ASSESSMENT OF WATER EUTROPHICATION IN KAMPAR CAMPUS

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A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering (Hons) Environmental Engineering

Faculty of Engineering and Green Technology
Universiti Tunku Abdul Rahman

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR of other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled "**ASSESSMENT OF WATER EUTROPHICATION IN KAMPAR CAMPUS**" was prepared by **DESMOND CHAN MIN PIN** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Engineering (Hons) Environmental Engineering at Universiti Tunku Abdul Rahman.

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ABSTRACT

Eutrophication also known as algae blooming when a water body enrich with nutrients such as phosphorus and nitrogen. Eutrophication can be natural process and anthropogenic process that accelerate the natural process by discharging sewage, agriculture runoff and industrial waste. This study investigated the overall trophic state of University Tunku Abdul Rahman (UTAR) lake, Kampar Campus Lake by using Carlson's Trophic State index (CTSI). Water sampling was taken from five collection points with different inlet and outlet from other sources (lakes or drains). There were several parameters had been examined such as in-situ test (dissolved oxygen, water temperature, pH value, turbidity and water transparency) and laboratory tests (total nitrogen, total phosphorus, chlorophyll-a, ammonia, and chemical oxygen demand). The data collection included the rainy season began from October 2018 to December 2018, and the dry season with a low rainfall rate started from January 2019 to March 2019. The highest Secchi Disk Transparency of 1.24 ± 0.05 m and the lowest chlorophyll-a concentration of 23.07 ± 2.28 µg/L at site 2 (centre of lake) compared to the low Secchi Disk Transparency of 0.81 ± 0.03 m and the highest chlorophyll-a concentration of 41.03 ± 5.27 µg/L at site 4 (cafeteria). The site 2 has a high water transparency due to less algae biomass and the absent of discharge inlet and outlet, meanwhile site 4 exposed to high discharged rate from the cafeteria causing a massive algae blooming. The Secchi Disk Transparency was inversely proportional to the chlorophyll-a concentration. The total phosphorus indicated that November 2018 have the highest concentration of 95 ± 5.7 µg/L due to high rainfall resulted runoff to the lake. The other parameters were compared to the Water Quality Index and it showed that the UTAR Kampar lake was classified as Class III (moderate). Thus, UTAR Kampar lake was nutrient pollution that causes eutrophication.

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°C	Degree Celsius
%	Percentage
kg	Kilogram
mg	Milligram
µg	Microgram
cm	Centimetre
m	Meter
nm	nanometre
µS	Micro Siemens
L	Litre
mL	Millilitre
APHA	American Public Health Association
BOD	Biological Oxygen Demand
Chl-a	Chlorophyll-a
COD	Chemical Oxygen Demand
$Cr_2O_7^{2}$	Dichromate
Cr^{3+}	Chromium
CTSI	Carlson’s Trophic State Index
Dec	December
DIN	Dissolved Inorganic Nutrients
DO	Dissolved Oxygen
DOE	Department of Environmental
DO%	Saturation of Dissolved Oxygen
E.I.	Eutrophication Index
EPA	Environmental Protection Agency
Eq.	Equation
Feb	February
H_2S	Hydrogen sulphide

IN	Inorganic Nitrogen
IP	Inorganic Phosphorous
Jan	January
Log_{10}	Logarithm 10
Mar	March
$MgCO_3$	Magnesium carbonate
N	Normality
NAHRIM	National Hydraulic Research Institute of Malaysia
NLWQCS	National Lake Water Quality Criteria and Standards
NRE	Ministry of Natural Resource and Environment
NWQI	National Water Quality Index
NH_3^-	Ammonia Ions
No.	Number
NO_3^-	Nitrate Ions
NO_2^-	Nitrite Ions
Nov	November
NTU	Nephelometric Turbidity Unit
Oct	October
OD	Optical Density
PO_4^{3-}	Phosphate Ions
SD	Secchi Disk Transparency
TDS	Total Dissolved Solids
TP	Total Phosphorus
TN	Total Nitrogen
TSI	Tropic State Index
TSS	Total Suspended Solid
TRIX	New Trophic Index
TRBIX	Turbidity Index
TRBR	Turbidity
TRSP	Transparency
USEPA	United States Environmental Protection Agency
UTAR	University Tunku Abdul Rahman
WQI	Water Quality Index
WRI	World Resources Institute

