Bangladesh J. Bot. **48**(4): 1037-1046, 2019 (December)

# ASSESSMENT OF WATER QUALITY IN THE VICINITY OF CHINI LAKE, MALAYSIA

YOUSSIF HUSSIN ABDUSALAM, SUJAUL IM[1], MD ABDUL KARIM[2], SALAH MG, M IDRIS ALI AND NORAM I RAMLI

*Faculty of Civil Engineering and Earth Resources, University Malaysia Pahang, 26300 Pahang, Malaysia*

*Keywords:* Assessment, Water quality, Chini lake

## Abstract

Chini lake water is used as a source of water for domestic, industrial and agriculture. The study was carried out to assess the water quality of the lake and surrounding area. Ten sampling sites were selected representing the open water body in the lake. A total of 14 water quality parameters *viz*.. temperature, EC, TDS, DO, pH, turbidity. BOD, COD, TSS, $PO_4$, $SO_4$, $NH_4$, $NO_3$ and salinity were measured. The lowest WQI value 77 was recorded at site S4, respectively, which were found to be slightly polluted. Considering the NWQS, temperature 30.04°C, EC 31.42 μS/cm, TDS 19.03 mg/l, $NO_3^-$ 0.21 mg/l, $SO_4^-$ 0.84 mg/l, $PO_4^-$ 0.05 mg/l, TSS 12.03 mg/l and salinity 0.03 ppt are categorized under class I, while DO 6.15 mg/l, pH 6.73, turbidity 4.22 NTU, BOD 1.63 mg/l, COD 19.50 mg/l and $NH_4$-N 0.20 mg/l the lake water quality are categorized under class II. Total coliform was 273, 412, 868, 267, 495, 406, 929, 953, 441 and 398 cfu/100 ml at all S1 - S10 sites, respectively. While *E. coli* was found 13, 7, 13, 5, 7, 5, 6, 106, 10 and 7 cfu/100 ml, respectively at all S1 - S10 sites. The highest number of both total coliform 953 cfu/100ml and *E. coli* 106 cfu/100ml were observed at site S8. The sources of coliforms and *E. coli* pollution were wastes from human and animals and domestic effluent, which might be due to lack of improper sanitation systems and effects of land use from surrounding agricultural area.

## Introduction

Lake is an important resource for human survival, life and production and one of the ecological landscapes with the highest biodiversity in nature and most important human living environment (Goudie 2018). Although serious water pollution has caused widespread concern around the world, lake resources are being threatened due to population growth and poor governance (WHO 2010).

Almost 90% of the nation's water supply comes from the lakes and reservoirs in Malaysia (Council 2012). Based on several analyses, it was found that important water quality parameters were beyond the permitted level set by the Department of Environment (DOE 2008). Water quality index (WQI) has been approved in order to evaluate the baseline water quality of the aquatic ecosystems (DOE 2008). Previous studies reported that, the WQI method was used to evaluate the effect of urban discharge on the water quality, spatial and temporal changes of river water quality, pollution levels along the river systems and effects of aquaculture on river water bodies (Wang *et al*. 2019).

Chini is a natural lake in Peninsular Malaysia, which is in the state of Pahang approximately 100 km from Kuantan, the capital of Pahang and drained by Chini river to the Pahang river (Fig. 1). The area of Chini lake varies from 150 - 350 ha, depending on the seasons and 700 ha of freshwater swamp and swamp forest (Gorde and Jadhav 2013). The state government developed large forest of oil palm and rubber trees around Chini areas (Hamzah and Hattasrul 2008). National service camp was also set up near the lake, which consequently adds some physical impact towards the water quality of the lake (Hamzah and Hattasrul 2008).

*Author for correspondence: <sujaul@ump.edu.my>. [1]Earth Resources & Sustainability Centre (ERAS), University Malaysia Pahang, Malaysia. [2]Department of Botany, University of Dhaka, Dhaka-1000, Bangladesh.

In recent years, Chini lake experienced major development in agriculture activities and was believed to release pollutants such as nitrate and phosphate into the lake (Sujaul *et al*. 2017). Soil erosion due to conversion of forest to agriculture increases the suspended solid in the lake (Sharip *et al*. 2012). The nutrients and organic loading may extend hazardous effect to aquatic life, as well as public health, especially human, consumers of freshwater fishes. In the study total coliform and *E. coli* were used as indicator of bacteriological pollution. Total coliforms are usually found in fecal-polluted water and are often associated with disease outbreaks (Hamzah and Hattasrul 2008). *E. coli*, a species of the coliform group, is always found in the feces and is, therefore an indicator of fecal contamination and the possible presence of another enteric pathogen (Hamzah and Hattasrul 2008). Therefore, the aim of the study was to evaluate the water quality of the Chini lake and its suitability for usage.

