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Assessment of water quality index in lake ecosystem

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ABSTRACT

Water is an important element that profoundly influence the living organisms. When water resources management is systematically and efficiently managed, it produces clean water sources without pollution. Therefore, it is very essential to assess the water quality status for assuring the good quality of water to the consumer. The objective of the study is to identify the status of water quality index in the catchment ecosystem of UniSZA Lake, Terengganu. Six water samplings were carried out for each two weeks during dry season where six parameters were measured and Malaysian Department of Environment-Water Quality Index (DOE-WQI) was calculated and classified based on the Interim National Water Quality Standards, Malaysia (INWQS). Results for chemicals parameters for dissolved oxygen range from 1.24 to 16.76 mg/L, biochemical oxygen demand range from 0.41 to 3.20 mg/L, chemical oxygen demand range from 18.67 to 111.33 mg/L, and ammoniacal nitrogen range from 0.05 to 10.03 mg/L. Results for physical parameters for total suspended solid range from 1.40 to 117.0 mg/L and pH range from 6.29 to 9.94. Overall, the WQI calculated for UniSZA Lake falls in Class II and Class III means that it is safe for recreational body contact and could support aquatic organism.

Keywords: Lake ecosystem; Water quality index; UniSZA Lake; Distribution of water quality

1. Introduction

Water sources are one of the most important elements in all aspects of life, whether it is for the survival of an animal or for the development of an area. Water also plays a major role in maintaining the balance of the world's ecosystems [1,2]. Malaysia is a country rich in natural water resources. Malaysia has areas of the southwest and northeast monsoons that cause the country to receive annual rainfall of more than 2,500 mm. This is, the annual source of water, at a total land mass of 330,000 km^2 to 990 billion m^3. Previous study reported that 7% or 64 billion m^3 of this water had been drained underground and 36% or 360 billion m^3 had returned to the atmosphere known as

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evapotranspiration [3]. There are many sources of water available such as river, lake, waterfall and ocean. The importance of clean water sources is undeniable. It is clear that human placement has been born in areas with water sources such as rivers, lakes and waterfalls since ancient times. It turns out that many civilizations have washed out due to the deterioration of water quality in this area [4].

Rapid urbanization has affected surface water quality due to poor waste treatment practices and overuse of natural resources. Department of Environment in their Environment Quality Report 2009 has reported that 46% out of the total rivers in Malaysia are polluted when compared to the previous year [5]. Watersheds have a great role to play in conserving water resources both in terms of quality and quantity. In order to provide good water quality to consumers, water distribution systems have an important aspect in the study of water quality [6,7].

Water quality is a primary ecological concern all over the world and it is affected by anthropogenic and natural disturbing influence such as: erosion, surface runoff, sedimentation, overflow effluents, wastewater, land recovery, environmental change and air testimony, among others [8]. Water quality is a state of biological, physical, and chemical characteristics of water in collaboration with anticipated use and a set of standards [9]. Moreover, surface waters are vulnerable and helpless to contamination resulting to the consequence of standard techniques, which include, precipitation data, disintegration, weathering of crustal materials, sedimentation, erosion and anthropogenic exercises such as industrial, urban, horticultural activities and agriculture [10–12].

In Malaysia, water quality status is determined by the water quality index developed by Department of Environment (DOE). Water quality index serve as indicator for water quality assessment through various physical and chemicals parameters of surface water. Measurement of the parameter will be used to classify the river by comparing with the Interim National Water Quality Standards for Malaysia (NWQS). Classification of water quality plays a great significant role to provide information on the condition of the water that suitable for each activities, uses or species.

Universiti Sultan Zainal Abidin had encountered major flood during 2014 that brought major damage to the university especially from the properties aspect. The incident has led to the restructure of the lake as retention pond for mitigation measure towards the upcoming flood incidents [13]. The UniSZA Lake also reserved as recreational area for the students and community as well as support the aquatic life that existed in it. Due to the population growth, urbanization and construction activities that occur nearby, water quality of the lake may be affected as these factors are highly related to the deterioration of water quality [14]. Therefore, this study was conducted to assess current water quality status of the lake as well as to identify the major threat that must be taken into account for proper management of the water quality in UniSZA Lake.

