

Evaluation of Eutrophication Indicators in Slim River Lake, Perak – Malaysia

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ABSTRACT

This study investigated the trophic state of Slim River Lake, and evaluated its water quality according to National Lake Water Quality Criteria and Standards, (NLWQS). Water samples were collected twice per month from August 2017 to July 2018 in three sampling stations around the Slim River Lake. The tested water quality parameters include water temperature, total nitrogen, total phosphorus, chl-a, chemical oxygen demand and cyanobacterial cells number. The rainfall and air temperature data from August 2017 to July 2018 were obtained from the Malaysian Meteorological Department and the mean values were recorded as 252.95 ± 36.84 mm and 26.96 ± 0.46 °C, respectively. The mean and standard error of water temperature, total nitrogen, total phosphorus, chemical oxygen demand, chl-a, cells number of cyanobacterial genera were 29.52 ± 0.30 °C, 5.32 ± 0.95 mg/L, 0.82 ± 0.12 mg/L, 31.89 ± 3.93 mg/L, 7.26 ± 1.96 mg/L, 18.3×10^4 cells /mL, respectively. High levels of total nitrogen and total phosphorus were quantified during high rainfall period, thus imply the significant load from the storm water runoff. High cyanobacterial cell numbers were also detected, which indicated the occurrence of cyanobacterial bloom. The comparison of water quality parameters with NLWQS suggests a hypereutrophic condition in the study lake. In conclusion, the state of eutrophication in Slim River Lake poses potential health risks, and future changes in climatic factors will enhance this risk. Therefore, more attention and control by local authorities are needed to reduce the severity of eutrophication progression in this lake.

1. Introduction

Eutrophication is the process of increasing nutrients represented by nitrogen and phosphorus in water bodies such as lakes, often accompanied by algae bloom(1). Eutrophication is a natural process by which organic productivity increases within a water body can degrade water quality and changes the microorganism concentrations in water ecosystems(2). In eutrophic lakes, phytoplankton is often dominated by cyanobacteria. Cyanobacterial bloom is a term used to describe a lake ecosystem condition where its phytoplankton community is mainly dominated by cyanobacteria(3). Cyanobacteria can produce toxins such as microcystins, poses potential health risks in water ecosystems(4). Local weather, hydrologic conditions, and land-use patterns are examples of factors that influence the nutrient loads and eutrophication in a water body (5). When the dissolved oxygen percentage in the water is less than 3mg /L, the condition is called hypoxia, and it is considered a significant problem in the lake (6).

In Malaysia, there are approximately 90 major lakes, of which 60 suffer from eutrophication. This was confirmed by a study conducted by the National Institute for Hydraulic Research in Malaysia(7).The assessment of lakes' eutrophication status was made based on NLWQS. This standard utilized water quality parameters including phosphorus, nitrogen, and chlorophyll-a. Phosphorus and

nitrogen are the critical determinant of algae level, while chlorophyll is a good indicator for assessing and determining algae biomass(8).

This study was conducted to evaluate the state of the eutrophication problem in a local urban shallow lake using the NLWQS standard. This study also investigates the influence of local weather patterns on the water quality and succession of cyanobacteria in Slim River Lake.

2. Methodology

Lake Description and Water Sampling

Slim River Lake ($3^{\circ} 49' 26.688''$ N; $101^{\circ} 24' 30.6216''$ E) is a human-made shallow lake located in the Muallim district of Perak state, Malaysia. Slim River Lake is an abandoned ore mine and currently used for recreation, fishing, and entertainment among local communities. Slim River Lake was chosen as a study site due to its high algae and floating macrophyte growth. Three locations around the lake were selected as sampling stations. The area of the Slim River Lake and sampling stations are illustrated in Figure 1. The first sampling station was located at the upstream of the lake. Meanwhile, the second station was on the western side of the lake, exactly beside the highway. The third sampling station was situated at the opposite side of sampling station 1, parallel to the Bernama River.