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

The industrial revolution began in the middle of 18^{th} century started by the European country, the development of modern farming transferred the limited land to farming in a short span of time to mass production of crops. The second transformation was urbanization which people have jobs and money to upgrade their family from rural area to urban. With the rapid economic growth, the side effect was critical health of waterbody due to discharge from urban point source, raw sewage and agriculture runoff (Helmer and Hespanhol, 1997). Excessive nutrient discharged from point source and runoff may be the beginning of the story. European lakes had been enriched with nutrients since 1850's and suffering from hypoxia and greatly accelerate to 1900's (Jenny et al., 2016). Europe Socioeconomic since resulted in rapid expansion urbanization. As urbanization consume land, deforestation may drive nutrients from terrestrial to aquatic system. The largest increase nutrient input was predicted for southern and Eastern Asia – large population contributed to increase usage of fertilizers and rapid industrialization (Rabalais et al., 2010). The high concentration of nutrient may cause eutrophication of freshwater. Eutrophication is a global problem which would affect by all lakes and reservoir. Malaysia is one of the countries that is facing this problem. Malaysia is a developing country where urbanization and agriculture is increasing. According to a study of National Hydraulic Research Institute of Malaysia (NAHRIM) in 2005, more than 60% of 90 major lakes in Malaysia were in eutrophication condition while the another 40% were in mesotrophic condition (Sharip and Zakaria, 2008). The famous lakes are Lake Bera, Bukit Merah and Loagan Bunut Lake. The major contribution to the degradation are sewage, logging and agriculture activities majority in the oil palm industry.

1.2 Problem Statement

Recently in University Tunku Abdul Rahman (UTAR) Kampar lake was suffering with massive algae blooming. The algae bloom occurred at the lake connected to West Lake and East Lake, and Block C cafeteria. Excessive nutrients discharged into the lake may accelerate algae growth in the lake. The most common algae bloom may result in deterioration the appearance of clean water and created odour. Eutrophication also known as algae bloom can be dangerous in long term effects to the aquatic organisms, environment and humans. The removal of nutrients may be the key to limit the algal growth for eutrophication control. There were no study or research in water parameters that contribute to eutrophication or water quality and the possible source that cause eutrophication for UTAR Kampar lake. Thus, this research was conducted to further understand the eutrophication situation in UTAR Kampar lake.

1.3 Aim and Objective

The aim of this study is to investigate the trophic state and water quality of UTAR Kampar lake by collecting water sampling monthly at different sampling sites.

The objectives of this study is:

1) To regularly monitor the water parameters related to eutrophication situation and water quality at the lake of UTAR Kampar.
2) To analyse the eutrophication situation and lake classification by Trophic State Index calculations

1.4 Scope of Study

This study was conducted to assess the water parameter at UTAR Kampar lake. The factors of algae blooming can be seen during the rainy seasons, nutrients availability and sediments runoff at different discharge points. In this research, the water parameters were analysed for pH, temperature, dissolved oxygen, water transparency, turbidity, chemical oxygen demand, ammonia, total nitrogen, total phosphorus and chlorophyll-a. The parameters used to indicate and compare the trophic state and water quality of UTAR Kampar lake by using Carlson's Trophic State Index (CTSI) and Water Quality Index for Malaysia (WQI).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of Eutrophication

Eutrophication also known as algae blooming can be defined when nutrients such as nitrogen and phosphorus were discharged into the water body that support the growth of algae (Yang et al., 2008). Excessive growth of algae may result in harmful effect to the environment and aquatic organisms. Eutrophication can be natural process or human activities. Natural eutrophication is a natural process that occurs over a period of centuries causing the lake be filled with materials results in the imbalance production and consumption within the lake, and the lake will slowly become over-fertilized (Callisto et al., 2014). Human activities also known as anthropogenic is accelerating the eutrophication by input nutrients via discharged sewages and industrial wastes into the water ecosystem (Qin et al., 2006).

