A Preliminary Assessment of Water Quality Status in Tasik Kenyir, Malaysia

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Abstract The preliminary study of water quality which involved the measurement of physical, chemical and microbiological parameters was conducted in Tasik Kenyir, Malaysia from August until October 2010. Results showed that the water quality of the surface water was in 'clean' status based on Malaysian Water Quality Index. However, the bottom water was in 'slightly polluted'. According to National Water Quality Standard, all stations was in Class I which is suitable for conservation of natural environment, water supply with practically no treatment and fishery activity for very sensitive aquatic species.

Keywords Water quality index · National water quality standard · Sustainable water · Tasik Kenyir

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Introduction

Numerous studies have been conducted in the early years since the establishment of Tasik Kenyir to determine water quality in relation to the effects of sustainable aquaculture, fish diversity and fish stock assessment, zooplankton dynamics and production (Jamaludin and Machiels 1999; Yusoff and Ambak 1999; Verhallen and Verhagen 1994). The increase of visitor numbers to Tasik Kenyir and the rapid development in the area might increase the possibility of deforestation and sewage discharge into the lake. These factors might then decrease the water quality of the lake. Therefore, the present study was carried out to establish the current status of the water quality by measuring the physical, chemical and microbiological (***Escherichia coli*** and total coliform) parameters. The Water Quality Index (WQI) was also calculated according to Department of Environment-WQI (DOE-WQI) as tabulated in Table 1 (Department of Environment 2011). In addition, data obtained was compared to National Water Quality Standard (NWQS) classification to understand the beneficial uses of the water body (Table 2) (Department of Environment 2011).

Table 1 DOE-WQI calculation formula (Department of Environment 2011)

Subindex DO (SIDO) (% saturation)	$x \leq 8$	SIDO = 0
	$8 < x < 92$	SIDO = 100
	$x \geq 92$	SIDO = $-0.395 + 0.03x^2 - 0.0002x^3$
Subindex BOD (SIBOD) (mg/L)	$x \leq 5$	SIBOD = $100.4 - 4.23x$
	$x > 5$	SIBOD = $108e^{-0.055x} - 0.1x$
Subindex COD (SICOD) (mg/L)	$x \leq 20$	SICOD = $-1.33x + 99.1$
	$x > 20$	SICOD = $103e^{-0.0157x} - 0.04x$
Subindex AN (SIAN) (mg/L)	$x \leq 0.3$	SIAN = $100.5 - 105x$
	$0.3 < x < 4$	SIAN = $94e^{-0.573x} - 5 \lvert x - 2 \rvert$
	$x \geq 4$	SIAN = 0
Subindex TSS (SITSS) (mg/L)	$x \leq 100$	SITSS = $97.5e^{-0.00676x} + 0.05x$
	$100 < x < 1000$	SITSS = $71e^{-0.0061x} - 0.015x$
	$x \geq 1000$	SITSS = 0
Subindex pH (SIpH)	$x < 5.5$	SIpH = $17.2 - 17.2x + 5.02x^2$
	$5.5 \leq x < 7$	SIpH = $-242 + 95.5x - 6.67x^2$
	$7 \leq x < 8.75$	SIpH = $-181 + 82.4x - 6.05x^2$
	$x \geq 8.75$	SIpH = $536 - 77x + 2.76x^2$

DOE-WQI = (0.22*SIDO) + (0.19*SIBOD) + (0.16*SICOD) + (0.15*SIAN) + (0.16*SITSS) + (0.12*SipH)

DOE-WQI = 0–59 (Polluted); 60–80 (Slightly Polluted); 81–100 (Clean)

Table 2 National water quality standards for Malaysia (Department of Environment 2011)

Parameter	Unit	Class					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen	mg/L	0.1	0.3	0.3	0.9	2.7	>2.7
BOD	mg/L	1	3	3	6	12	>12
COD	mg/L	10	25	25	50	100	>100
DO	mg/L	7	5–7	5–7	3–5	<3	<1
pH	–	6.5–8.5	6–9	6–9	5–9	5–9	–
TSS	mg/L	25	50	50	150	300	300
Temperature	°C	–	Normal +2 °C	–	Normal +2 °C	–	–
Total Coliform	count/100 mL	100	5000	5000	50,000	50,000	>50,000

Class	Uses
Class I	Conservation of natural environment
	Water supply I – Practically no treatment necessary
	Fishery I – Very sensitive aquatic species
Class IIA	Water supply II – Conventional treatment required
	Fishery II – Sensitive aquatic species
Class IIB	Recreational use with body contact
Class III	Water supply III – Extensive treatment required
	Fishery III – Common of economic value and tolerant species; livestock drinking
Class IV	Irrigation
Class V	None of the above