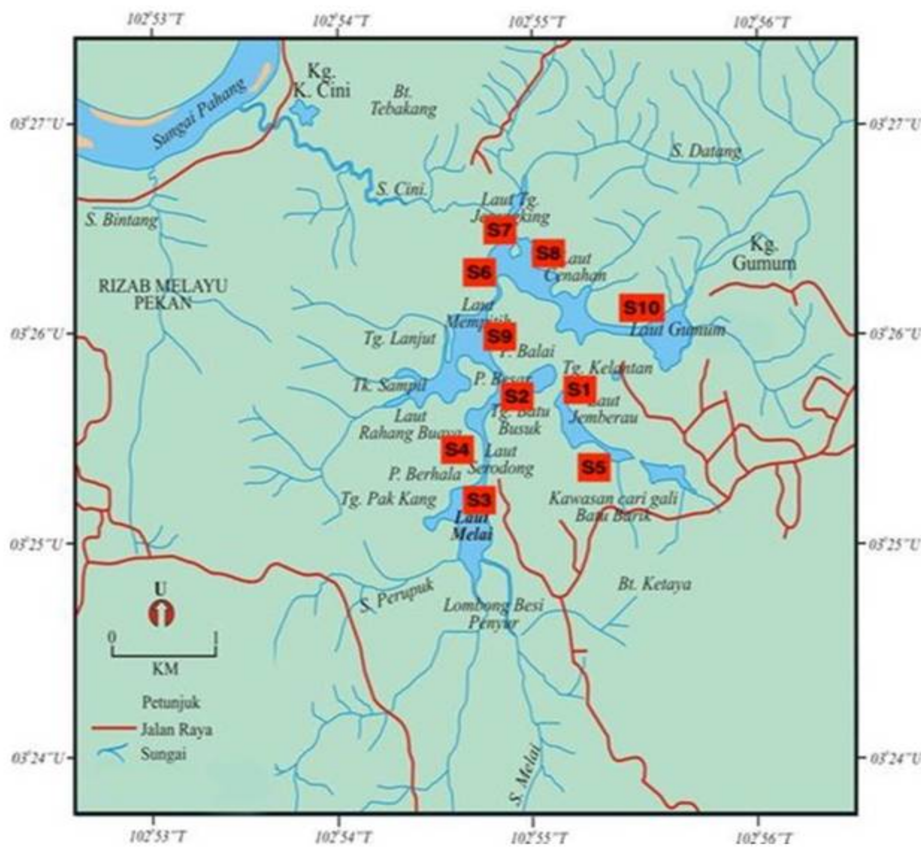


Fig. 1. Location of the study area and the sampling sites.

## Materials and Methods

Water samples were collected from 10 sites bimonthly throughout the year from June, 2017 to April, 2018 about 10 - 15 cm below the surface (Hamzah and Hattasrul 2008) (Table 1). Sampling for BOD was collected by using dark BOD bottles (300 ml) (APHA 2012). Samples were preserved in the cool boxes during sampling and before transported to the laboratory.

Six parameters (Temperature, pH, turbidity, DO, EC and salinity) were measured *in situ* by using a portable YSI multisensory meter (model 6600-M, USA). Analysis of $NH_4$-N, $PO_4^-$, $SO_4^-$, $NO_3^-$ and COD were measured by Spectrophotometer (HACH DR5000 model) (HACH 2010). BOD was analysed by DO meter (YSI 5100, USA), whereas TSS and TDS were measured in the laboratory using the Gravimetric method. The assessment of water quality was done using Water Quality Index (WQI) and National Water Quality Standard (NWQS), Malaysia and WQI have been categorized into 6 classes according to the Department of Environment, Malaysia (DOE 2008). Six parameters were obtained to calculate WQI (DO, BOD, COD, $NH_4$-N, TSS and pH) (DOE 2008). The following equation (1) was used to calculate WQI:

$$WQI = 0.22 \times SIDO + 0.19 \times SIBOD + 0.16 \times SICOD + 0.15 \times SINH_4\text{-}N + 0.16 \times SITSS + 0.12 \times SIpH \quad (1)$$

where, the SI indicates the sub-index function and the coefficients are the weightages for the corresponding parameters with a total value of unity.