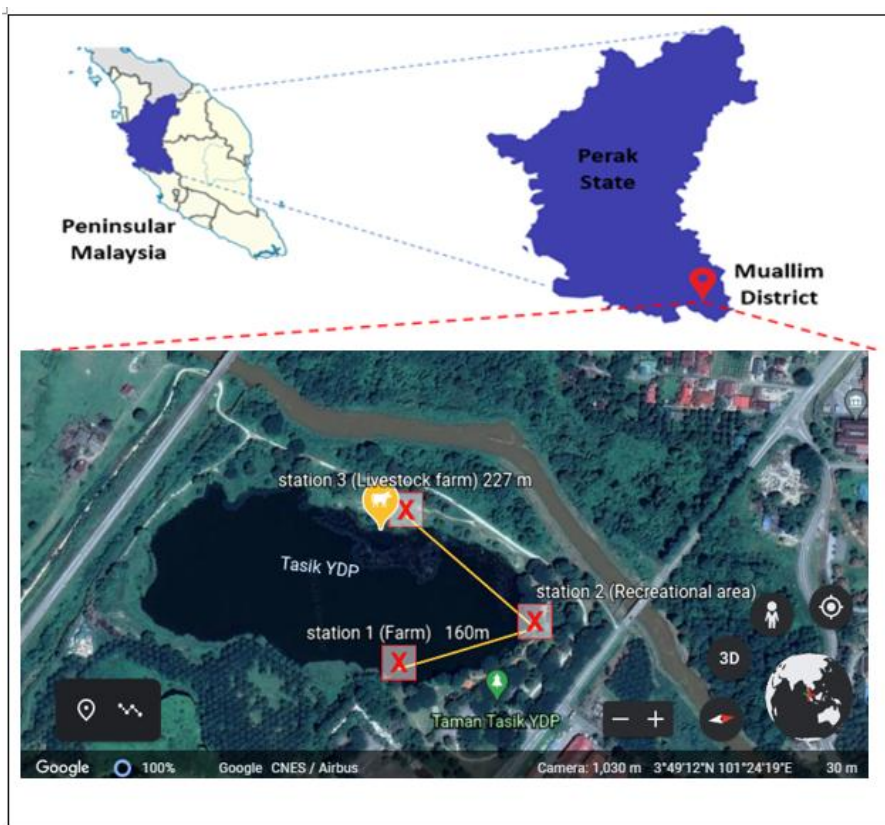


Figure 1. Location of the slim river lake and the sampling stations.

Water sampling was conducted monthly from August 2017 to July 2018. In-situ measurements for water temperature were performed by using a portable meter (HACH SensION+ PH1, Spain) equipped with a temperature sensor. Three water samples were collected from three different stations during each sampling event. Water samples were collected from 15 - 20 cm below the surface to avoid floating debris. The collected water samples were immediately delivered back to the laboratory for further laboratory analyses.

The total phosphorus (TP), total nitrogen (TN) and chemical oxygen demand (COD) were tested using HACH method number 10127, 10072, 8000, respectively. For total chlorophyll-a (chl-a) analysis, a minimum of 600 mL of each water sample was filtered through glass fiber filter paper (Whatman Glass Microfiber GF/C 47 mm, UK). Algae-containing filter paper was freeze-thawed three times before it was submerged in a test tube containing 10 mL of 10% acetone, and sonicated in a cold water bath for 7 min to break up algae cell wall. Then, the extract was subjected to 5 min centrifugation at 5000 rpm to separate the particulate matter and remaining debris. The absorbance at 750 nm and 665 nm was measured using spectrophotometer (PRIM-SECOMAM, France) against 90% acetone blank, before and after acidification with 0.2 mL of 1% HCl. The level of chl-a was then calculated based on modified Lorenzen's equation(9). The estimation of cyanobacterial cell numbers(cells/mL) was performed using a light microscope (Leica DME Microscope,

Germany) and haemocytometer (QIUJING, China) with a cell depth of 0.10 mm. This haemocytometer consisted of improved Neubauer ruling pattern with 0.0025 mm² square.

Data Processing and Statistical Analysis

The averages values of the parameters (except rainfall and air temperature) were calculated from the monthly measurements made at three sampling sites during the twelve months' period. The mean of the three readings was calculated for each of the studied parameters.