2.1.1 Eutrophication Cycle

Excessive nutrients that stimulate primary production of phytoplankton may promote eutrophication (Paerl et al., 2006). Phytoplankton are microorganism that flood on the surface of water, they are single-celled but they may grow in large colonies even visible by naked eyes. Phytoplankton produce about 70% of Earth's oxygen to the atmosphere and it is sustaining the aquatic ecosystem food web (Diana, 2018). Phytoplankton means photosynthesis that have the ability to convert sunlight, minerals from raw water, and carbon dioxide to produce energy and oxygen. The algae biosynthesis where ammonia and nitrate are the nitrogen source displayed in Eq. (2.1) and (2.2) respectively. The chemical formula $C_{106}H_{263}O_{110}N_{16}P$ which composed its bioplasm by sunlight or light energy and inorganic nitrogen and phosphorous through photosynthesis, inorganic nitrogen and phosphorous are the major controlling factor for the propagation of algae (Dalrymple et al., 2013).

$$16NH_4^{+} + 92CO_2 + 92H_2O + 14HCO_3^{-} + HPO_4^{2-} \rightarrow C_{106}H_{263}O_{110}N_{16}P + 106O_2 \quad (2.1)$$

$$16NO_3^{-} + 124CO_2 + 140H_2O + 14HCO_3^{-} + HPO_4^{2-} \rightarrow C_{106}H_{263}O_{110}N_{16}P + 138O_2 + 18HCO_3^{-} \quad (2.2)$$

Some phytoplankton can be bacteria, protist (plant or fungus) and single-celled plants. The common kinds are algae and cyanobacteria, both are similar contain chlorophyll-a performs photosynthesis, but different in cell structure (Lindsey and Scott, 2010). Algae are plant-like organisms, a simple structure from a single-celled phytoplankton that float on the surface of water to large seaweeds (macrooalgae) that located at the ground ocean. Algae are difficult to classify as they have various species such as different pigmentation, complexity, cell structural, and environment factors (National Taiwan Museum, 2007). Cyanobacteria are bacteria also known as blue-green algae, it is not algae because it does not contain nucleus or cell wall but it performs photosynthesis to produce its own food and energy. Algae and cyanobacteria have one common similarity, oxygenic photosynthesis process used by plants and both can be found in freshwater and saltwater (Saad and Atia, 2014).

At this stage, algae grow rapidly as it concentration may reach millions of cell per millilitre, excessive growth of algae and cyanobacteria may result in green pigment layer forming on the surface water. The green thick layer absorbs sunlight for photosynthesis, and act as a barrier that reflects sunlight resulted less oxygen production for aquatic plants at the ground level of the waterbody, and decreasing the water quality (Bista, 2016). Since aquatic plants fail to produce oxygen during daytime, it eventually consumes oxygen via respiration until night cause oxygen depletion at the bottom of the waterbody (Yang et al., 2008). Since algae and cyanobacteria are floating on the water surface, sunlight reaches them before the aquatic plants resulting a high biomass production, and consume all the nutrients available in the water. Due to insufficient sunlight, the aquatic plant will be exasperated and lack of oxygen and nutrients will eventually die. Bacteria and fungi are playing their role to oxidize organic matter whenever death algae that sink to the bottom and recycle materials such as released nutrients (Lee and Bong, 2006). Furthermore, when oxygen depletion it will create an environment called hypoxia - low oxygen content and no living organisms except microorganisms also known as dead zone (WRI, 2018). The illustration of eutrophication process shown in Figure 2.1.