Table 1. Location of sampling sites and surrounding area.

| Sites | Grid references | Location | Sources of pollution |
|---|---|---|---|
| S1 | 03º25′331″ 102º55′662″ | Laut Jemberau, near to the Jemberau river | Mining zone and primary forest area |
| S2 | 03º25′413″ 102º55′385″ | Laut Batu Busuk | National service training camp, forest area, and logging zone |
| S3 | 03º24′877″ 102º54′727″ | Laut Melai, near the Melai river | Logging, mining and agricultural area |
| S4 | 03º24′970″ 102º54′642″ | Laut Serodong | Mining and agricultural area |
| S5 | 03º25′940″ 102º54′653″ | Laut Kenawar | Upland primary forest and rubber plantation area |
| S6 | 03º26′283″ 102º54′726″ | Laut Gt. Teratai | Upland primary forest and rubber plantation area |
| S7 | 03º26′512″ 102º54′773″ | Draining point of the lake at the initiation of Chini river | Draining end point of the lake at Chini river |
| S8 | 03º26′248″ 102º55′89″ | Laut Cenahan, near to the jetty | Agricultural area and Cenahan village |
| S9 | 03º25′986″ 102º55′334″ | Laut Pulau Balai, near the tourist main jetty | Secondary forest, rubber plantation and tourist settlement zone |
| S10 | 03º26′131″ 102º55′707″ | Laut Gumum, near the jetty | Agricultural land, shifting cultivation, oil palm plantation and Gumum village |

The total coliform was determined using membrane filtration technique according to standard procedures for water analysis (APHA 2012). Colilert method was used for determination of total coliform and *E. coli* and the Chromocult® coliform agar (Merck) medium was used for detection of total coliform and *E. coli* (Hamzah and Hattasrul 2008).

IBM SPSS software (version 22) was used to calculate Pearson regression and correlation to identify the significant differences among the physicochemical water quality parameters.

**Results and Discussion**

Physiochemical water quality parameters were analysed by descriptive statistics from 10 sampling sites which are presented in Table 2.

The temperature measured along the Chini lake ranged from 29.80 - 30.62ºC. The temperature did not show any spatial change but indicated temporal variation. The value of EC was 24.30 - 47.81 µS/cm. The highly significant variation observed at site S3 47.81µS/cm followed by 36.47 µS/cm at site S4. Still the maximum (30.65 ± 5.13 µS/cm) detected level of EC was within normal range for natural environment and aquaculture (class I) compared to the national standard NWQS (Arafat *et al*. 2017).

In Malaysia, standard pH value accepted within 6.50 - 6.80 and threshold level is 5.00 - 9.00 (Monica and Choi 2016). The pH was in very weekly acidic range between 6.48 (S8) and 6.92 (S9). In the case of natural waters, low pH value indicates the availability of abundant organic matter (Matilainen *et al*. 2011). The dissolved oxygen (DO) ranged from 4.83 - 7.25 mg/l, TDS ranged from 15.00 (S10) - 28.42 mg/l (S3) and turbidity 25.41 NTU (S9) - 113.31 NTU (S6). Turbidity found at site S6 was three-folds higher than acceptable level, although overall situation was under normal condition, whereas International Standards acceptable limit for domestic water use ranges 0 - 25 NTU (Seeboonruang 2012). COD value ranged 16.51 (S1) - 23.97 mg/l (S5). The highest COD level indicates higher pollution in that definite area (Varunprasath and Daniel 2010). The highest TSS 30.38 mg/l recorded at site S6 and the lowest TSS 3.90 mg/l at site S1. The BOD was found to range 1.45 - 1.86 mg/l with highest 1.86 mg/l at site S4 and lowest 1.45 mg/l at site S6. The $NO_3^-$ concentration ranged from 0.10 - 0.46 mg/l, the highest 0.46 mg/l was found at site S6 and the lowest 0.10 mg/l at site S10. The nutrients leaching from agricultural fields enhance flourish of microorganisms and algae and the rate of decomposition influencing DO (Mohammad and Assefa 2017).

The $PO_4^-$ concentration measured across the seasons ranged from 0.02 - 0.07 mg/l. The use of detergents and human excretions, which are the livelihood activities of ordinary settlers, are the main source of phosphates. The $SO_4^-$ concentration found to range from 0.48 - 1.62 mg/l. The highest 1.62 mg/l recorded at site S10 and the lowest 0.48 mg/l at site S4.

The relationship among the water quality parameters was measured by using Pearson correlation (two-tailed) analysis (Table 3). Correlation analysis showed that pH had positive significant relationship with temperature ($r = 0.285$, $p < 0.01$), TSS ($r = 0.183$, $p < 0.05$), BOD ($r = 0.404$, $p < 0.01$) and DO ($r = 0.196$, $p < 0.01$). The study showed that the DO value positively correlated with temperature ($r = 0.435$, $p < 0.01$), pH ($r = 0.196$, $p < 0.01$), BOD ($r = 0.200$, $p <0.01$), and COD ($r = 0.213$, $p <0.01$). The relation among the parameters indicates that the main contributing factors affecting DO in the study area are photosynthesis, seasonal variance and decomposition rate of organic matter (Sujaul *et al*. 2013).