2. Materials and methods

2.1. Study area

The Universiti Sultan Zainal Abidin (UniSZA) lake located within latitude of 524'19.07" N and longitude of 103 5'3.84" E. UniSZA Lake acts as a retention pond in the Universiti Sultan Zainal Abidin, campus Gong Badak, in the area of Kuala Nerus, Terengganu (Fig. 1). UniSZA Lake received water flow from three inlets, where one of the inlets is the water channel from the university hostel, while another two inlets started from water channel that connected to the residential area of Kampung Gong Badak and Kampung Gong Pak Jin respectively.

Referring to the sampling points (Fig. 2) in this study, a total of thirteen points were selected, covering the three inlets from upstream to downstream (S1, S2, S3, S4, S5, S6 and S8), Station 7 was located in the outlet of the lake,

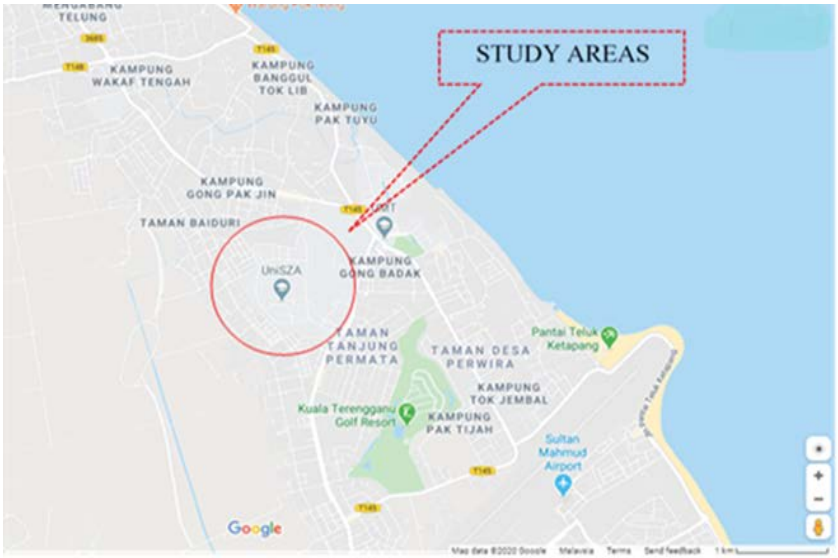

Fig. 1. Study areas at UniSZA Lake catchment ecosystem, Kuala Nerus, Terengganu.

Fig. 2. Locations of sampling stations in the UniSZA Lake, Terengganu, Malaysia.

four sampling stations (S9 to S12) in the surrounding of the lake and station 13 was in the center of UniSZA Lake. The sampling was taken place from May to July 2019, every two weeks with the total of six water samplings in thirteen stations to represent dry season in the area.

2.2. Water quality analysis

Water samples were collected from 13 stations as shown in Fig. 2, which are ranging from upstream to downstream of the three inlets, outlet and around the lake itself. All the sample preparation and reservations conducted were following the standard procedures provided by American Public Health Association (APHA) and the United States Environmental Protection Agency (USEPA) methods. Water samples were taken from the sampling stations using 1,000 mL polyethylene bottles and preserved using nitric acid before kept in the refrigerator with temperature 4°C.

The water quality analysis was divided into two which were *in-situ* analysis and in the laboratory analysis. Three parameters were measured *in-situ* (pH, dissolved oxygen and ammoniacal nitrogen) using YSI Professional Plus Handheld Multiparameter. While biochemical oxygen demand was measured using portable BOD meter (Modern Water BOD Check) [15,16]. Two parameters were analyzed in the laboratory which were total suspended solid (TSS) and chemical oxygen demand (COD) [17,18]. COD was determined using reactor digestion method with Hach's DR Spectrophotometers. TSS was measured using gravimetric method with membrane filter 45 mm and vacuum pump.

The results from the laboratory analysis were recorded and water quality index (WQI) equation was used to classify the water quality index of the samples according to National Water Quality Standard (NWQS) by Department of Environment Malaysia in Tables 1 and 2.