3. Results and Discussion

The local weather (rainfall and air temperature) of the Slim River Lake region was found to be varied throughout the study period. The monthly average for air temperature are given in Figure 2. The average rainfall measured within the study period was recorded at 252.95 mm with a standard error of 36.84 mm. The maximum rainfall was recorded in March 2018, which up to 528.50 mm. On the other hand, February had the least rain of only 68.10 mm. The average air temperature recorded was recorded at 26.96 °C with a standard error of 0.46 °C. The highest air temperature of 27.43 °C was recorded in April 2018, while the lowest air temperature of 25.85 °C was recorded in January 2018.

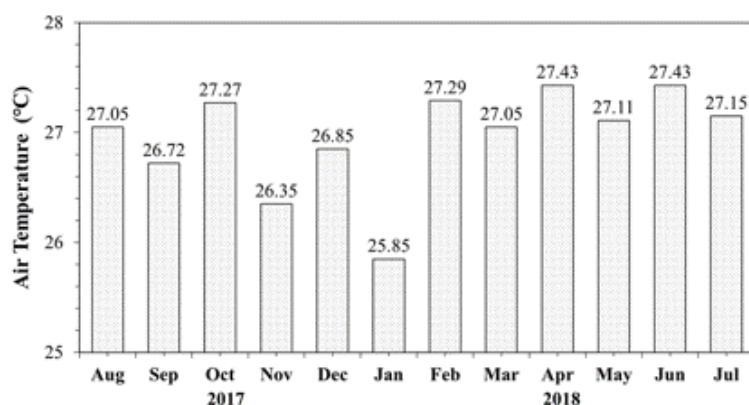


Figure 2. Monthly average air temperature throughout the sampling period

Rainfall intensity is considered as the primary force which driving the inflow of sediment into a lake ecosystem(10). These high-density inflows coupled with the significant release of pollutants (11). The seasonal succession of phytoplankton biomass and communities is greatly influenced by rainfall patterns (12). In addition to rainfall, the air temperature of the area has a possible impact on the temperature of the aquatic environment, thereby affecting the nutrients concentrations in the water (13). Alteration of some physical, chemical and biological factors in the water ecosystem has a significant influence on the aquatic biota (14). The average water

temperature of the lake was recorded at 29.52 °Cwith a standard error of 0.30 degrees (Figure3). As shown in Table 1, water temperature of freshwater is suggested at 28°C in NLWQS (15). The level of water temperature can be related to the amount of humidity and rainfall received in the area at a particular time (16). Continuous changes in water temperatures and events in hydrological cycles, as well as the increase of nutrients as a whole, contribute to the formation of biomass of phytoplankton and increase its production within water bodies(17).

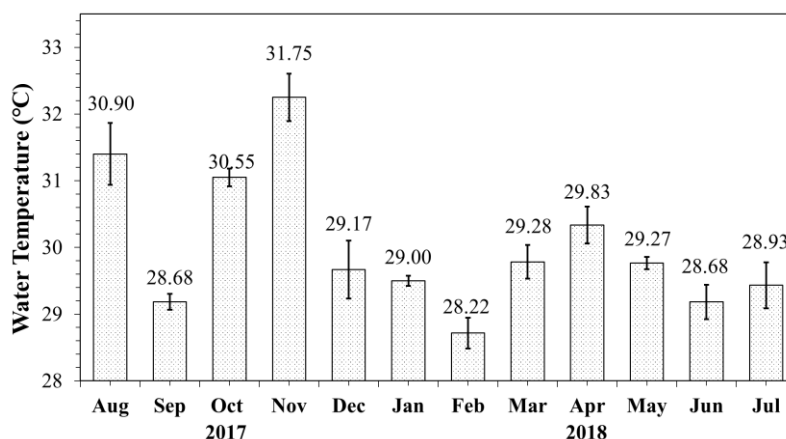


Figure 3. Monthly average water temperature throughout the sampling period

Table 1: Recommended values for water quality parameters according to NLWQS- Category A (15)