Electrical conductivity was positively correlated with TDS ($r = 0.535$, $p < 0.01$) and COD ($r = 0.184$, $p < 0.05$). Correlation analysis shows TDS only a positively significant correlation with EC ($r = 0.535$, $p < 0.01$). Turbidity has positive relationship with TSS ($r = 0.521$, $p < 0.01$), salinity ($r = 0.193$, $p < 0.01$), $SO_4^-$ ($r = 0.295$, $p < 0.01$) and $NO_3^-$ ($r = 159$, $p < 0.05$). According to NWQS, average value of turbidity at all sites were categorized as class II. The tributary flows through the villages carries organic matter from partially open sanitation (Xiaoping *et al*. 2017, Rasul *et al*. 2018). The TSS has positive relationship with pH (0.183, $p < 0.05$), turbidity ($r = 0.521$, $p < 0.01$). The BOD value was positively correlated with temperature (($r = 0.407$, $p < 0.01$), pH ($r = 0.404$, $p < 0.01$), DO ($r = 0.200$, $p < 0.01$), $SO_4^-$ (0.173, $p < 0.05$), $NO_3^-$ (0.154, $p < 0.05$) and negatively correlated with EC ($r = –0.232$, $p < 0.01$) and TDS (–0.362, $p < 0.01$). The COD value was

**Table 2. Physicochemical parameters of water quality.**

| Sites | Temp. | EC | TDS | DO | pH | Turbidity | BOD | COD | TSS | $PO_4^-$ | $SO_4^-$ | $NH_4$-N | $NO_3^-$ | Salinity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S1 | 29.90 ± 1.44 | 27.52 ± 2.58 | 17.62 ± 1.66 | 6.10 ± 0.74 | 6.67 ± 0.20 | 44.21 ± 19.71 | 1.82 ± 0.96 | 16.51 ± 4.06 | 3.90 ± 3.89 | 0.07 ± 0.09 | 1.00 ± 0.34 | 0.22± 0.10 | 0.14 ± 0.22 | 0.01 ± 0.01 |
| S2 | 29.98 ± 1.40 | 29.21 ± 2.64 | 17.75 ± 1.68 | 6.16 ± 0.81 | 6.78 ± 0.21 | 36.80 ± 14.96 | 1.77 ± 0.92 | 16.60 ± 3.62 | 6.21 ± 3.66 | 0.06 ± 0.03 | 0.67 ± 0.33 | 0.22± 0.14 | 0.35 ± 0.72 | 0.02 ± 0.01 |
| S3 | 29.95 ± 1.33 | 47.81 ± 2.07 | 28.42 ± 1.32 | 4.83 ± 0.81 | 6.73 ± 0.25 | 43.01 ± 20.87 | 1.52 ± 1.23 | 16.98 ± 4.40 | 5.61 ± 4.31 | 0.05 ± 0.02 | 0.49 ± 0.35 | 0.18± 0.08 | 0.22 ± 0.48 | 0.01 ± 0.05 |
| S4 | 29.95 ± 1.52 | 36.47 ± 2.21 | 23.20 ± 1.42 | 6.29 ± 1.02 | 6.80 ± 0.20 | 43.42 ± 20.71 | 1.86 ± 0.94 | 22.63 ± 4.85 | 11.41 ± 6.17 | 0.05 ± 0.02 | 0.48 ± 0.28 | 0.20 ± 0.15 | 0.23 ± 0.57 | 0.01 ± 0.01 |
| S5 | 30.00 ± 1.49 | 30.75 ± 4.08 | 18.48 ± 2.60 | 7.25 ± 1.04 | 6.79 ± 0.49 | 46.26 ± 26.92 | 1.86 ± 0.83 | 23.97 ± 4.40 | 19.40 ± 5.65 | 0.06 ± 0.02 | 0.67 ± 0.35 | 0.22 ± 0.21 | 0.16 ± 0.12 | 0.04 ± 0.02 |
| S6 | 30.25 ± 1.57 | 27.42 ± 6.24 | 16.59 ± 3.98 | 6.09 ± 1.10 | 6.77 ± 0.32 | 113.31 ± 57.63 | 1.45 ± 0.81 | 19.90 ± 5.61 | 30.38 ± 6.19 | 0.05 ± 0.02 | 1.00 ± 0.34 | 0.36 ± 0.29 | 0.46 ± 0.21 | 0.03 ± 0.01 |
| S7 | 30.10 ± 1.34 | 25.80 ± 3.11 | 15.76 ± 1.98 | 6.01 ± 1.33 | 6.68 ± 0.16 | 34.81 ± 17.35 | 1.50 ± 0.72 | 18.93 ± 5.02 | 15.77 ± 7.45 | 0.07 ± 0.03 | 0.67 ± 0.51 | 0.18 ± 0.14 | 0.11 ± 0.09 | 0.05 ± 0.02 |
| S8 | 30.62 ± 1.27 | 24.30 ± 3.56 | 19.13 ± 2.28 | 6.15 ± 1.26 | 6.48 ± 0.18 | 28.37 ± 12.32 | 1.59 ± 0.83 | 17.42 ± 5.51 | 11.21 ± 7.73 | 0.04 ± 0.03 | 0.53 ± 0.14 | 0.15 ± 0.14 | 0.11 ± 0.07 | 0.03 ± 0.01 |
| S9 | 29.80 ± 1.20 | 35.12 ± 3.76 | 18.32 ± 2.40 | 6.22 ± 1.17 | 6.92 ± 0.17 | 25.41 ± 10.64 | 1.70 ± 0.95 | 20.57 ± 4.54 | 11.50 ± 1.63 | 0.07 ± 0.02 | 1.27 ± 0.58 | 0.15 ± 0.13 | 0.22 ± 0.12 | 0.05 ± 0.04 |
| S10 | 29.84 ± 1.38 | 29.84 ± 4.61 | 15.00 ± 2.95 | 6.35 ± 1.31 | 6.72 ± 0.24 | 26.64 ± 9.45 | 1.63 ± 0.84 | 21.48 ± 3.31 | 4.93 ± 4.21 | 0.02 ± 0.02 | 1.62 ± 0.70 | 0.15 ± 0.11 | 0.10 ± 0.06 | 0.03 ± 0.00 |