Three sampling surveys were conducted from August until October 2010. Generally, there were two major areas involved, the eastern part of Tasik Kenyir (ELK, stations K1–K15) and Terengganu National Park (TNP, stations N1–N17) which is located in western part of Tasik Kenyir (Fig. 1). In ELK, the water samples were collected from both surface (~1 m depth) and bottom waters (i.e. 30 m depth), along two main transects, which were Transect one (station K1–K10) and Transect two (station K11–K15) using a Van Dorn sampler. In TNP, scattered sampling stations were distributed throughout the region and only surface waters (~1 m) were collected due to shallowness of the water column. In addition, samples for microbiological parameters were only carried out at TNP. Water samples were filtered through 0.45 μm pore size cellulose acetate membrane filters and decanted into 1 L

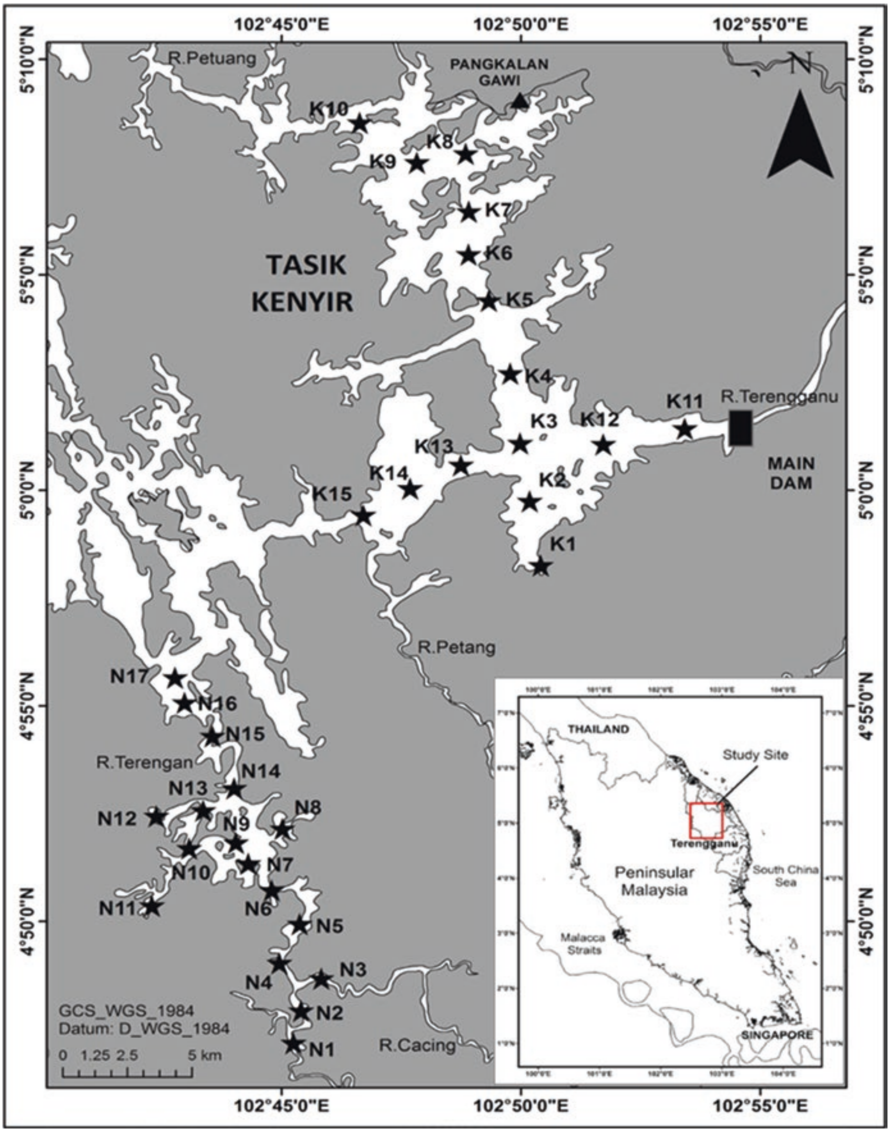

Fig. 1 Sampling stations in Tasik Kenyir

polyethylene bottles for storage prior to dissolved ammonia determination. Surface water samples for microbiological analysis were subsampled directly into 500 mL sterilized Scott bottles. All water samples were stored in an ice chest and transported to the laboratory where all samples were analysed on the same day.

