mixed crops (Gasim *et al*. 2006). The presence of toxic contaminants in the reservoir might be due to the application of fertilizer and pesticide from the agricultural areas. One more major problem is mining activities on the shoreline of the catchment hill that immediately affects with rain water resulting increased sedimentation and heavy metals in the lake system. Among other agents include; local inhabitants faces and waste, building infrastructure in the riparian zone, boating etc. These freaky activities might be hastening

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this beautiful, tranquil and legendary water reservoir system to perish in near future (Islam *et al*. 2013). Therefore, it is important to investigate spatial variation in the study area in terms of water quality changes and other activities influencing the lake water for sustainable management.

Materials and Methods

The lake originates from surrounding waterfalls including rainwater and situated at 3º2440´´ to 3º 2642´´N and 102º5418´´ to 102º5554´´E 70 km away from the capital of Pahang in Peninsular Malaysia (Fig. 1) (http://mistisfiles.historiansecret.com/wp-content/uploads/2014/11/chini.jpg). It has an area of about 200 to 400 ha depending on seasons and outstretched 700 ha riparian dipterocarp forest as well. The basin enclosed by hilly areas with mining industrial activity.

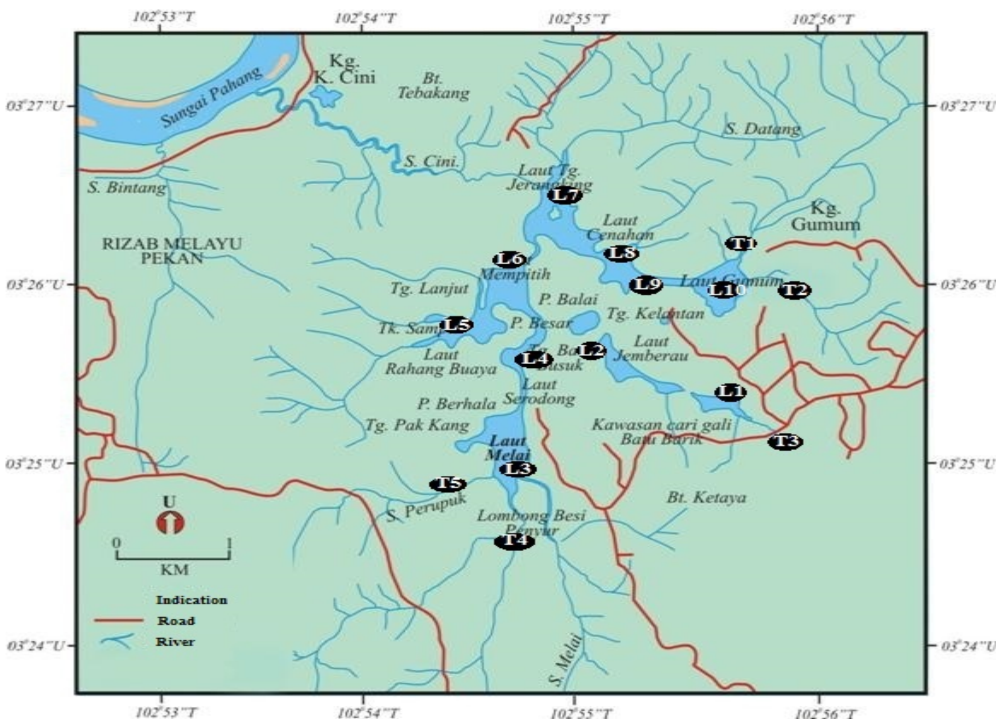

Fig. 1. Study area map showing 15 different sampling locations.

Samples were collected in three replications at each station plunging approximately 10 cm below the surface. A volume of 1L metal free Niskin (Model 1010, General Oceanic's, Germany) high-density polyethylene (HDPE) bottles were used to collect water samples for physicochemical analysis. The containers were cleaned by soaking in 15% nitric acid for 48 hours and subsequently rinsed in distilled water twice prior to use. Amber rubber coated 300 ml BOD_5 bottles with glass cork and plastic caps were used for BOD_5 observation. Collected samples were immediately transferred into insulated 50 quart cooler box (The Coleman Company Inc.) containing ice till transported to the laboratory and stored below 4^{o}C for further analysis.