± = Sd, N = 10.

**Table 3. Pearson correlation coefficient (r) among the water quality parameters.**

| | Temp | pH | DO | EC | TDS | Tur | TSS | BOD | COD | $NH_4$-N | Salinity | $PO_4^-$ | $SO_4^-$ | $NO_3^-$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp | 1 | | | | | | | | | | | | | |
| pH | 0.285** | 1 | | | | | | | | | | | | |
| DO | 0.435** | 0.196** | 1 | | | | | | | | | | | |
| EC | −0.271** | −0.079 | −0.210** | 1 | | | | | | | | | | |
| TDS | −0.366** | −0.178* | −0.161* | 0.535** | 1 | | | | | | | | | |
| TUR | 0.044 | 0.052 | −0.008 | −0.073 | −0.043 | 1 | | | | | | | | |
| TSS | −0.370** | 0.183* | −0.382** | 0.069 | −0.262** | 0.521** | 1 | | | | | | | |
| BOD | 0.407** | 0.404** | 0.200** | −0.232** | −0.362** | 0.050 | 0.006 | 1 | | | | | | |
| COD | 0.161* | −0.219** | 0.213** | 0.184* | −0.044 | −0.037 | −0.076 | −0.003 | 1 | | | | | |
| $NH_4$-N | 0.105 | −0.294** | 0.143 | 0.064 | 0.045 | 0.001 | −0.127 | −0.078 | 0.263** | 1 | | | | |
| Salinity | −0.108 | 0.033 | −0.084 | −0.086 | 0.075 | 0.193** | −0.083 | −0.023 | −0.128 | −0.095 | 1 | | | |
| $PO_4^-$ | 0.092 | 0.101 | 0.098 | −0.019 | −0.052 | −0.103 | −0.042 | 0.002 | 0.106 | −0.052 | −0.040 | 1 | | |
| $SO_4^-$ | 0.073 | −0.104 | −0.043 | −0.075 | −0.147* | 0.295** | 0.044 | 0.173* | 0.039 | 0.219** | −0.119 | 0.051 | 1 | |
| $NO_3^-$ | 0.053 | −0.003 | −0.031 | 0.031 | −0.077 | 0.159* | 0.048 | 0.154* | −0.027 | −0.108 | −0.004 | −0.067 | −0.046 | 1 |

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

positively correlated with temperature ($r = 0.161$, $p < 0.05$), DO ($r = 0.213$, $p < 0.01$), EC ($r = 0.184$, $p < 0.05$) and $NH_4$-N ($r = 0.263$, $p < 0.01$).