3. Results and discussion

3.1. Chemical parameters

3.1.1. Dissolved oxygen

Fig. 3 shows the range of dissolved oxygen recorded during 6 times of sampling in 13 stations. The range of concentration of dissolved oxygen during first sampling was from 1.26 to 13.76 mg/L, the highest (13.76 mg/L) was recorded at Station 3 and the lowest (1.26 mg/L) at Station 4, with average of 7.9 mg/L. During second sampling, the average of dissolved oxygen concentration is 9.2 mg/L, range from 1.49 to 16.76 mg/L, with highest (16.76 mg/L) at Station 7 and the lowest (1.49 mg/L) at Station 4. The highest and lowest of dissolved oxygen were recorded in forth sampling are 13.43 mg/L at Station 9 and 3.93 mg/L at Station 4. Fifth sampling recorded 2.34 to 13.96 mg/L of dissolved oxygen with average of 10.52 mg/L where the highest (13.96 mg/L) was recorded at Station 8 and the lowest (2.34 mg/L) at Station 4. The highest dissolved oxygen concentration has been recorded during sixth sampling at Station 8 with 15.59 mg/L, with the range 1.24–15.59 mg/L and average of 10.2 mg/L.

The dissolved oxygen (DO) value in this study is higher than the value of DO reported by previous study in Tasik Chini, Pahang [19] which is from 0.6 to 6.4 mg/L. Station 4 recorded the lowest dissolved oxygen concentration with range 1.24–3.95 mg/L compare to other stations. The low concentration of dissolved oxygen in Station 4 is corresponding to its high biochemical oxygen demand (BOD) (Fig. 4) and COD (Fig. 5) concentration, implying that organic matters have been rapidly consumed the oxygen content of the water during the decomposition [20]. Based on DOE water quality index classification, average concentration of dissolved oxygen during this

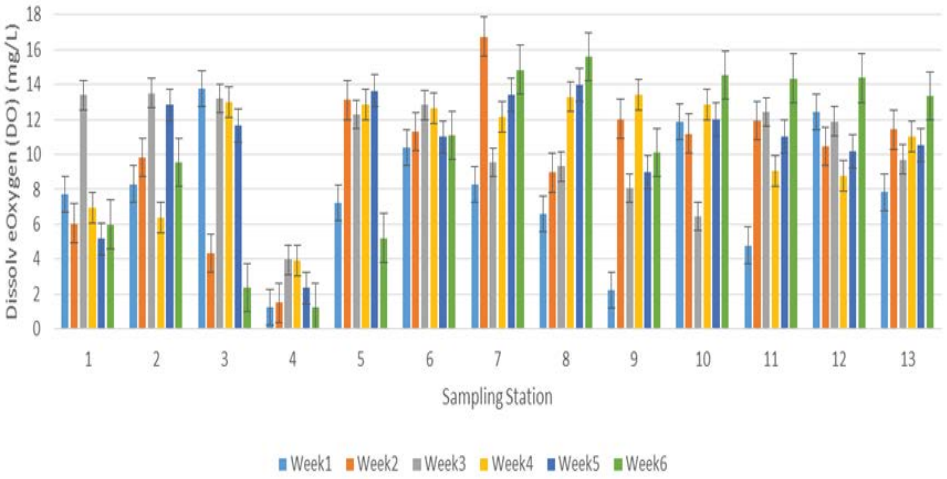

Fig. 3. Distribution of dissolved oxygen (DO) between six samplings.