Table 1. Geographical details at the sampling sites and possible sources of contamination.

St. No.	Name of the reservoir	Latitude	Longitude	Possible pollution sources
L1	Jemberau	$3^0$25′331″	$102^0$55′662″	Mining zone
L2	Batu Busuk	$3^0$25′413″	$102^0$55′385″	National service training camp, forest area, and logging zone
L3	Melai	$3^0$24′877″	$102^0$54′727″	Logging, mining and agriculture
L4	Serodong	$3^0$24′970″	$102^0$54′642″	Mining and agriculture
L5	Kenawar	$3^0$25′940″	$102^0$54′653″	Upland wild forest
L6	Gt. Teratai	$3^0$26′283″	$102^0$54′726″	Upland wild forest
L7	Jeranking	$3^0$26′512″	$102^0$54′773″	Draining end point of the lake at Chini river
L8	Cenahan	$3^0$26′248″	$102^0$55′89″	Tribal village area
L9	Pulau Balai	$3^0$25′986″	$102^0$55′334″	Jetty, hotel and restaurant for tourist.
L10	Gumum	$3^0$26′131″	$102^0$55′707″	Agriculture and tribal village area
T1	Sg. Gumum	$3^0$26′110″	$102^0$55′680″	Tributary flowing through agriculture and village
T2	Sg. Kura-Kura	$3^0$25′981″	$102^0$55′884″	Tributary flowing down through agriculture and village
T3	Sg. Jemberau	$3^0$25′175″	$102^0$55′869″	Tributary running through mining hills
T4	Sg. Melai	$3^0$24′758″	$102^0$54′425″	Tributary flowing through mining hills, upland agriculture and tribal village
T5	Sg. Paya Merapuk	$3^0$24′956″	$102^0$54′625″	Tributary flowing through mining, agriculture and tribal village

In situ parameters data were recorded using a quality multiparameter water quality monitoring instrument (YSI Incorporated, Yellow Springs, Ohio, USA). All other analyses to detect chemical concentration were performed with spectrophotometer (HACH DR 5000 model) for NO_3, AN, TN, TP, SO_4, PO_4 and COD (HACH 2010). Standard protocols recommended by American Public Health Association (APHA 2012) were followed as recommended. BOD_5 was calculated using DO meter quantifying initial dissolve oxygen and 5th day incubated dissolve oxygen at 20^{o}C. The formula that develops WQI (Water Quality Index) is as follows:

WQI = 0.22 (SIDO) + 0.19 (SI BOD) + 0.16 (SI COD) + 015 (SI AN) + 0.16 (SI SS) + 0.12 (SI pH)

where, SI refers to the sub-index function for each of the given parameters and the coefficients are the weighting factors derived from the opinion poll.

Statistical analysis: Results obtained were subjected for mathematical and statistical computation using Microsoft Office Excel 2010 and Statistical Package for Social Scientists (IBM SPSS Statistics) 21th version. Two-way ANOVA was carried out over the sampling data to determine the significance among the sampling stations (Monica 2016). Kolmogorov-Smirnov test (K-S test) was performed for the normality distribution of all measured indicators. Regression and correlation (two-tailed Pearson correlation) were analyzed to elucidate the significant relationship among the physicochemical water quality variables with statistical significances at the $p < 0.01$ and $p < 0.05$ level.

Results and Discussion

Table 2 demonstrates the descriptive statistical value of the measured indicators from 15 sampling points along the Chini Lake reservoir and its tributaries. In general the lake water quality found better compared to the tributaries. ANOVA (Monica and Choi 2016) reveals that all indicators had significant differences over the sampling sites except pH, turbidity, sulphate, phosphate, total nitrogen and total phosphate. Pearson correlation (two-tailed) analysis was conducted to correlate with the water quality parameters. Hence, $r = 0.01$ should be accepted as truly 'significant' and $r = 0.05$ should be viewed as possibly significant relationships. Meanwhile, the level of variability over space is perfectly illustrated in Fig. 2, precisely comparing different sites using of a box plot for further analyze (Kilonzo *et al*. 2014).