Parameter	Unit	Guideline Values
Water temperature	°C	28
Chemical oxygen demand (COD)	mg/L	10
Total Phosphorus	mg/L	0.01
Total Nitrogen	mg/L	0.35
Chlorophyll-a	mg/L	0.01
Cyanobacteria	Cells/ml	15000

The TN level in Slim River Lake was also varied throughout the study. The average TN level in Slim River Lake was recorded at 5.32 mg/L with a standard error of 0.95 mg/L (Figure 4). The results suggest that the TN level in this lake was consistently exceeded the recommended limit of 0.35mg/L as set by NLWQS, as shown in Table 1. Generally, the excessive nitrogen level in freshwater could be linked to possible runoff nearby disturbed land, which is directly

associated to the amount of rainfall in the area (18). The highest nitrogen level recorded in March 2018 could be linked to the highest rainfall of 528.5 mm recorded in the same month. Excessive levels of nitrogen in the aquatic environment could lead to a low level of dissolved oxygen and, therefore, negatively altering the ecosystem and encouraging eutrophication (19).

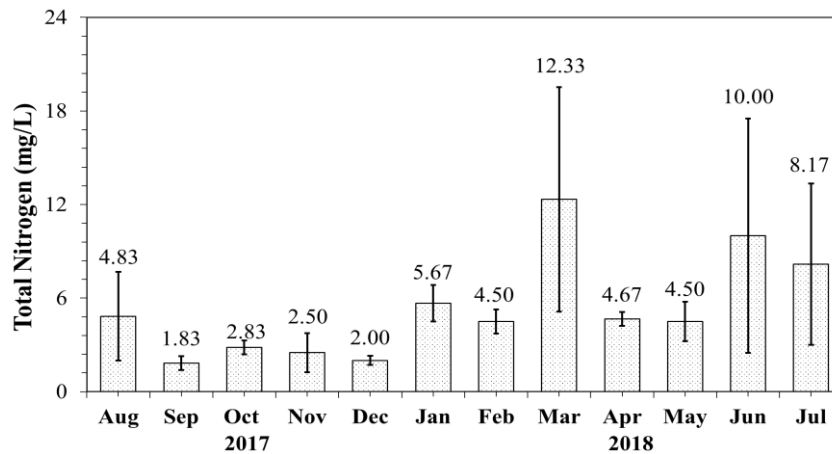


Figure 4. Monthly average total nitrogen throughout the sampling period (mg/L).

The average TP level in the lake was recorded at 0.82 mg/L with a standard error of 0.12 mg/L (Figure 5). The results suggest that the TP level in this lake was consistently exceeded the recommended limit of 0.01mg/L set by NLWQS, as shown Table 1. TP occurs naturally in different mineral deposits and rocks, which are gradually released into the water during natural processes such as weathering (20). In addition,

TP level in freshwater could be a result of various anthropogenic activities such as untreated or partially treated wastewater and runoff containing fertilizer from agricultural land (21). The excessive TP level in freshwater could distort the ecosystem balance by negatively affecting the population of zooplankton and positively promoting the community of phytoplankton (22).

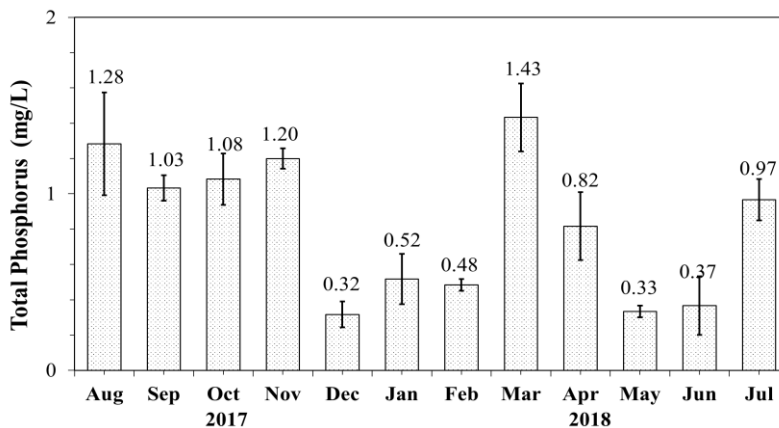


Figure 5. Monthly average total phosphorus throughout the sampling period (mg/L)

The average chlorophyll-a level obtained in the lake was recorded at 7.26 mg/L, with a standard error of 1.96 mg/L as shown in Figure 6. The chlorophyll-a level in Slim River Lake showed a distinctive variation across the study period of a year.