Temperature, pH and dissolved oxygen (DO) were measured in-situ using YSI 6600 multiparameter data logger. Calibration of the instrument was made 24 h before the sampling as per the manufacturer's recommendation. Ammonia was determined colorimetrically according to Grasshoff et al. (1983) with total suspended solids (TSS), biochemical oxygen demand (BOD) and chemical oxygen demand (COD) were based on standard methods (American Public Health Association, 2005). The membrane filtration technique used for the detection and quantification of *E. coli* and total coliform according to the standard methods (American Public Health Association 2005). The number of coliforms were reported on a colony-forming unit per 100 mL basis (CFU/100 mL). Six parameters i.e. pH, DO, BOD, COD, TSS and ammonia were used to calculate the DOE-WQI (Department of Environment 2011). Significant difference for each parameter between different stations and depths were determined by using Analysis of Variance (ANOVA) test.

Temperature

The temperature for surface water of ELK was in the range of 29.9–30.8 °C (mean: 30.4 ± 0.3 °C) (Fig. 2a, b). The range of temperature for surface water in TNP was wider, with values between 23.7 and 31.7 °C (mean: 29.6 ± 2.5 °C). The temperature of bottom water in ELK stations are not reported due to loss of data. Low values recorded at few stations upstream of TNP were expected to be due to sampling being carried out under the trees which shaded the water column.

ANOVA test showed there no significance difference between sampling stations ($p > 0.05$). Temperature values were in Class IIA and above based on NWQS classification. In general, the temperature range was normal for tropical Malaysia rainforest climate especially in lake system (Jawan and Sumin 2012; Wan Mohd Afiq and Md Pauzi 2012; Othman et al. 2009).

pH

In ELK, the pH value varied from 7.0 to 7.7 (mean: 7.3 ± 0.2) for surface water (Fig. 2). Meanwhile, the pH value for the bottom water was between 3.9 and 7.2 (mean: 5.4 ± 1.1). For TNP area, the pH value was ranging from 6.6 to 8.0 (mean: 7.5 ± 0.4). The two-way ANOVA test showed no significant difference between the stations ($p > 0.05$) for both ELK and TNP. However, there was significant difference between the surface and bottom water ($p < 0.05$) for ELK. Based on NWQS classification, most of the surface water was in Class I for both ELK and TNP. In contrast, most of bottom water fell into Class IV.

The pH values for surface and bottom waters were similar at station K1 and K8, due to the shallow of the water (<10 m). Generally, the pH value was in neutral range (6.6–8.0) for surface water while the bottom water (for depth ≥30 m) was acidic (pH ≤6.5). This was probably due to the decomposition process of organic matter (dead trees) at the bottom part of the lake that caused the lower pH of the bottom water. The decomposition produced dissolved CO_2 gases in which turn into the weak acid known as carbonic acid (H_2CO_3) (Moran and Stottrup 2011).