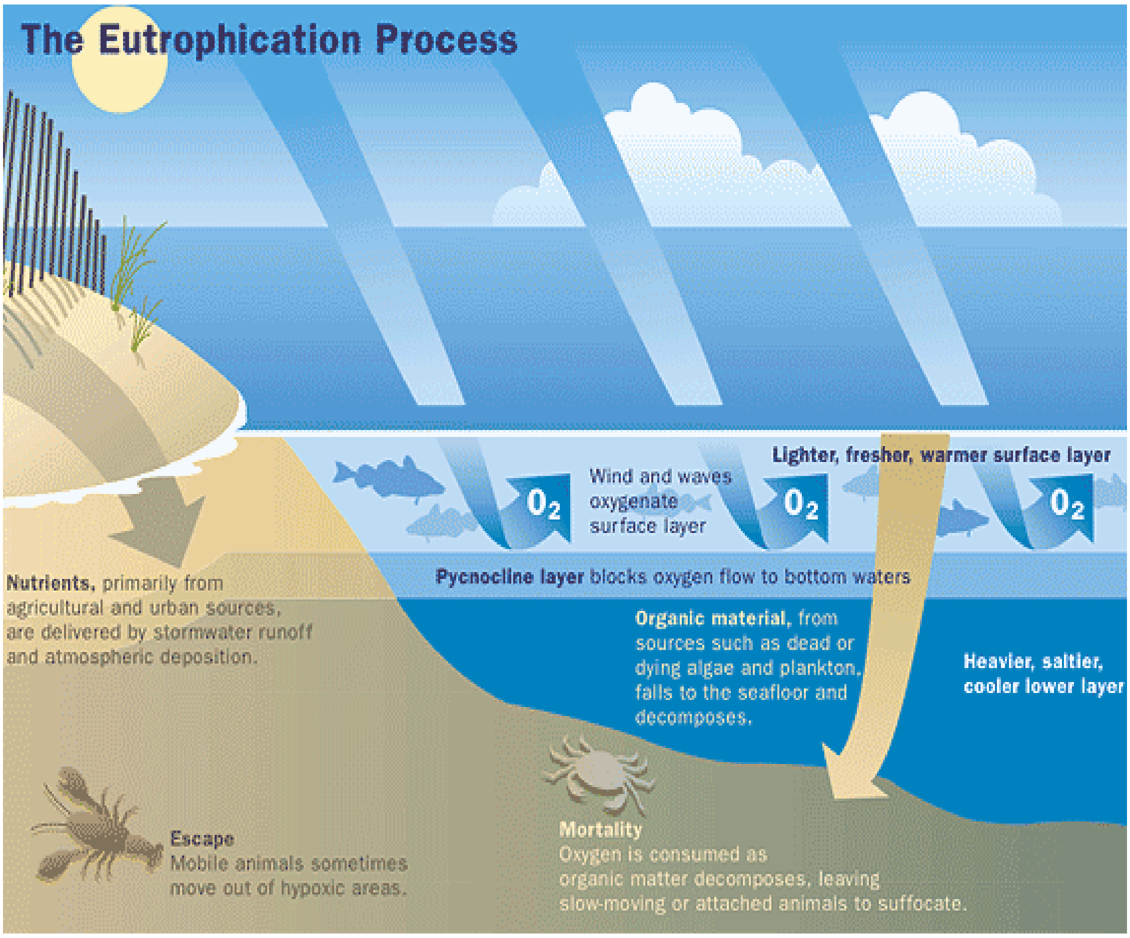


Figure 2.1: Eutrophication process (WRI, 2018).

2.1.2 Freshwater and Coastal Marine Ecosystems

Eutrophication can occur in any type of water body even with freshwater and coastal marine ecosystem. The freshwater habits can be classified by different factors such as temperature, sunlight absorption, and vegetation. Freshwater ecosystem can be classified into two major groups, Lentic and Lotic ecosystems. The term Lentic ecosystem is given to standing water or a still water bodies that includes ponds, lakes, swamps and bogs. The term Lotic ecosystem is flowing water that will eventually flows to the ocean at the estuaries including river, springs, and creek (Balasubramanian, 2016). The river at the upstream carried tons of nutrients, sediments, pollutants discharged from any non-point source and point source while on the way to the estuaries. In freshwater ecosystem, phosphorus is the major growth-limiting nutrient for algal and all form of concentration phosphorus played as limiting factor for algal biomass (Carlson, 1977).