The $NH_3$-N was found to be positively correlated with COD ($r = 0.263$, $p < 0.01$) and negatively with pH ($r = –0.294$, $p < 0.01$). High concentration of $NH_3$-N coined with high turbidity and TSS loading when the lake was flooded. The $SO_4^-$ was positively correlated with turbidity ($r = 0.295$, $p < 0.01$), BOD ($r = 0.173$, $p < 0.05$) and $NH_4$-N ($r = 0.219$, $p < 0.01$)., while the $NO_3$- was positively correlated with turbidity ($r = 0.159$ $p < 0.05$) and BOD ($r = 0.154$, $p < 0.05$).

Water quality in Chini lake varies with the sampling sites. In term of water quality index, site S1, S2, S5, S6, S7, S8, S9 and S10 have the highest value of the WQI and ranged from 83 - 86 (class II), while the lowest WQI value found at sites S3 and S4 (Table 4). The water quality class of these sites was classified into slightly polluted. The site S3 showed lowest DO compared to other sites in the lake due to the flooded water. The sites S4 and S5 are more affected by the organic substance. Improper sanitation system in local villages, resort and camp might bring extra biological loadings into the lake, thus increasing the BOD values.

**Table 4. Water quality classification in all sites based on DOE-WQI.**

| Sampling sites | WQI | Class | WQ status |
|---|---|---|---|
| S1 | 84 | II | SP |
| S2 | 83 | II | SP |
| S3 | 80 | II | SP |
| S4 | 77 | II | SP |
| S5 | 83 | II | SP |
| S6 | 86 | II | SP |
| S7 | 83 | II | SP |
| S8 | 84 | II | SP |
| S9 | 83 | II | SP |
| S10 | 83 | II | SP |

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

Considering the distribution of total coliform throughout the year, the highest total coliform 954 ± 715.59 cfu/100 ml was recorded in December, while the lowest 333 ± 210.91 cfu/100 ml was in July (Table 5). In case of *E. coli*, the highest 52 ± 34.93 cfu/100 ml was also in December and the lowest 4 ± 0.93 cfu/ 100 ml was both in October (Table 5).

The total coliform levels found across the seasons ranged from 121 ± 13.23 - 237245.34 cfu/100 ml (Table 6). Site S8 was recorded with maximum total coliform ranged 436 - 1788 cfu/100 ml throughout the sampling months and the lowest value was at site S4 ranged 121 ± 13.23 - 380 ± 6.15 cfu/100 ml (Table 6). Total coliform was positively correlated with EC ($r = 0.291$, $p < 0.01$), Turbidity ($r = 0.524$, $p < 0.01$), TDS ($r = 0.308$, $p < 0.01$), TSS ($r = 0.300$, $p < 0.01$), $SO_4$ ($r = 0.680$, $p < 0.01$), $PO_4$ ($r = 0.444$, $p < 0.01$), $NH_4$ ($r = 0.375$, $p < 0.01$). While total coliform was negatively correlated with BOD ($r = –0.362$, $p < 0.01$).

The *E. coli* levels measured across the seasons ranged from 1±0.00 to 365 ± 55.79 cfu/100 ml (Table 7). Site S8 was recorded with the maximum *E. coli* (6 ± 1.15 - 365 ± 55.79 cfu/100 ml, on average 106 ± 14.08 cfu/100 ml) throughout the sampling months and lowest number (1 ± 0.00

cfu/100 ml) was in April at site S4, in July at site S2, S4 and S7, in October at site S5, S6 and S10. at different sites throughout the seasons (Table 7). *E. coli* was positively correlated with EC (r = 0.278, $p < 0.01$). Turbidity (r = 0.632, $p < 0.01$), TDS (r = 0.405, $p < 0.01$), TSS (r = 0.275, $p < 0.01$), $SO_4$ (r = 0.573, $p < 0.01$), $NH_4$ (r = 0.483, $p < 0.01$) and Total coliform (r = 0.567, $p < 0.01$).

**Table 5. Seasonal distribution of total coliform and *E. coli* (cfu/100 ml) at Chini lake in sampling months.**

| Bacteria | Months | | | | | |
|---|---|---|---|---|---|---|
| | February | April | July | August | October | December |
| Total coliform | 511 ± 114.18 | 356 ± 248.81 | 333 ± 210.91 | 728 ± 292.85 | 384 ± 136.04 | 954 ± 715.59 |
| *E. coli* | 29 ± 20.59 | 7 ± 1.41 | 4 ± 1.01 | 12 ± 1.67 | 4 ± 0.93 | 52 ± 34.93 |