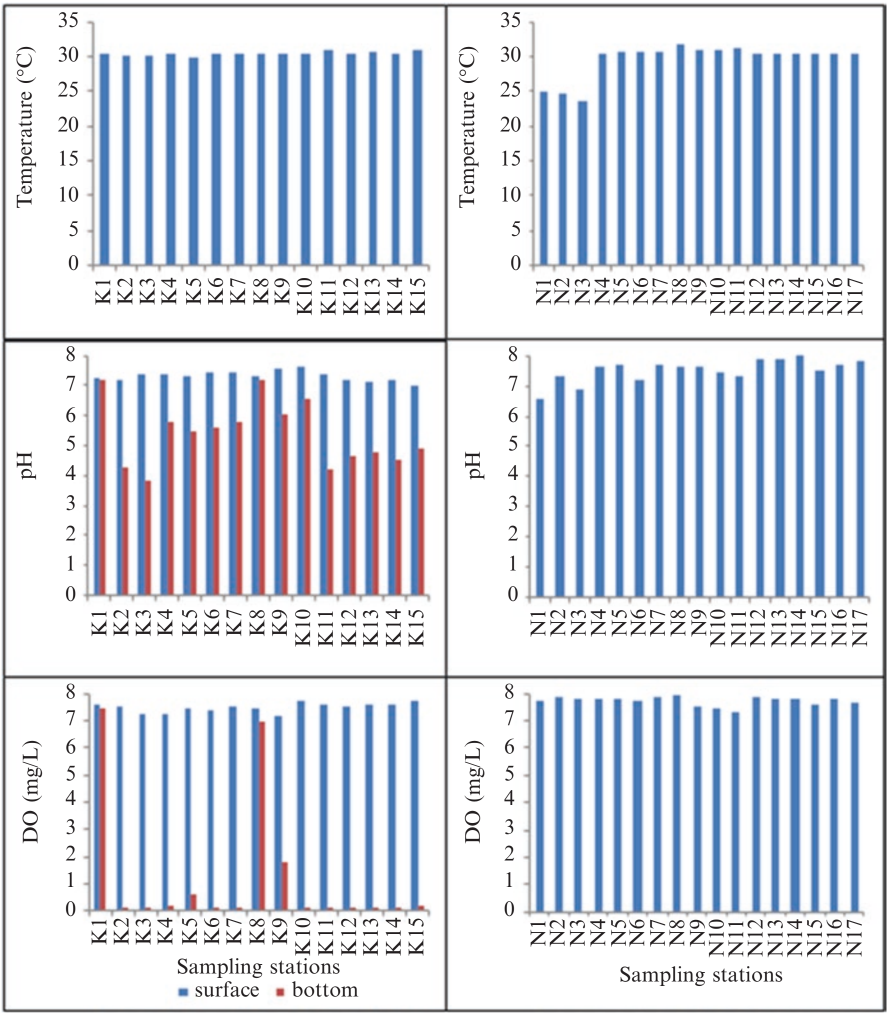

Fig. 2 (**a**) Physical and chemical characteristics of Tasik Kenyir during present study. (**b**) Physical and chemical characteristics of Tasik Kenyir during present study

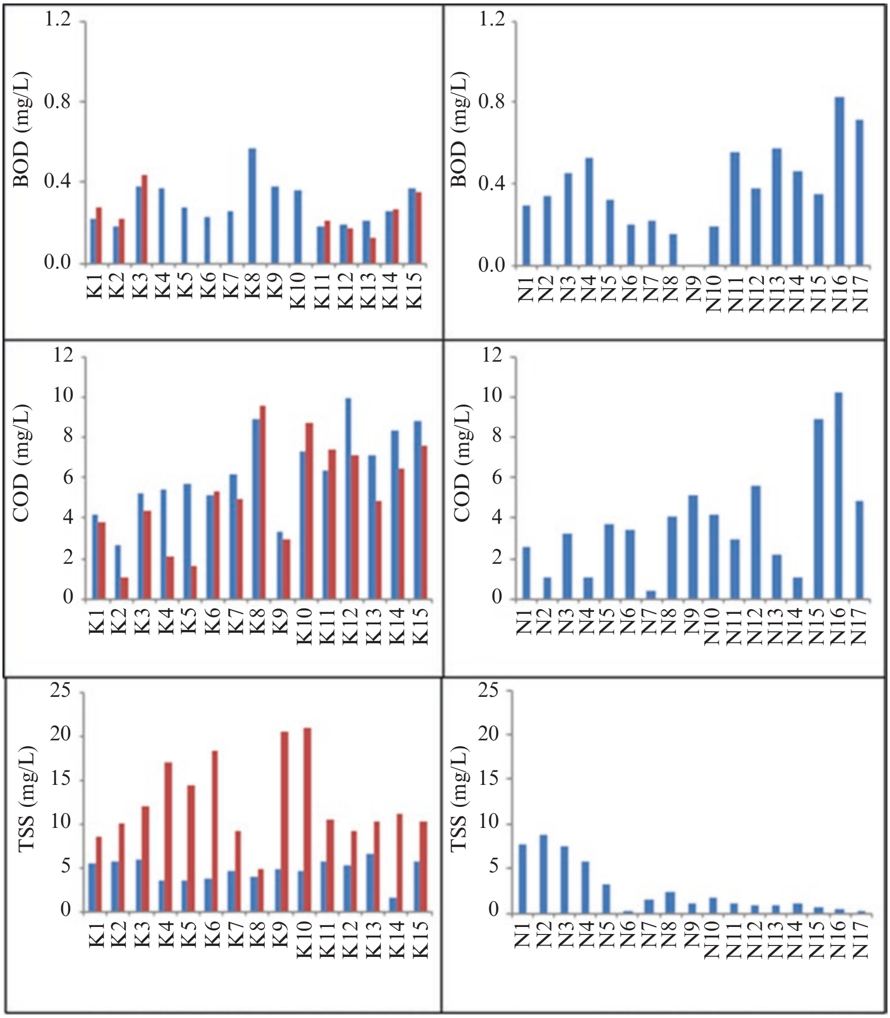

Fig. 2 (continued)

Dissolved Oxygen

Figure 2 shows the DO concentration for surface water in ELK was in the range of 7.2–7.8 mg/L (mean: 7.5 ± 0.2 mg/L) while the bottom water was 0.1–7.5 mg/L (mean: 1.2 ± 2.5 mg/L). A two-way ANOVA test showed no significant difference between the stations ($p > 0.05$). However, the difference was significant between surface and bottom water ($p < 0.05$). Meanwhile, in TNP, the concentration of DO was in the range of 7.3–7.9 mg/L (mean: 7.7 ± 0.2). Similar to ELK for surface water, the values showed no significant difference between stations ($p > 0.05$). According to NWQS, all the surface water was classified as Class I for both ELK and TNP area. Meanwhile, most of the bottom water in ELK fell into Classes IV and V.