The average level of 7.26 mg/L in the study lake indicates high chlorophyll-a when compared to NLWQS standard criteria (category A) of 0.01mg/L as reported by (15) (Table 1).

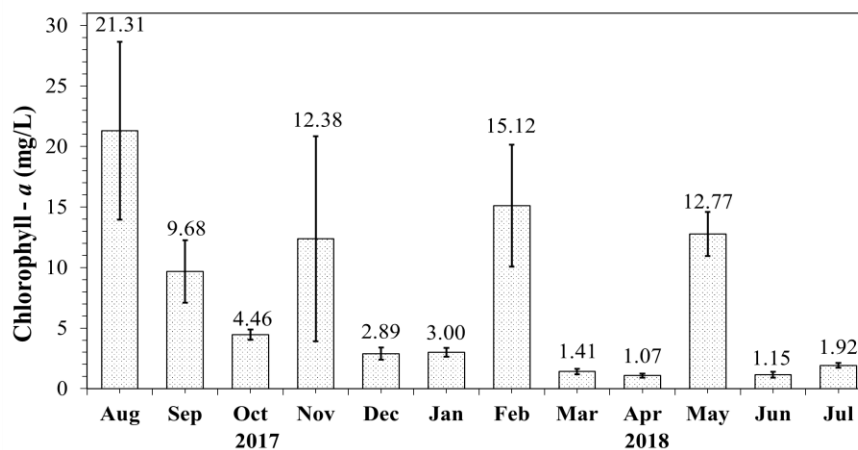


Figure 6. Monthly average chlorophyll-a concentration throughout the sampling period(mg/L)

The chlorophyll-a level in Slim River Lake was (7.26 mg/L) recorded at within the range of hypereutrophic based on the NLWQS (15) (Table 1). In the study lake, the level of chlorophyll-a in water could fluctuate over time, particularly during the raining season when nutrients are flushed into the water. Hypereutrophic level is generally associated with bloom-forming cyanobacteria (23). The chlorophyll-a level in the lake justified the presence of nutrients detected in the lake. The harmful proliferation of planktonic algae is a leading agent for the disruption of the aquatic environment (24). High productivity in several freshwater ecosystems has occurred in majority of lakes worldwide due to an uncontrolled influx of nutrients in the water (25). In the study lake, the level of chlorophyll-a in water

could fluctuate over time, particularly during the raining season when nutrients are flushed into the water.

The average COD was recorded at 31.89 mg/L with a standard error of 3.93 mg/L as shown in Figure 7. Theoretically, a high COD level indicates the polluted water (26). The COD level in Slim River Lake has consistently exceeded the standard limit of 10 mg/L set in NLWQS standard criteria (category A). A high level of COD in the water indicates the presence of a high level of biodegradable organic matter(27). High COD in the aquatic ecosystem often caused by agricultural runoff, leading to the deterioration of water quality, making it inhabitable to many aquatic organisms and unfit for other usages (28).