**Table 6. Spatial variation of total coliform (cfu/100 ml) along the sampling sites at Chini lake.**

| Sampling sites | Months | | | | | |
|---|---|---|---|---|---|---|
| | February | April | July | August | October | December |
| S1 | 252 ± 8.47 | 179 ± 7.09 | 163 ± 3.8 | 409 ± 86.61 | 294 ± 39.74 | 340 ± 11.17 |
| S 2 | 512 ± 20.54 | 130 ± 7.54 | 219 ± 31.71 | 792 ± 214.54 | 249 ± 19.15 | 566 ± 12.4 |
| S 3 | 661 ±10.51 | 287 ± 11.06 | 246 ± 16.99 | 1284 ± 189.37 | 353 ± 37.67 | 2372 ± 45.34 |
| S 4 | 295 ± 9.31 | 210 ± 16.93 | 121 ± 13.23 | 395 ± 95.38 | 199 ± 23.76 | 380 ± 6.15 |
| S 5 | 267 ± 10.97 | 127 ± 5.12 | 183 ± 15.33 | 921 ± 136.01 | 473 ± 66.53 | 997 ± 8.97 |
| S 6 | 172 ± 11.85 | 525 ± 52.58 | 436 ± 46.36 | 432 ± 69.08 | 550 ± 70.62 | 321 ± 2.51 |
| S 7 | 1296 ± 127.28 | 617 ± 33.67 | 525 ± 66.02 | 981 ± 249.26 | 572 ± 59.91 | 1578 ± 3.57 |
| S 8 | 935 ± 25.21 | 871 ± 154.78 | 817 ± 137.21 | 871 ± 160.71 | 436 ± 91.92 | 1788 ± 9.95 |
| S 9 | 451 ± 13.83 | 184 ± 5.8 | 295 ± 43.81 | 617 ± 137.14 | 479 ± 120.62 | 616 ± 4.53 |
| S 10 | 260 ± 15.61 | 425 ± 36.68 | 316 ± 81.77 | 572 ± 156.6 | 234 ± 16.95 | 581 ± 5.68 |

**Table 7. Spatial variation of *E. coli* (cfu/100ml) along the sampling sites at Chini lake.**

| Sampling sites | Months | | | | | |
|---|---|---|---|---|---|---|
| | February | April | July | August | October | December |
| S1 | 15 ± 1.72 | 7 ± 1.00 | 6 ± 2.05 | 17 ± 2.34 | 9 ± 1.27 | 23 ± 1.96 |
| S 2 | 5 ± 1.21 | 2 ± 0.58 | 1 ± 0.00 | 9 ± 1.85 | 2 ± 0.58 | 18 ± 3.11 |
| S 3 | 12 ± 1.3 | 6 ± 1.63 | 3 ± 1.00 | 19 ± 1.62 | 3 ± 0.61 | 33 ± 3.09 |
| S 4 | 3 ± 0.58 | 1 ± 0.00 | 1 ± 0.00 | 7 ± 1.27 | 6 ± 1.24 | 12 ± 1.96 |
| S 5 | 11 ± 2.4 | 8 ± 2.20 | 2 ± 0.58 | 8 ± 1.21 | 1 ± 0.00 | 11 ± 1.44 |
| S 6 | 7 ± 1.85 | 4 ± 1.05 | 2 ± 0.58 | 6 ± 0.00 | 1 ± 0.00 | 10 ± 1.31 |
| S 7 | 4 ± 0.64 | 8 ± 2.79 | 1 ± 0.00 | 8 ± 0.61 | 2 ± 0.58 | 10 ± 1.99 |
| S 8 | 214 ± 20.12 | 17 ± 3.07 | 11 ± 2.31 | 20 ± 2.04 | 6 ± 1.15 | 365 ± 55.79 |
| S 9 | 12 ± 1.2 | 9 ± 1.85 | 6 ± 1.21 | 12 ± 2.43 | 7 ± 1.24 | 14 ± 2.62 |
| S 10 | 7 ± 1.27 | 5 ± 1.05 | 3 ± 1.15 | 8 ± 1.21 | 1 ± 0.00 | 17 ± 1.53 |

Chini lake is a shallow and natural lake, which has a sensitive ecosystem and responded to the changes, episodes from its surroundings. These sites are near to the settlement of the indigenous people at Gumum area, a resort and a National Service Centre camp which could contribute the organic loading. Overall, water quality in Chini lake is classified as class II. WQI also varies with location of the site in the lake. The rapid expanding of agriculture land used was a major threat to the lake water quality as some plantation areas (oil palm) are close to the edge of the lake water body. Lake resource sustainable management approaches should be given a serious consideration as it is a natural lake and plays an important role in maintaining a stable ecosystem. WQI depicts lake water quality mostly clean on their standards (clean, slightly polluted and polluted) except at sites S3 and at S4. However, the present results are baseline information to assist government and management to make evidence-based water ecological restoration decisions in the freshwater area of the Chini lake. Furthermore, to revive the aquatic environmental condition and to protect the large biodiversity of the Chini lake, the entire catchment should bring under some form of extensive management.