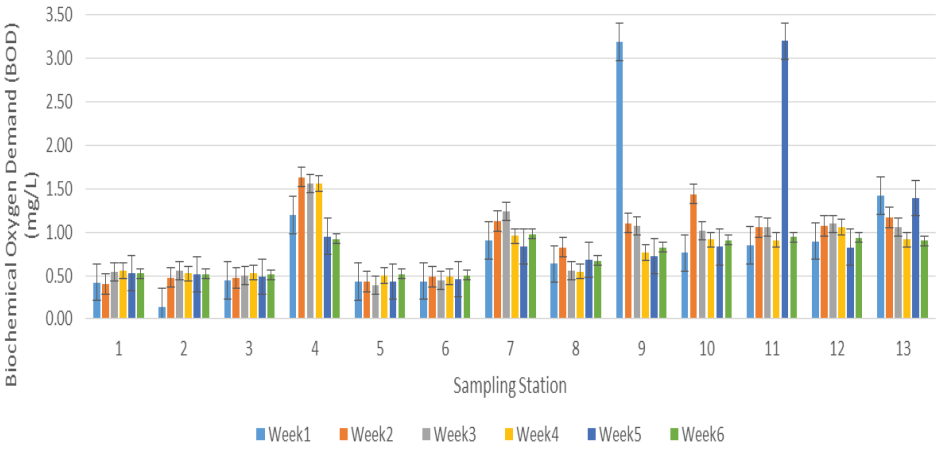

Fig. 4. Distribution of biochemical oxygen demand (BOD).

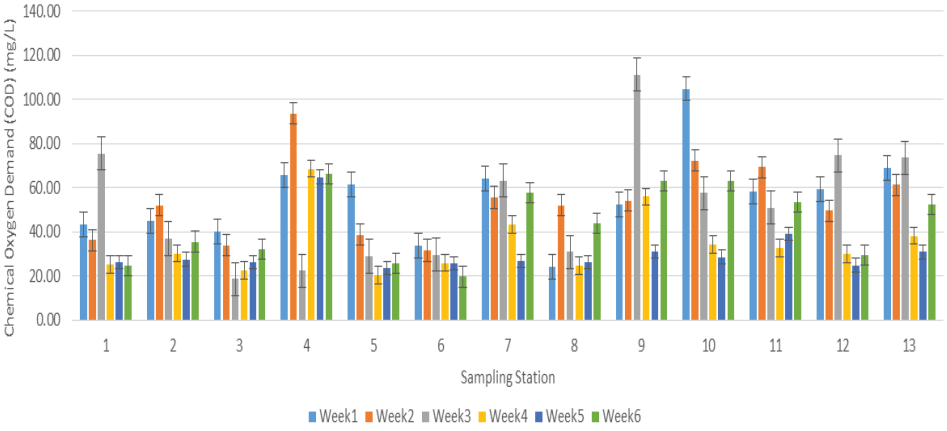

Fig. 5. Distribution of chemical oxygen demand (COD) between six samplings.

study is greater than 7 mg/L, hence the classification of water under dissolved oxygen in this lake is Class I for all stations, except for Station 4 with average of 2.37 mg/L from six sampling and classified under Class IV. It means that water in Class IV is safe for irrigation purpose only, while water in Class I can support very sensitive aquatic species with no treatment needed.

3.1.2. Biochemical oxygen demand

BOD concentration recorded during first sampling was between 0.14 to 3.2 mg/L, the highest (3.2 mg/L) was recorded at Station 9 and the lowest (0.14 mg/L) at Station 2, with average of 0.9 mg/L. During second sampling, the average of BOD concentration is 0.9 mg/L, range from 0.4 to 1.64 mg/L, with highest (1.64 mg/L) at Station 4 and the lowest (0.4 mg/L) at Station 1. The range of BOD recorded during third sampling was 0.39 to 1.56 mg/L with average of 0.85 mg/L, where the highest (1.56 mg/L) at Station 4 and lowest (0.39 mg/L) at Station 5. The highest and lowest of BOD were recorded in forth sampling are 1.56 mg/L at Station 4 and 0.49 mg/L at Station 6 respectively. Fifth sampling recorded BOD between 0.43 to 3.2 mg/L with average of 0.91 mg/L where the highest (3.2 mg/L) was recorded at Station 11 and the lowest (0.43 mg/L) at Station 5. The highest BOD concentration has been recorded during sixth sampling at Station 7 is 0.98 mg/L, with range from 0.51 to 0.98 mg/L and average of 0.74 mg/L (Fig. 4).