In this study, K1 (7.6 mg/L) and K8 (7.5 mg/L) had higher DO value for bottom water because the depth was less than 10 m. Most of the stations had DO value <1 mg/L for bottom water, due to oxygen depletion, caused by the decomposition of submerged vegetation, leaf litter and phytoplankton. There is no obvious trend of high and low DO values between stations, although stations located near the human activities (jetty and restaurants) such as Pangkalan Gawi (K8) may has low DO value due to waste discharge which contained organic compounds directly into the lake. This is contrast to those observed at other lake systems such as Chini Lake, Pahang (Othman et al. 2009), oxbow lakes, Sabah (Jawan and Sumin 2012) and Titiwangsa Lake, Selangor (Said et al. 2012) which recorded low DO content nearby human activities. Waste which contained organic compounds will decrease the DO content in the water column as a result of degradation process by microbial activity (Chapman 1992). It is suggested that due to great volume of the Tasik Kenyir relative to degradation process, the water column of the lake did not show the lower DO often associated with waste and associated nutrient. Thus, the DO content in the water column is still high.

Biochemical and Chemical Oxygen Demand

The BOD concentration for surface water in ELK varies from 0.18 to 0.57 mg/L with a mean concentration of 0.30 ± 0.11 mg/L (Fig. 2). In addition, the bottom water recorded almost similar values to the surface water ranging from 0.12 to 0.44 mg/L (mean: 0.26 ± 0.10 mg/L). No data was available for bottom water in stations K4–K10 due to sample loss. According to two-way ANOVA test, the results showed no significant difference between the stations ($p > 0.05$) and depth profiles ($p > 0.05$). On the other hand, in TNP, the BOD value ranged from 0.15 to 0.71 mg/L (mean: 0.41 ± 0.19 mg/L). There was no significant difference between stations ($p > 0.05$) based on ANOVA test for TNP. For both ELK and TNP area, BOD values were in Class I of the NWQS classification.

In ELK, the lowest and highest values of COD for surface water were 2.70 mg/L and 9.98 mg/L, respectively (Fig. 2). For bottom water in the same area, the lowest value was 1.08 mg/L and the highest value was 9.54 mg/L. The mean values of COD for surface and bottom water were 6.31 ± 2.11 mg/L and 5.19 ± 2.60 mg/L, respectively. The two-way ANOVA test revealed significant difference ($p < 0.05$) between all the stations, and between surface and bottom waters. According to NWQS, all the stations in ELK were in Class I for both surface and bottom waters. Meanwhile, in TNP, the value of COD varied from 0.4 to 10.2 mg/L (mean: 3.80 ± 2.65 mg/L). The values of COD in TNP showed a significant difference between stations ($p < 0.05$) according to ANOVA test. Based on NWQS classification, all stations in TNP were classified as Class I.

BOD is a measurement of amount of DO used by bacteria to oxidise the biodegradable organic compounds present in water. Whereas COD is the amount of oxygen used to oxidise all organic compounds which include biodegradable and non-biodegradable. Hence, as observed in this study, the COD value is always greater than BOD value. Calculations were made in order to estimate to the ratio of biodegradable and non-biodegradable organic compounds in Tasik Kenyir for surface water (Suratman et al. 2015; Kumar et al. 2010). Most of the stations in ELK recorded higher non-biodegradable compounds i.e. 9–53 times much higher compared to biodegradable compounds. In contrast, much lower values were found in TNP i.e. 2–27 times higher between non-biodegradable and biodegradable compounds. These results suggested that most of the organic compounds in Tasik Kenyir is non-biodegradable especially at ELK.

Total Suspended Solids

In ELK, the highest value of TSS for surface water was 65 mg/L and the lowest was 1.5 mg/L (Fig. 2a, b). For bottom water, the highest TSS concentration was 20.9 mg/L and the lowest was 8.6 mg/L. The mean concentration of TSS for surface and bottom water was 4.7 ± 1.3 mg/L and 12.5 ± 4.7 mg/L, respectively. From the result, the bottom water showed higher TSS values compared to surface water. As the dead trees and leaf litter may fall into the lake and then decay underwater, suspended organic particles were released and contribute to high TSS concentration in the bottom water. A two-way ANOVA test showed no significant difference between the stations ($p > 0.05$). However, there was significant difference demonstrated between the surface and bottom water ($p < 0.05$). According to NWQS, all surface and bottom waters into Class I.