Surface water temperature was beyond normal limit of the national standard due to dry and hot tropical temperature, resulting from shallow water table. Station along the tributaries T2, T4 and T5 are located in the upper part of the lake and flowing through a dense forest, so temperature is significantly lower than the lake ignoring depth effect. The lake was slightly acidic (6.38 ± 0.88) with relatively stable trend line (Fig. 2). Strongly positive correlation of depth, BOD_5 and COD with pH ($r = 0.764$, $p < 0.01$, $r = 0.768$, $p < 0.01$ and $r = 0.688$, $p < 0.01$ considerably) indicates that the shallow areas (i.e. tributaries and banks of the lake) were rich in biologically active organic matter (Monica and Choi 2016). Different studies conducted by Islam *et al*. (2015) and Reza and Singh (2010) also found acidic water reservoir in relation with high temperature, that is similar to the current study.

EC and TDS were found in negligible concentration but they had a strong positive correlation in between ($r = 0.998$, $p = 0.01$) and also with salinity, TSS, nutrient sulphate and AN ($r = 0.950$, 0.725, 0.661, 0.704 and $r = 0.954$, 0.753, 0.673, 0.710 considerably for EC and TDS with $p < 0.01$), which proves that nutrients were washed away downstream into the lake with sediments. Maximum TDS and conductivity were detected at station T4 with the values of 125.00 µS/cm and 80.00 mg/l considerably. This might be due to increased sedimentation with heavy rain from the surrounding bare iron mining hills along this narrow course of flow. Positive correlation between DO and pH ($r = 0.557$, $p < 0.05$) is consistent with other study by Sing *et al*. (2013). The nutrient leaching from agricultural fields enhances flourish of microorganism and algae and decomposition rate influencing DO Turbidity was detected 3 fold higher than acceptable limit at station T5 although overall situation was under normal condition, whereas International Standards acceptable limit for domestic water use ranges 0 - 25 NTU (Gasim *et al*. 2006). Station T5 was influenced by bare hills and station L8 was forced by villager's activity, as it is in front of the village jetty.

Mean BOD_5 value at Chini Lake was 1.50 ± 0.92 mg/l, which ranged from 0.09 - 4.20 mg/l. Station L5, L3 and L9 were listed for higher BOD_5 considerably. The mean value of COD was recorded 21.53 ± 7.51 mg/l and the values ranged from 7.00 - 42.00 mg/l. Raised COD level indicates higher pollution in that definite area (Varunprasath and Daniel 2010) and strong positive correlation between BOD_5 and COD indicates the presence of biologically active organic matter. BOD_5 and COD revealed strong correlation between them of ($r = 0.945$, $p < 0.01$).

Sulphate concentration found in Chini lake was very low with the mean value of 1.49 ± 2.56 mg/l (ranges from 0.00 - 11.00 mg/l). The presence of sulphate was significant at station T4 and T2. Probably this might be due to the activities of iron-mining around the station T4 and station T2 by the sulphate of fertilizer and pesticides from extensive hill agriculture. The primary source of sulphate could be the precipitation of sulfur, produced by the combustion of fuel and also from mining area (Wetzel 1983) and moreover incorporation of waste discharges (Hem 2002). Whereas, palm oil and rubber plantation are the major source of sulphate at the current study. From the results, it is believed that effluents and sulphate were carried along with sediment through the

Table 2. Mean and standard deviation (Sd) of *in situ* and *ex situ* parameters at 15 sampling stations during the study period.