The concentration of BOD in this study can be considered low except for two stations that recorded slightly high, more than 3 mg/L which are Station 9 and Station 11. This is because these two locations are located in the UniSZA Lake, where there are many decayed plants in the surrounding area which flew into the lake hence affect the BOD concentration. The existence of natural plant decaying process and other contributors that increase the total nutrient in water bodies such as fertilizer, construction effluent, animal farm and septic system will continuously increase BOD concentration [21]. BOD concentration in this study which varied from 0.14 to 3.20 mg/L is higher compare to the finding in Kuantan River [22] with 0.42 to 0.71 mg/L. According to DOE water quality index classification, the average concentration of BOD in UniSZA Lake during 6 sampling is classified under Class I except for Station 4, 9 and 11 which classified under Class II. Based on National Water Quality Standard (NWQS), water under Class I is suitable for very sensitive aquatic species and safe for water supply while Class II required conventional treatment for water supply.

Table 1
National Water Quality Standards for Malaysia

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

Source: Department of Environment, Malaysia

3.1.3. Chemical oxygen demand

Fig. 5 shows that during first sampling, the range of BOD concentration was 24.33–105 mg/L, the highest (105 mg/L) was recorded at Station 10 and the lowest (24.33 mg/L) at Station 8, with average of 55.6 mg/L. During the second sampling, the average of COD concentration is 53.93 mg/L, range from 36.33 to 93.67 mg/L, with highest (93.67 mg/L) at Station 4 and the lowest (36.33 mg/L) at Station 1. The range of COD recorded during third sampling was 18.67–111.33 mg/L with average of 51.92 mg/L, where the highest (111.33 mg/L) at Station 9 and lowest (18.67 mg/L) at Station 3. The highest and lowest of COD were recorded in forth sampling are 68.67 mg/L at Station 4 and 22.67 mg/L at Station 3 respectively, with average of 34.81 mg/L. Fifth sampling recorded range from 23.67 to 65 mg/L of COD with average of 30.97 mg/L where the highest (65 mg/L) was recorded at Station 4 and the lowest (23.67 mg/L) at Station 5. The highest COD concentration has been recorded during

Table 2
Water classes and uses in this study

Parameter	Class				
	I	II	III	IV	V
Ammoniacal nitrogen, mg/L	<0.1	0.1–0.3	0.3–0.9	0.9–2.7	>2.7
Biochemical oxygen demand, mg/L	<1	1–3	3–6	6–12	>12
Chemical oxygen demand, mg/L	<10	10–25	25–50	50–100	>100
Dissolved oxygen, mg/L	>7	5–7	3–5	1–3	<1
pH	>7	6–7	5–6	<5	>5
Total suspended solid, mg/L	<25	25–50	50–150	150–300	>300
Water quality index	<92.7	76.5–92.7	51.9–76.5	31.0–51.9	>31.0

Source: Department of Environment, Malaysia

sixth sampling at Station 4 is 66.33 mg/L, while Station 1 recorded the lowest concentration; 24.67 mg/L, with average of 43.67 mg/L.

One of the indicator that can be used to subject the existence of organic pollutant for surface water is the concentration of chemical oxygen demand. In this study, the COD concentration varied from 18.67 to 111.33 mg/L, considered as high especially in Station 4 mostly. We can see that Station 4 recorded highest value of COD for 4 weeks, station located at upstream of the inlet where the residential and restaurants areas located. The high concentration of COD because of the organic matter and inorganic chemicals from the houses and restaurants such as food waste and waste water from areas nearby the lake, hence contribute to the water pollution [23,24]. Based on DOE water quality index Classification, the concentration of COD recorded at station in the lake during the samplings was classified as Class III (Station 1, 2, 3, 5, 6, 8 and 12) and IV (Station 4, 7, 9, 10, 11 and 13). As a result, water under Class IV is safe for irrigation purpose only while Class III need extensive treatment for water supply purpose and safe for livestock drinking.