Marine ecosystems are classified into two habitats of open seas and coastal zone. The open seas ecosystem include lagoon, coral reefs, and mangrove while coastal zone includes salt marshes and wetlands where river mouth and shores are connected such as estuaries (Balasubramanian, 2016). Estuaries normally enrich with nutrients when river came in contact with ocean, normally have a trophic state of eutrophic because of land-derived nutrient via runoff (Smith et al., 2006). Nitrogen is the limiting nutrient in marine ecosystem, thus nitrogen is an essential nutrient for eutrophication problems (Smith, 2003). Redfield found particular matter of ocean water and dissolved nutrient in the ocean were somehow correlate to C:N:P ratio, with the atomic ratio of $C_{106}N_{16}P_1$ in phytoplankton (Lee and Bong, 2006). Carbon and nitrogen are stoichiometric balance with phosphorous, demands of the oceanic biota. When either carbon or nitrogen is limited, the nitrogen cycle showed that nitrogen in atmosphere was undergoing nitrogen fixation that tapped into the soil or water. Likewise, excessive of carbon or nitrogen will denitrified by bacteria back to the atmosphere. Unlike nitrogen and carbon that involve gaseous phase, phosphorous is controlled by the rate of runoff from river. Redfield ratio is the overall means for many species growing lacking strong single element nutrient limitation – to determine the limiting nutrient and even understand formation of algae blooming, with that, Redfield ratio can be compared with different region nutrient ratio (Sterner, 2009).

2.2 Main Cause of Eutrophication

Non-point source caused by rainfall that wash off and carry away the natural nutrients and pollutants created by human from the surface of the ground and groundwater seepage, finally depositing at water bodies (Viman et al., 2010). The most common non-point source pollution that is agriculture runoff. Agriculture can be divided into two segments, crop and livestock – whereas crop involves vegetable, grain, fruit and forage products while livestock involves eggs, milk, dairy, goat, cow, sheep and horse. Crop production used fertilizers to boost and support its growth whilst fertilizers made up of nitrogen, phosphorous and other elements that contain in the soil natural (U.S Department of Agriculture, 2007). As crop production used fertilizers when operation, the water seepage and ran over the ground by passing through the loosen soil, absorbed and carried pollutants, which can deposit to the nearest water body (U.S National Library of Medicine, 2017). Livestock production that included feeding operation and animal waste contributed quite a bit to runoff as well. Livestock in United State produced about 335 million tons of manure each year (U.S Department of Agriculture, 2007). If agriculture does not take this seriously, the manures will be decomposed by microbial and will eventually entered into ground water and deposited into lake or ocean (Macklin, 2017). If there is no proper management or disintegrate in handling animal wastes, it will eventually carry away with the enrich runoff and microorganism, causing further eutrophication (Nakai, 2001). Last but not least, aquaculture also known as fish farming can also accelerate eutrophication process as well. Farmers normally feed the marine fish and shrimp with artificial food that is full of nutrients and minerals, thus these farms can also generate high concentration of phosphorous, nitrogen, and other organic minerals from excrement, uneaten food, and organic waste within the area (Lazzari and Baldisserotto, 2008). If this is not properly managed, the enrich water may directly discharge to surrounding water. A ton of agriculture fish produced about 42 kg to 66 kg of nitrogen waste and 7 kg to 10 kg of phosphorous waste (WRI, 2018)

Point source pollution is that pollutants were conveyed via discharge pipes or discrete conveyance. Most of the discharged pollutants were from factories, urban runoff, power plants and residential areas. In some developing nations, sewage water directly discharged into water body. Sewage water consists of chemical, detergent and excretion including harmful bacteria and viruses (Viman et al., 2010). It is also known that some households' septic system is not connected to wastewater treatment plants. Septic tank helped to purify waste by releasing back to the soil, when leeching; about 14 kg of nitrogen were discharged into the groundwater per year (WRI, 2018). Urban runoff happens when there is storm flushing nutrients from residential areas and surface of the urban areas into nearby water body. Many cities and towns in Malaysia used separate sewer system thus, wastewater was transported in separate pipes (Othman et al., 2016). In other words, urban runoff in Malaysia was directly discharged into the nearby water body resulting in the water quality change.