Indicator	Site														
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	T1	T2	T3	T4	T5
Temp	29.76	30.2	30.06	30.58	31.4	30.99	30.8	30.99	31.32	30.46	30.48	26.86	30.61	28.29	26.36
$(25 \pm 2)^*$	0.41	0.7	0.51	0.54	0.57	0.88	1.37	0.69	0.19	1.24	1.91	1.33	2.79	2.04	0.97
EC $(1)^*$	32.33	32.67	40.67	38	32.33	31.67	42.26	41.25	32.33	30.74	33	42	25.67	113.67	41
	5.13	4.04	7.09	8.89	3.21	2.08	0.93	1.62	1.5	1.16	0	20.52	0.58	19.63	25.16
TDS $(500)^*$	19.67	20	24	22.33	18.67	18.33	25.65	25.39	18.67	19.33	19.33	26.33	15	70.33	26.67
	3.51	1.73	4	5.13	2.08	0.58	0.72	0.53	0.58	0.58	0.58	13.5	1	11.93	15.04
Turbi $(5)^*$	12.33	2.18	11 .47	11.17	6.73	8.3	9.6	24.33	7.03	6.77	11.87	4.33	4.37	11.15	35.77
	7.28	1.94	5.77	6.79	5.87	5.85	6.34	33.05	6.77	6.65	14.09	5.2	4.34	7.93	34
TSS $(25)^*$	2.76	2.78	2.27	2.48	1.98	2.39	4.18	4.13	2.35	2.75	3.05	6.29	2.5	11.53	9.58
	1.45	2.23	0.15	0.95	0.87	1.03	3.22	3.34	1.84	2.25	4.02	4.13	0.96	1.91	4.13
DO $(7)^*$	5.46	6.2	6.14	5.76	6.88	6.09	4.94	5.59	6.19	6.5	5.46	4.68	3.53	5.46	6.09
	0.75	0.95	1.21	1.97	0.77	1.28	1.8	2.34	1.26	1.45	1.84	0.9	2.93	0.53	0.84
pH $(6.5 - 8.5)^*$	6.57	6.61	6.65	6.53	6.73	6.64	6.62	6.58	6.62	6.68	6.65	4.93	5.93	6.14	5.84
	0.61	0.57	0.64	0.58	0.82	1.06	1.18	1.17	1.13	1.1	1.24	0.22	0.58	1.04	0.86
BOD $(1)^*$	1.68	1.97	2.05	1.86	2.34	1.73	1.61	1.54	1.91	1.39	1.26	0.73	1.1	0.74	0.75
	0.65	0.9	1.68	1.21	1.75	0.66	0.37	0.4	1.18	0.64	0.87	0.74	0.57	0.13	0.69
COD $(10)^*$	24.83	27.3	39.79	27.31	33.57	25.63	23.8	23.36	27.45	21.26	19.74	13.43	16.08	12.1	12.78
	11.66	8	8.66	3.4	0.57	11.55	5.96	8.58	5.46	6.41	5.43	5.68	12.54	3.52	7.93
SO_4	0	0.33	2.67	1.33	1.67	2.33	0.33	0.33	0.67	0.33	0.33	3.67	0.33	4.33	3.67
	0	0.58	1.53	2.31	1.53	2.52	0.58	0.58	0.58	0.58	0.58	6.35	0.58	5.77	2.52
PO_4 $(0.20)^*$	0.11	0.12	0.86	0.43	0.08	0.29	0.45	0.6	0.5	0.05	0.11	0.43	0.43	0.46	0.26
	0.12	0.16	1.39	0.56	0.01	0.38	0.68	0.81	0.71	0.03	0.06	0.59	0.66	0.67	0.4
AN $(0.10)^*$	0.06	0.1	0.18	0.06	0.07	0.07	0.18	0.25	0.09	0.08	0.1	0.06	0.09	0.28	0.17
	0.015	0.04	0.11	0.02	0.03	0.03	0.07	0.04	0.02	0.05	0.017	0.04	0.07	0.079	0.11
TN	0.84	1.22	1.02	1.37	0.7	1.37	1.33	1.1	1.1	0.67	0.73	1.53	1.4	1.07	1.1
	1.31	0.53	0.63	1.34	0.26	0.85	0.4	0.87	1.11	0.4	0.25	0.95	1.21	1.12	1.48
TP	0.24	0.28	0.26	0.22	0.23	0.22	0.2	0.22	0.23	0.5	0.2	0.18	0.21	0.22	0.19
	0.1	0.16	0.16	0.05	0.04	0.1	0.05	0.04	0.1	0.47	0.11	0.07	0.03	0.11	0.02

* = NWQS standards Malaysia. All parameters are in mg/l except temperature in °C and EC in µS/cm and turbidity in NTU.