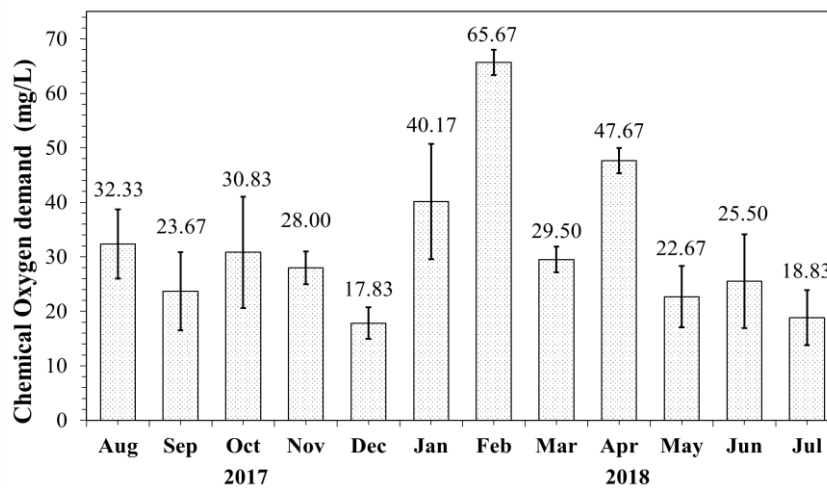


Figure 7. Monthly average chemical oxygen demand throughout the sampling period (mg/L)

The total cyanobacterial cell number (*Microcystis* spp, *Oscillatoria* spp and *Phormidium* spp) detected in Slim River Lake was recorded at 183,000 cells /mL over the study period

Figure 8. This result indicates extremely high cyanobacteria cell number as compared to the NLWQS standard criteria (category A) of 15,000 cells/mL.

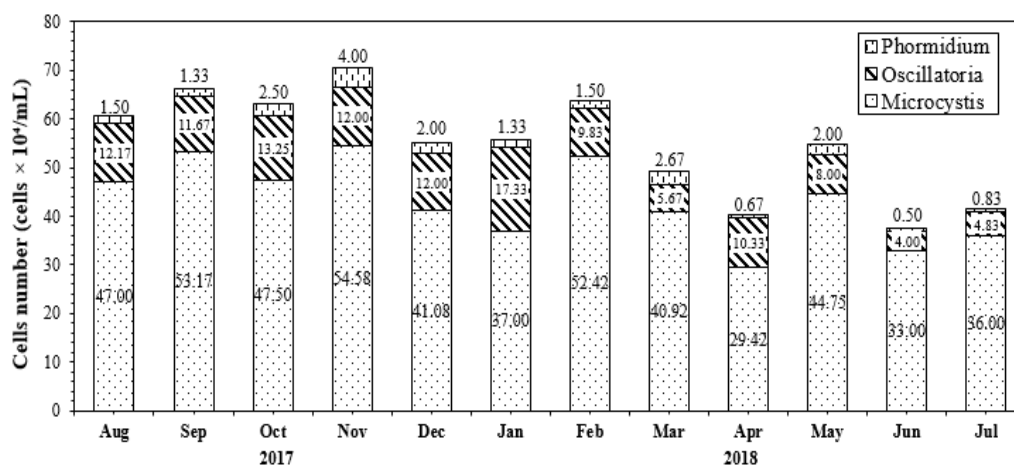


Figure 8. Monthly average cells number of cyanobacteria genera throughout the sampling period

In addition, the obtained results in Figure 9 show variability in the distribution of cyanobacteria genera in the Slim River Lake. These results indicate the presence of high level of cyanobacteria biomass which affect the water quality and making it unfit recreational purposes such as swimming, fishing, etc. This is due to the fact that cyanobacterial genera can produce various cyanotoxins such as neurotoxin, dermatotoxin, hepatotoxin (29). Cyanobacteria genera exposure could be

via absorption through skin surface, inhalation, drinking infected water, and contaminated food-products through bioaccumulation (30). With regard to the climate change, an increase in temperature and change in rainfall patterns in the future is expected and thus bring a significant impact on inland water such as lakes. The higher temperature also could promote the cyanobacterial bloom (31).

4. Conclusion

In conclusion, study findings suggest that the lake is having serious eutrophication problem and can be classified as hypereutrophic. Changes in precipitation associated with climate change could increase the risk of eutrophication and cause a cascade of adverse ecosystem impacts in water bodies. The parameters such as chlorophyll-*a* and nutrients

such as TP, TN were dependent on the amount of rainfall. Overall, the present state of this lake requires effective restoration strategies such as a chemical treatment to reduce nutrients level or increase the number of trees the discharge points as the trees assimilate the nutrients.

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