3.1.4. Ammoniacal nitrogen

Fig. 6 shows the range of concentration of ammoniacal nitrogen (AN) at 13 stations for six samplings in the area of UniSZA Lake. During first sampling, AN concentration was from 0.18 to 6.64 mg/L, the highest (6.64 mg/L) was recorded at Station 4 and the lowest (0.18 mg/L) at Station 6, with mean of 1.12 mg/L. During second sampling, the average of AN concentration is 1.4 mg/L, range from 0.09 to 10.03 mg/L, with highest (10.03 mg/L) at Station 4 and the lowest (0.09 mg/L) at Station 10. The concentration of AN recorded during third sampling was between 0.05 to 6.01 mg/L with mean of 0.74 mg/L, where the highest (6.01 mg/L) at Station 4 and lowest (0.05 mg/L) at Station 6 and 10. The highest and lowest of AN were recorded in forth sampling are 6.01 mg/L at Station 4 and 0.05 mg/L at Station 11 respectively, with average of 0.76 mg/L. Fifth sampling recorded AN concentration from 0.06 to 3.29 mg/L with average of 0.48 mg/L where the highest (3.29 mg/L) was recorded at Station 4 and the lowest (0.06 mg/L) at Station 9, 11 and 12. The highest AN concentration has been recorded during sixth sampling at Station 4 is 5.42 mg/L, while Station 10 recorded the lowest concentration which is 0.09 mg/L, with average of 0.95 mg/L.

All the highest value of AN that has been recorded from this study are from Station 4. The antropogenic discharge such as wastewater and detergent from the residential area is directly being discharged into the river. Hence, high level of ammonia was detected at Station 4. The average of AN in all stations for whole period of samplings according to NWQS is Class II except for Station 4 which classified as Class III. According to the NWQS, water that classified as Class II is suitable for body contact but extensive treatment must be applied for Class III. A study reported that high concentration of AN can be harmful to the aquatic organism, but in small amount it can serve as nutrients to the algae [25]. The concentration of AN in this study (0.05 to 10.03 mg/L) is higher compared to the AN value in Chini Lake [26] with its range from 0.003 to 0.57 mg/L.

3.2. Physical parameters

3.2.1. Total suspended solid

Due to its nature, oxygen will easily dissolve in surface water that has low suspended solids, hence, total suspended solid is an essential parameter for water quality study. The range of concentration of total suspended solid during the first sampling was 8.4–78 mg/L, the highest (78 mg/L) was recorded at Station 10 and the lowest (8.4 mg/L) at Station 1, with average of 33.01 mg/L. During second sampling, the average of TSS concentration is 19.38 mg/L, range 2.6–47.43 mg/L, with the highest 47.43 mg/L at Station 10 and the lowest 2.6 mg/L at Station 1. The range of TSS recorded during third sampling was 4.0–50.29 mg/L with average of 23.50 mg/L, where the highest 50.29 mg/L at Station 9 and the lowest 4.0 mg/L at Station 3. The highest and lowest of TSS were recorded in forth sampling are 117.0 mg/L at Station 2 and 1.4 mg/L at Station 6 respectively with average of 21.71 mg/L. The fifth sampling recorded range from 1.62 to 23.20 mg/L of TSS with the average of 11.98 mg/L where the highest 23.20 mg/L was recorded at Station 10 and the lowest 1.62 mg/L at Station 5. The highest TSS concentration has been recorded during

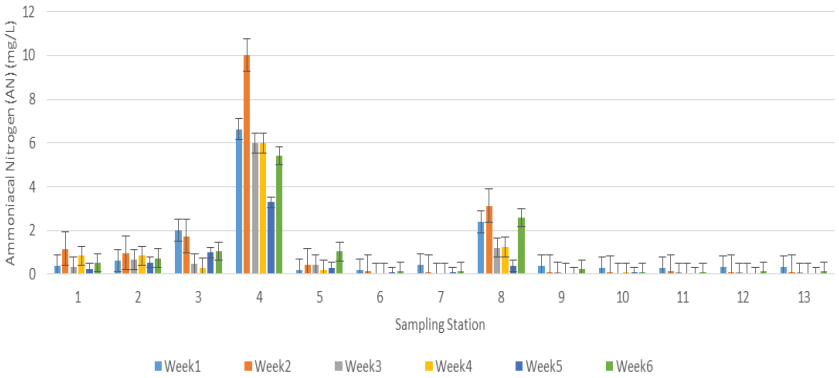

Fig. 6. Distribution of ammoniacal nitrogen (AN) between six samplings.

sixth sampling at Station 2 is 41.33 mg/L, while the lowest is 2.95 mg/L at Station 6 and average of 21.44 mg/L (Fig. 7).