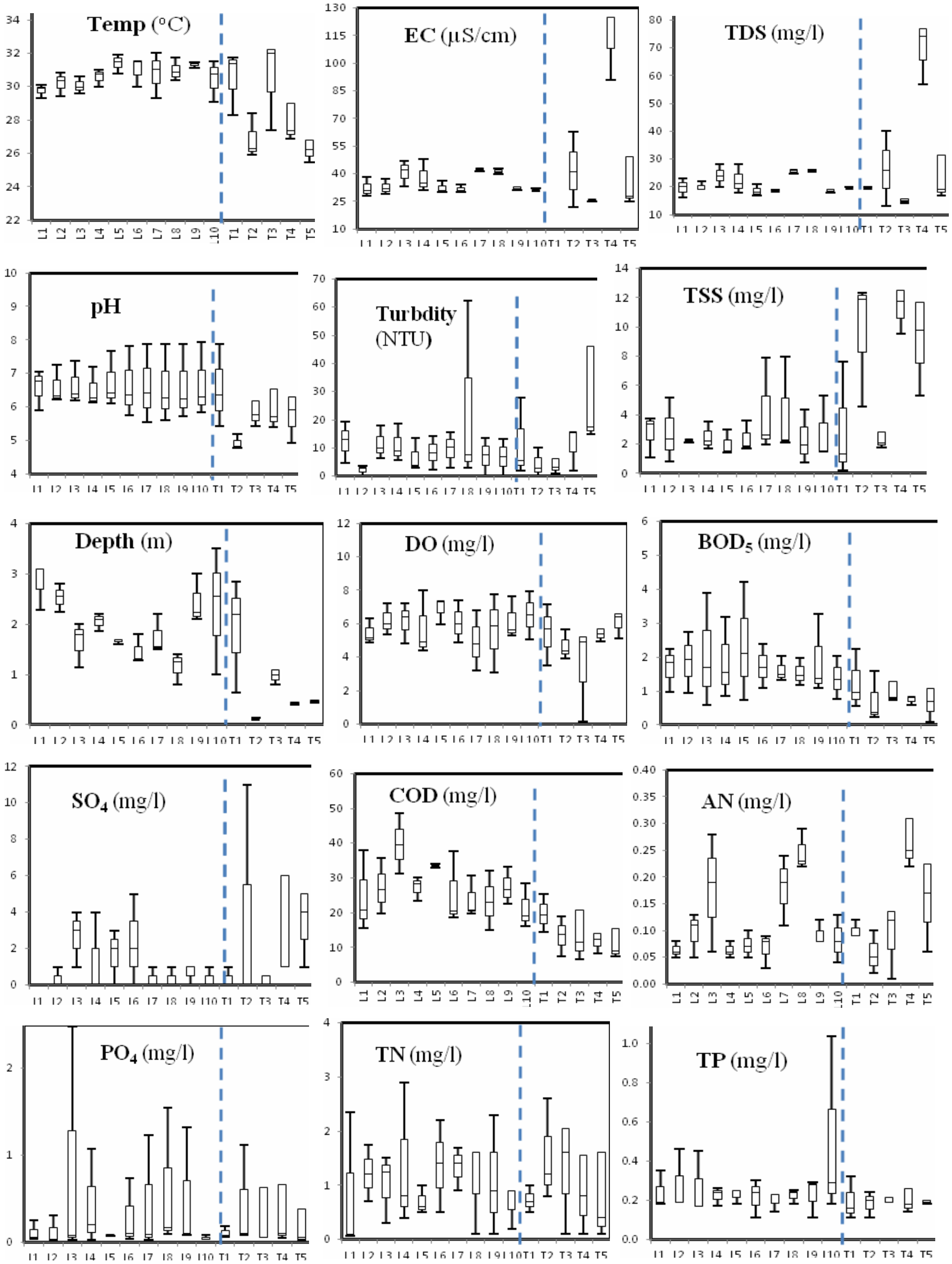

Fig. 2. The trend of water quality parameter at different sampling sites over Chini lake.

tributaries into surrounding water reserves like the station T3 and T4. However, stations far away from these two demonstrate the lower content of sulphate. Both sulphate and TSS concentration noted significantly higher at station L7, L8 and T2 holding a strong positive correlation of ($r = 0.810$, $p < 0.01$).