Meanwhile, in TNP, the highest and lowest concentrations of TSS were 8.8 mg/L and 0.2 mg/L. The mean concentration of TSS was 2.7 ± 2.9 mg/L. No significant different of TSS between stations ($p > 0.05$) based on the ANOVA test. Due to low TSS value, surface water in TNP area was classified as Class I, according to NWQS. The result showed a drastic reduction of TSS in TNP area, which was a protected and reserved area. The high TSS value in ELK was probably due to the higher amount of precipitation from boats activities and land clearing into the ELK, which was more densely visited by tourists and fishing enthusiasts.

Ammonia

For ELK, the range of ammonia concentrations recorded for surface and bottom waters was 20.3–77.2 µg/L N (mean: 50.95 ± 18.42 µg/L N) and 37.8–88.4 µg/L N (mean: 63.8 ± 16.2 µg/L N), respectively (Fig. 3). Based on two-way ANOVA test, the ammonia concentration showed significant difference between the sampling stations ($p < 0.05$) as well as between the surface and bottom water ($p < 0.05$). According to NWQS, the concentration for all sampling stations in surface and

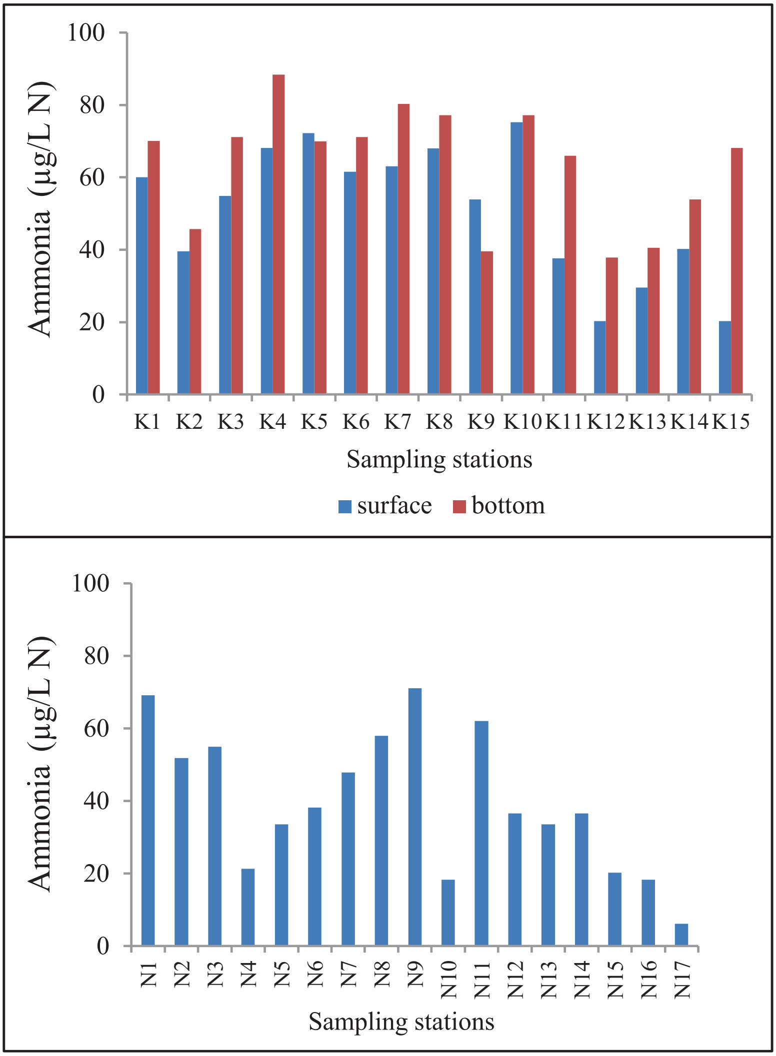

Fig. 3 Ammonia concentration of Tasik Kenyir during present study

bottom water were classified as Class I. In addition, the concentration of ammonia in TNP varied from 6.1 to 71.1 μg/L N (mean: 39.8 ± 19.3 μg/L N). There was a significant different between stations ($p < 0.05$) according to ANOVA test. Similar to ELK, all stations in TNP was in Class I based on NWQS classification.