Fig. 7 shows there are few station that has high concentration of TSS which are Station 2 during forth sampling, Station 9 and 10 during first sampling. Out of these three stations, the highest amount of TSS recorded at Station 2 which is 117.0 mg/L. The high value of TSS found in Station 2 is due to the soil runoff that occur at area nearby. Despite the high concentration of TSS in certain stations, according to NWQS, the average of TSS concentration in UniSZA Lake during the samplings falls within the range of Class I for Station 1, 3, 4, 5, 6, and 8, while Class II for Station 2, 7, 9, 10, 11, 12 and 13, means that the water is safe for recreational body contact and suitable for sensitive aquatic species.

3.2.2. pH

The acidity of a solution or water can be determined using pH value. Fig. 8 shows the distribution of pH value at 13 stations for six samplings in the area of UniSZA Lake. During the first sampling, the range of pH was from 6.29 to 7.98 where the highest (7.98) was recorded at Station 10 and the lowest (6.29) at Station 2, with average of 7.09. During the second sampling the average of pH value is 8.16, range from 6.46 to 9.94, with the highest 9.94 at Station 10 and 11 while the lowest 6.46 at Station 1. The range of pH recorded during the third sampling was 6.28–9.02 with the average of 7.53, where the highest 9.02 was at Station 10 and the lowest 6.28 at Station 1. The highest and lowest of pH were recorded in forth sampling are 7.54 at Station 11 and 6.38 at Station 2 respectively, with average of 7.14. The fifth sampling recorded range of pH value from 6.45 to 8.87 with average of 7.66 where the highest 8.87 was recorded at Station 7 and the lowest 6.45 at Station 1. The highest pH value has been recorded during sixth sampling at Station 12 is 9.58, while Station 1 recorded the lowest concentration; 6.5, with average of 8.08.

Based on Fig. 8, the stations located in the lake (S9–13) has higher value of pH comparing to stations that located in the inlets. Overall, pH with range from 6 to 9 is suitable for aquatic species in water. Generally, photosynthetic activities by algae may affect the value of pH by consuming carbon dioxide that dissolve in water [27]. So it is important to maintain ideal pH value to avoid any harmful effects towards the aquatic life. Based on NWQS, average of pH in the inlet station (S1–5) are in Class II, while the stations in the lake fall into Class I, means that the water is suitable for safe for recreational body contact and can support sensitive aquatic lives.

3.3. Analysis of water quality index

Table 3 summarizes the water quality index (WQI) for all thirteen sampling stations during six samplings activities in this study. The calculated WQI values show that

Table 3
Distribution of water quality index in UniSZA Lake

Week	1	2	3	4	5	6
S1	85.39	80.6	80.08	86.44	83.36	84.25
	II	II	II	II	II	II
S2	83.55	81.52	83.72	74.54	86.95	81.91
	II	II	II	III	II	II
S3	79.06	76.69	89.11	89.8	85.46	67.47
	II	II	II	II	II	III
S4	50.49	68.5	67.79	60.65	61.92	52.14
	IV	III	III	III	III	III
S5	80.88	86.21	87.95	91.65	89.83	84.69
	II	II	II	II	II	II
S6	89.01	90.62	91.89	92.65	91.29	92.21
	II	II	II	II	II	II
S7	80.81	79.63	81.21	88.25	87.25	79.23
	II	II	II	II	II	II
S8	78.63	75.79	83.67	85.07	87.26	77.42
	II	III	II	II	II	II
S9	60.15	79.09	78.65	86.41	89.36	80.06
	III	II	II	II	II	II
S10	74.26	75.31	79.76	89.24	89.38	79.11
	III	III	II	II	II	II
S11	75.82	76.27	82.51	89.64	85.19	79.94
	III	III	II	II	II	II
S12	81.7	80.66	82.79	89.56	88.76	83.11
	II	II	II	II	II	II
S13	78.62	77.73	81.25	88.61	88.4	80.26
	II	II	II	II	II	II