In Malaysia, the three main sources of water pollution were sewage, agriculture and industrial waste (Afroz et al., 2014). The sources of water pollution can be classified into non-point source and point source. Non-point sources are from diffuse source that does not have any specific discharge points either from agriculture or surface runoff; it may accumulate from many different sources. In 2008, Department of Environment (DOE) reported that there were 17,633 water pollution point source in Malaysia (Afroz et al., 2014). The percentage of water pollution point sources were categories into manufacturing industry, sewage treatment plants, animal farm and agro-based industry (Figure 2.2). An analysis of manufacturing industries, the highest industrial discharge in Malaysia are the food and beverage industry, that covers approximately 23.7 percent of total source of water pollution, followed by electrical and electronics industry contributing 11.4 percent. The chemical industry contributed 11.2 percent, whilst the paper industry produced 8.8 percent. The smaller percentage were finishing industry, textile industry and agro-based industry (Afroz and Rahman, 2017).

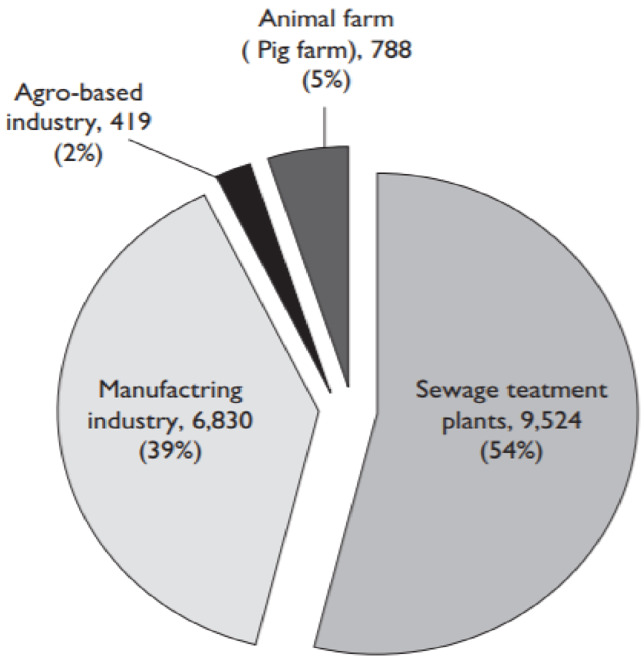


Figure 2.2: Composition of water pollution in Malaysia (Afroz et al., 2014).

2.3 Effect of Eutrophication

Enrichment of nutrient in the ecosystem sometimes provided positive impact to enhancing plant production (e.g. Phytoplankton) and fish farming production, it can benefit humans to have food supply and increase job opportunities and incomes. However, excessive nutrient may give high negative impact; example the ecological and environment impact, human impact, and economic impact.

2.3.1 Ecology and Environment Impact

Excessive nutrients mean excessive growth of algae leads to eutrophication. These algae may cause harmful impacts to the ecosystem. Aquatic plants and coral reef will be damaged and die due to excessive growth of algae as it is grown a green layer that cover the water surface and it will reduce light penetration. Once covered, coral and algae will compete for nutrients in order to grow (Bell, 1992). Secondly, when aquatic plants and coral died, they will stop producing oxygen, resulting in aquatic animals losing their home and eventually reducing biodiversity (WRI, 2018). Thirdly, eutrophication may contain cyanobacteria also known as harmful algae that exist on eutrophic surface water. It produces toxins that can kill fish and cause human sickness through shellfish poisoning, and death of animals (Alves Da Costa et al., 2018). When algae and cyanobacteria died off at hypolimnion, they were degraded by aerobic, anaerobic microbe and sulphate reduction bacteria, which could cause depletion of dissolved oxygen (DO). When water body has DO lower than 4 mg/L, it creates an environmental called hypoxia. Hypoxia becomes harmful to aquatic animals when physiological and behavioural response altered behaviour such as reduced reproductive rate, stress and loss biodiversity shown in Figure 2.3 (Diaz, 2010). At the lowest level of DO at 0.2 mg/L, hydrogen sulphide (H_2S) will be produced by sulphate reduction bacteria – Odour of rotten egg smell, harmful to marine and it could activate the phosphorus release from sediment (Henny and Nomosatryo, 2016).