The main source of phosphate in the Chini lake was the regular livelihood activities by the aborigine settlers near the tributaries of the lake such as human excretion and the use of detergent. In natural water orthophosphate originates from detergent polyphosphate by hydrolysis, which is the only utilizable form of soluble organic phosphorous preciously (Wetzel 1983). According to EPA (1976), phosphate concentration exceeding 0.025 mg/l may stimulate the vigorous growth of algae and other aquatic plants which can bother the reservoir whereas Chini lake detects 0.35 mg/l on average.

Apart the tributaries, station L3, L7, L8 and partly L4 are more affected by organic substance and some nutrients especially sulphate, AN and phosphate. These stations are closed by the indigenous people settlement at Melai, Cenahan and Paya catchment (Table 1), a tourist resort and a national service center training camp which could contribute to the organic loading. Imperfect sanitation system (in some cases open space) in the clinging villages, resort and training center might be responsible for the flux of biological loading into the lake. Thus, decreased DO increases COD value, ranging from 3.11 - 8.02 mg/l for DO and 15.03 - 48.60 mg/l for COD considerably.

According to Department of Environment, Malaysia (DOE-WQI); water quality of the study area was classified as class II with a mean of 86.77 ± 3.22, which ranged from 80.32 - 91.35 (Table 3). National Water Quality Standard (NWQS) differentiates EC, TDS, salinity and TSS in class I; temperature in class II (normal to class II), DO in class II (I - V), pH in class II (I-III), turbidity in class II (I - II), BOD_5 in class II (I - III), COD in class II (I - III) and TN found in class II (I-II). No phosphate and TN were given in NWQS (EQR 2006). These results are comparable with the research findings conducted in Bera lake that showed the range of temperature was 23.70 - 31.20ºC; DO 1.36 - 4.00 mg/l; pH 4.45 - 6.83; EC 10.50 - 23.00 µS/cm; sulphate 0.96 - 5.59 mg/l; phosphate 0.00 - 0.11 mg/l; and AN 0.00 - 0.77 mg/l (Furtado and Mori 2014).

Table 3. Water quality classification of the study area by DOE-WQI.

Sampling site	DOE-WQI values	Water quality class	WQI status	Sampling site	DOE-WQI values	Water quality class	WQI status
L1	87.52	II	SP	L9	89.10	II	C
L2	88.72	II	C	L10	91.34	II	C
L3	85.21	II	C	T1	88.03	II	C
L4	88.14	II	C	T2	80.64	II	SP
L5	89.92	II	C	T3	80.32	II	SP
L6	89.56	II	C	T4	85.30	II	C
L7	84.13	II	C	T5	87.97	II	C
L8	85.57	II	C				

*C = Clean and SP = Slightly polluted. *Class I = > 92.7, Class II = 76.5 - 92.7, Class III = 51.9 - 76.5, Class IV = < 31.0.

In general water quality in the Chini Lake varies with the sampling station location. Station L6, L7 and L8 are strategically important as of their location at draining area of the lake. According to WQI values on Table 3, station L10, L5 and L6 scored least polluted (class I and II) and station T2 and T3 recorded most polluted. These polluted stations show lower DO compared to others due to stagnation and insufficient flow of water. Station T4, L3, L7 and T5 are more affected by AN. WQI depicts lake water quality mostly clean on their standards (clean, slightly polluted and polluted) except at stations T2 and at T3.

Acknowledgement

Authors are grateful to University Malaysia Pahang (UMP) and Faculty of Civil Engineering and Earth Resources for financial support through the project RDU 140366, RDU 131004 and GRS 140397.

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(Manuscript received on 14 August, 2016; revised on 18 January, 2017)