**Acknowledgements**

Authors are grateful to University Malaysia Pahang (UMP) and Faculty of Civil Engineering and Earth Resources for financial support through the project RDU 170342 and PGRS 180312.

**References**

APHA 2012. Standard methods for the examination of water and wastewater. American Public Health Association, American Water Works Association, Water Environment Federation, Washington, DC.

Arafat MY, Islam MS, Karim MA, Wahid ZA and Aziz EBA 2017. Characterization of chini lake water quality with Malaysian WQI using multivariate statistical analysis. Bangladesh J. Bot. **46**(2): 691-699.

Council NR 2012. Water reuse: potential for expanding the nation’s water supply through reuse of municipal wastewater. National Academies Press.

DOE 2008. Interim National Water Quality Standards for Malaysia, Department of Environment, Kuala Lumpur, Malaysia: Department of Environment.

EQR 2016. Environmental quality report 2015: Department of Environment , Ministry of Natural Resources and Environemn. Malaysia. ISSn 9789839795295. Retrieved from http://enviro.doe.gov.my/ekmc/digital-content/environmental-quality-report-2015/.

Gorde SP and Jadhav MV 2013. Assessment of water quality parameters: a review. Journal of Engineering Research and Applications **3**(6): 2029-2035.

Goudie AS 2018. Human impact on the natural environment. John Wiley & Sons.

HACH, 2010. Data Sheet DR 500 UV-Vis Laboratory Spectrophotometer. Colorado, USA.

Hamzah A and Hattasrul Y 2008. Water quality and bacterial study in Tasik Chini, Pahang. *In*: Proceedings of Taal 2007: The 12th world lake conference, Sengupta M and Dalwani R (Eds), pp. 184-189.

Matilainen A, Gjessing ET, Lahtinen T, Hed L, Bhatnagar A and Sillanpää M 2011. An overview of the methods used in the characterisation of natural organic matter (NOM) in relation to drinking water treatment. Chemosphere **83**(11): 1431-1442.

Mohammad H and Assefa MM 2017. Assortment and spatiotemporal analysis of surface water quality using cluster and discriminant analyses. Catena **151**(2017): 247-258.

Monica N and Choi K 2016. Temporal and spatial analysis of water quality in Saemangeum watershed using multivariate statistical techniques. Paddy and Water Environment **14**(1): 3-17.

Rasul MG, Sujaul IM, Rosli MY, Mazlin BM and Arafat MY 2018. Adverse impact of land use changes on degrading environment in Bertam River catchment, Cameron Highlands, Malaysia. International Journal of Ecology and Environmental Sciences **44**(2): 171-184.

Seeboonruang U 2012. A statistical assessment of the impact of land uses on surface water quality indexes. Journal of Environmental Management **101**: 134-142.

Sharip Z, Schooler SS, Hipsey MR and Hobbs RJ 2012. Eutrophication, agriculture and water level control shift aquatic plant communities from floating-leaved to submerged macrophytes in Lake Chini, Malaysia. Biological Invasions **14**(5): 1029-1044.

Sujaul I, Hossain M, Nasly MA and Sobahan MA 2013. Effect of industrial pollution on the spatial variation of surface water quality. A. J. Environ. Sci. **9**: 120-129.

Sujaul I, Salah MG, Arafat M, Syukor A and Razak A 2017. Surface water quality assessment of the Gebeng industrial area using water quality standard and index. Journal of Engineering and Science Research **1**(2): 118-126.

Varunprasath K and Daniel NA 2010. Physico-chemical parameters of river Bhavani in three sites, Tamilnadu, India. Iranica J. Energy Environ. **1**(4): 321-325.

Wang J, Fu Z, Qiao H and Liu F 2019. Assessment of eutrophication and water quality in the estuarine area of Lake Wuli, Lake Taihu, China. Science of the Total Environment 650: 1392-1402.

WHO 2010. Drinking water quality in the South-East Asia region. WHO Regional Office for South-East Asia. World Health Organization.

Xiaoping W, Fei Z, Hsiang-te K, Abdulwasit G, Adam L, Jianying Y, Yan R and Yunqing J 2017. Evaluation and estimation of surface water quality in an arid region based on EEM- PARAFAC and 3D fluorescence spectral index: A case study of the Ebinur Lake Watershed, China. Catena **155**: 62-74.

*(Manuscript received on 10 February, 2018; revised on 27 July, 2019)*