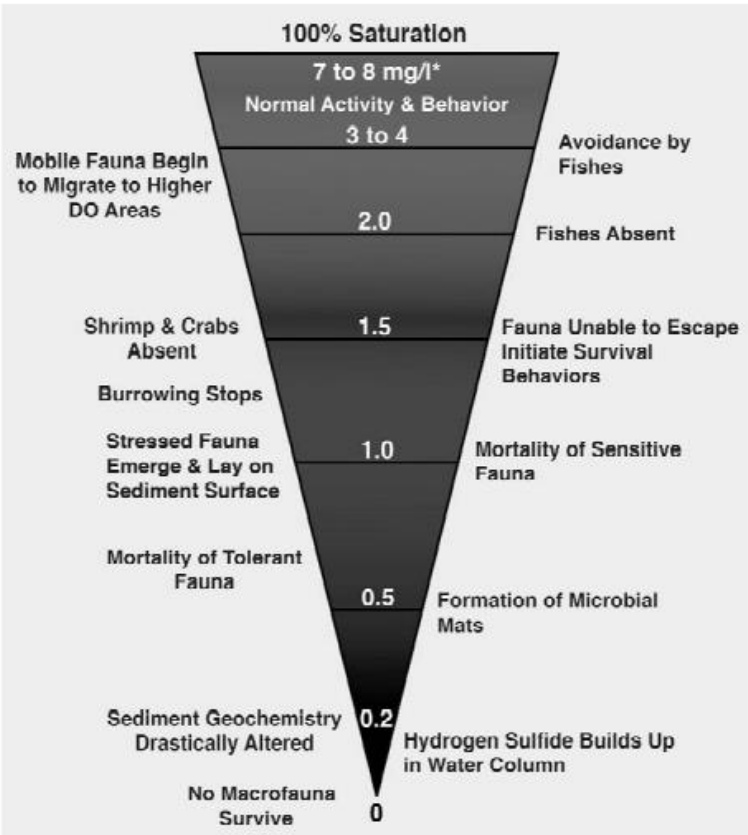


Figure 2.3: Bearable dissolved oxygen level for organisms (Diaz, 2010)

2.3.2 Human Impact

Cyanobacteria growth particular favoured in fresh water body where eutrophication occurs, it can produce biotoxin which is a major concern in human and animal health. The common hepatotoxic biotoxins are microcystins and nodularins (Figure 2.4) which primary target is the liver organ in mammals (World Health Organization, 2010). The pathway of exposure of these biotoxins are mostly through water either ingestion or aspiration of water or food that containing cyanobacterial cells. When consummation of these toxics from freshwater, algae bloom can accumulate toxicity and threaten livestock health. The toxic compound makes its way up to the food chain reaching human which may cause carcinogenic effect. In 2007, it was reported that a wastewater treatment plants in Wu Xi, China stopped water supply to consumer due to the toxic blooms from their pipes (Earth Eclipse, 2018).

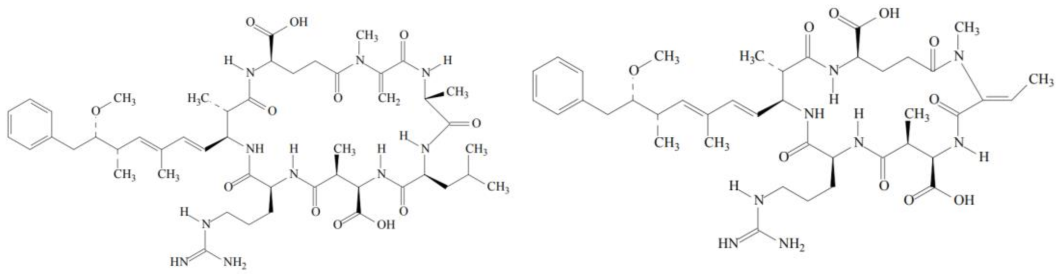


Figure 2.4 Structural formula for Microcystin ($C_{49}H_{74}N_{10}O_{12}$) and Nodularin ($C_{41}H_{60}N_8O_{10}$) (World Health Organization, 2010).