In ELK, most of bottom water recorded higher concentrations of ammonia compared to surface water. Most probably the decomposition of organic matter from dead trees, leaf litter and phytoplankton in the bottom waters of the lake by heterotropic bacteria that had increased the concentration of this nutrient. Previous study at Bakun Reservoir, Sarawak also recorded the same trend of lower and higher concentrations of ammonia at surface and bottom waters, respectively due to remineri-sation of organic matter to ammonia (Ling et al. 2016a). In addition, a previous study showed that nutrients, especially ammonia, present in deep water will not be utilised by the phytoplankton as light could not reach the bottom of the lake, with these nutrients 'trapped' in this hypolimnion due to thermal stratification in ELK (Yusoff et al. 1994). In addition, our results agree with Yusoff and Ambak (1999), in which they found that lower nutrients level were present in the epilimnion layer (upper layer of the lake) compared to the metalimnetic and hypolimnetic areas (lower layers of the lake) during the period of strong stratification.

The concentrations of ammonia were compared with some selected previous studies in Malaysia area. In general, the ammonia concentrations in the current study covered a lower range of concentration as relative to Chini Lake, Pahang (0–597 μg/L N; Shuhaimi-Othman et al. 2007), Bakun Reservoir, Sarawak (20–1340 μg/L N; Ling et al. 2016a) and Batang Ai Reservoir, Sarawak (17–567 μg/L N; Ling et al. 2016b). The lower concentration in Tasik Kenyir was probably due to less anthropogenic activities in this lake. In contrast, wastes from human and aquaculture activities contributed to high ammonia concentration in Chini Lake, Bakun and Batang Ai Reservoirs.

Microbiological Parameters

Figure 4 shows the concentrations of *E. coli* and total coliform in TNP. No measurement was made at ELK and some stations (N4, N9, N10, N14, N15, and N16) in TNP. The range of concentrations of *E. coli* and total coliform were undetected-126 counts/100 mL (38 ± 41 counts/100 mL) and 68–408 counts/100 mL (139 ± 66 counts/100 mL), respectively. Based on one-way ANOVA test, there was a significant difference between sampling stations ($p < 0.05$) for these two parameters. The concentrations of total coliform in most of the stations were in Class I (≤100 counts/100 mL) according to NWQS classification, although some stations recorded higher values. No comparison could be made for *E. coli* as it is still not listed in this classification

Total coliform and *E. coli* are used as microbiological indicators of water quality. Total coliform count has been used as a tool to test the bacterial contamination in water. The bacteria are not necessarily pathogenic, but indicates the presence of

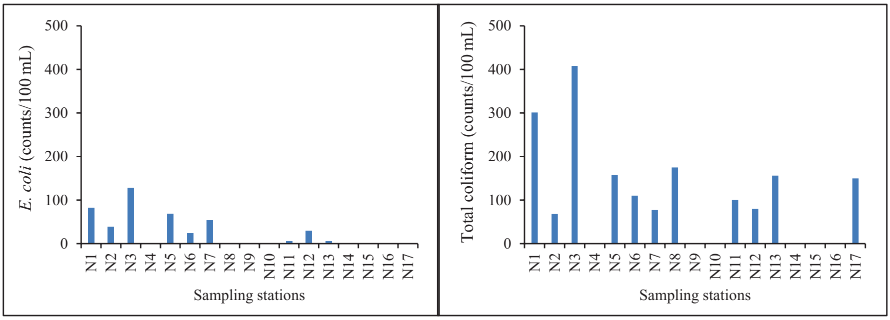

Fig. 4 Microbiological concentration of Tasik Kenyir during present study

disease-causing organisms. It is a large collection of different kinds of bacteria and can be found in the environment (plant and soil material), digestive systems and feces of all warm-blooded animals including humans. *E. coli* is a species of fecal coliform bacteria (i.e. sub-group of total coliform) are harmless and capable of causing many diseases. They exist specifically in the intestines and feces of humans and animals. Due to their origin they are more specific to what compared to general total coliform group of bacteria, and *E. coli* are therefore considered a more accurate indication of presence of animal or human feces than the total coliform.

Generally, *E. coli* were detected at most of the stations (i.e. N1, N2, N3, N5, N6, N7 and N12) in Tasik Kenyir with relatively higher concentration of *E. coli* recorded at station N3 (Cacing River) (126 counts/100 mL). The presence of *E. coli* in this present study was from animal or human feces. Tasik Kenyir is one of tourist attraction especially for fishing activities. Most of them rent the houseboats which do not have the proper facilities of disposal of sewage and waste water. All were disposed directly into the lake water. However, the *E. coli* found in Tasik Kenyir is far below the recorded value for Chini Lake, Pahang with a maximum value of 52×10^4 counts/100 mL (Hamzah and Hattasrul 2009). This was due to the use of traditional methods of sewage disposal by the indigenous people where the untreated sewage enters directly into Chini Lake.