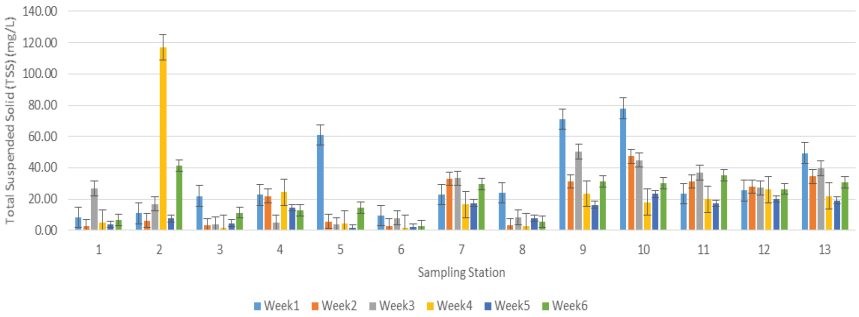

Fig. 7. Distribution of total suspended solid (TSS) between six samplings.

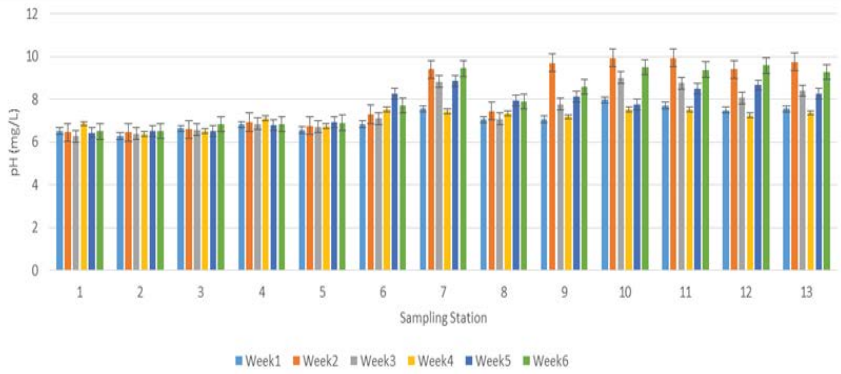

Fig. 8. Distribution of pH between six sampling.

most of the stations can be classified under Class II and III, which is beneficial for fishery and recreational activities. DOE-WQI also highlighted that water in UniSZA Lake has been graded as clean in Station 1, 5, 6, and 12 throughout the sampling period. While the stations in the lake (S9–13 except for S12) has been graded as slightly polluted in during first three sampling activities. Other than that, Station 4 shows worrying WQI status as it falls into Class IV during first sampling and Class III for the rest of the samplings. Range of WQI for Station 4 was from 50.49 to 68.5, indicates that the water had been polluted. The source of pollution could be due to the antropogenic activities coming organic and inorganic content from residential area nearby. It shows that the water in Station 4 required intensive treatment and continuous monitoring are needed. The calculated WQI for the UniSZA Lake that fall in Class II and Class III signed that the water is safe for recreational activities and survival of the organism. The result from Class II status is similar with study from National Hydraulic Research Institute of Malaysia (NAHRIM) Lake [28]. However, this result in contrast with the finding [29] in Kenyir Lake with all the surface water was recorded as clean. Previous study [30] reported in their study on two campus varsity lakes in University Putra Malaysia (Engineering and Serumpun Lake).

4. Conclusions

The results of this study indicated that the parameters have varied in classification depend on their period of sampling. The average concentrations for some parameters such as BOD, TSS and pH were within normal range and falls into Class I and Class II. While AN fall into Class II and III, COD under Class III and IV. Last but not least, DO is classified under Class I and IV. WQI calculation shows that most of the station is categorized under Class II and Class III. This is due to the contamination that occurs of their water body by the urban activities such as residential areas, anthropogenic activities and soil runoff that generated organic and inorganic waste which lead to contamination in the water.

Overall, the WQI from 13 stations shows that water of UniSZA Lake is under control, with slightly polluted. In conclusions, classification within Class II and III shows that UniSZA Lake could serve as recreational area where the water is safe for body contact and suitable for tolerant species and livestock drinking. However, continuous monitoring and appropriate treatment need to be taken to sustain the good water quality status. The result has brought new knowledge of UniSZA Lake water quality and offer a platform for further studies.

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