Water Quality Index

The DOE-WQI of Malaysia guideline was used to determine the water pollution status in Tasik Kenyir. The DOE-WQI scale classifies the water quality as ‘clean’ (81–100%), ‘slightly polluted’ (60–80%) and ‘polluted’ (0–59%) (Department of Environment 2011). In ELK, the WQI values were varied from 94.8% to 97.5% (mean: 96.2 ± 0.7%) for surface water while 65.2–96.4% (mean: 70.9 ± 10.4%) for bottom water. The results suggest that the surface water of ELK has a ‘clean’ status for all stations whereas for bottom water is classified as ‘slightly polluted’. Low

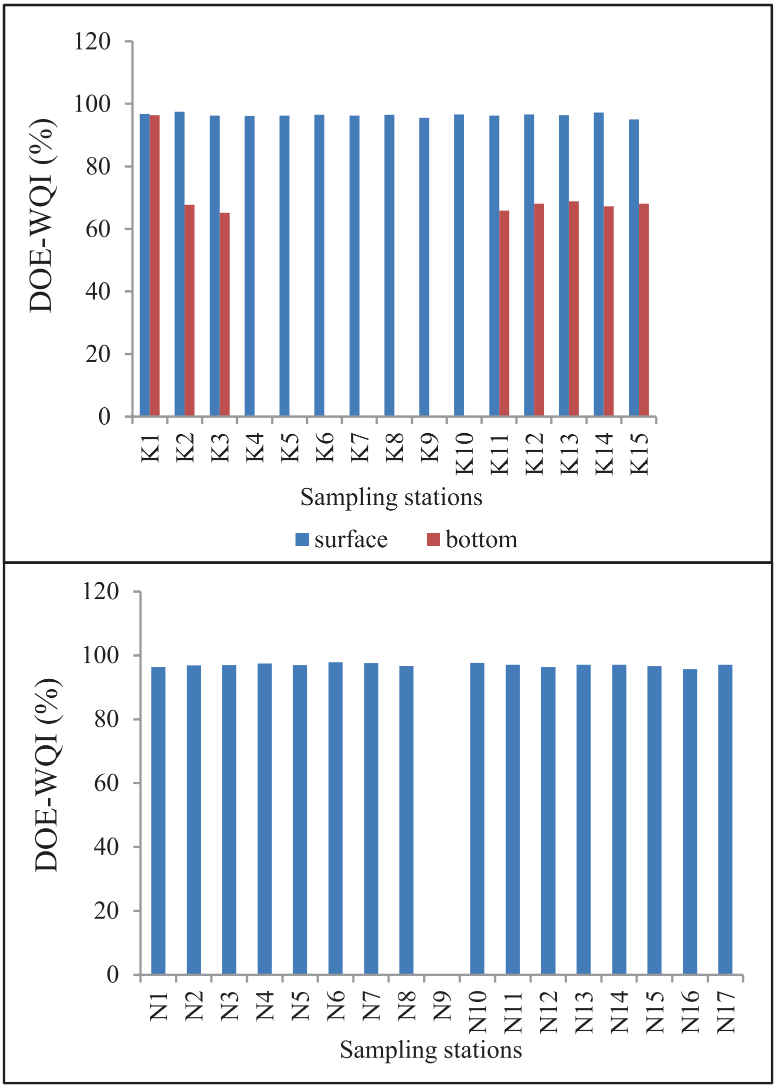

Fig. 5 DOE-WQI of Tasik Kenyir during present study

values of DOE-WQI for bottom water was due to deterioration of the water quality parameters especially the pH and DO. In TNP, the WQI value for the surface water throughout the area was lies within 95.6–97.9% (mean: 96.9 ± 0.6%) (Fig. 5). Therefore, the surface water for each station in TNP can be classified as 'clean' status.

Conclusion

The results from this preliminary study have shown that most of the stations in Tasik Kenyir (ELK and TNP) can be classified as 'clean' status based on the DOE-WQI with respect to surface water. However, 'slightly polluted' status was recorded for bottom water which was due to deterioration of pH and DO values. Based on the NWQS classification, all stations for surface water in Tasik Kenyir were classified as Class I which is suitable for conservation of natural environment, water supply with practically no treatment and fishery activity for very sensitive aquatic species. Data from this study can be used by other researchers as a baseline comparison for their study in this area. Although this study has shown that Tasik Kenyir is still in good condition, our findings is only based on the short term sampling and this may therefore vary over other times of the year when sampling did not take place and also interannually. We therefore recommend that long term water quality monitoring is carried out at Tasik Kenyir on water quality to help ensure the water quality and conservation of this status is maintained and the associated mechanisms better understood for this important conservation site.

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