2.3.3 Socio-economic Impact

The water body can be economically essential to the local community as food source, water supply and quality, employment and income of the community, tourism attraction to participate water activities, and recreation view. The green layer of phytoplankton may be unpleasant sight, creating a taste and odour in water supply (hydrogen sulphide), increase the number of mosquitos (EPA, 2001). Furthermore, poor environmental management will kill the aquatic plant and animals resulting in the marine industry losing their jobs and poor tourists attraction (Heshani et al., 2015).

2.4 Tropic State Index

The classification of lake based on various methods and different types of indication created by various researchers or workers. Eutrophication generally based on the productivity of biomass in the water body. The trophic state index can be an important water quality indication, but principally used to indicate the lake usage (e.g. fishing and swimming). The concentration nitrogen and phosphorous can indicate the productivity of algae in the lake, its location whether in different regional variations in correlate to algae production; lake in agriculture and industry (Gibson et al., 2000). In other words, the trophic state index (TSI) measures the nutrients tend to be limiting resource in the water body, resulting the increase of plant growth and increase the trophic level.

The trophic level is the nutrient content or productivity in the lake, and can be classify into three major components; oligotrophic, mesotrophic, and eutrophic (Figure 2.5). Oligotrophic is low productivity also known as "poorly-fed" and generally clear water with little amount of aquatic plants with sufficient amount of DO to support the existing aquatic animals. The exact opposite meaning of eutrophic lakes are turbid, support abundant aquatic plant growth, and low or no DO at the bottom of the lake. Mesotrophic lake falls in between mesotrophic and eutrophic as it has an average amount of nutrients to support aquatic life (North American Lake Management Society, 2018). Bacteria were the main respires and recycled a large pool of dissolved organic matter to higher trophic levels (Lee et al., 2009).

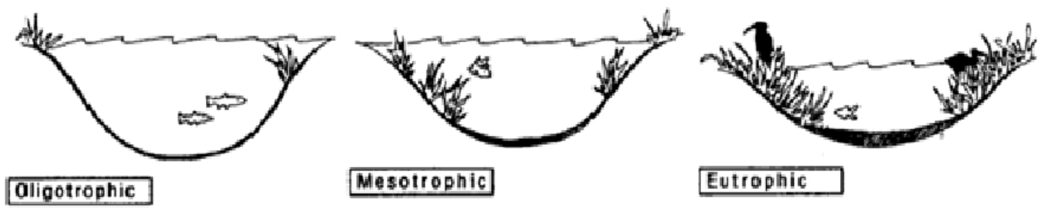


Figure 2.5: Lake classification (Michigan Department of Environmental Quality, 2008)

2.4.1 Carlson's Trophic State Index

Carlson (1977), developed Carlson's Trophic State Index (CTSI), a numerical trophic index that ranges from 0 to 100, It is used as classification of trophic state lake and a popular method for examining algal biomass. Algal biomass and nutrient loading can be the basic and simple measurements of any trophic category to determine the trophic state. Physical chemical variables chlorophyll a (Chl-a), total phosphorous (TP) and Secchi disk transparency (SD) were determined to classify the lake as presented in Eq. (2.3) till (2.5). SD used to determine the algae biomass (Chl-a) and TP as the sum of the absorbance of light by water, dissolved substances and particular matter were inversely proportional to SD (Carlson, 1977).

$$\text{TSI (SD)} = 10\left(6 - \frac{\ln \text{SD}}{\ln 2}\right) \tag{2.3}$$

$$\text{TSI (Chl-a)} = 10\left(6 - \frac{2.04 - 0.68 \ln \text{Chl-a}}{\ln 2}\right) \tag{2.4}$$

$$\text{TSI (TP)} = 10\left(6 - \frac{\ln \frac{48}{\text{TP}}}{\ln 2}\right) \tag{2.5}$$

$$\text{TSI} = [\text{TSI(SD)} + \text{TSI(Chl-a)} + \text{TSI(TP)}]/3 \tag{2.6}$$

Where:

SD = Secchi Disk transparency (m)

Chl-a = Chlorophyll-a (µg/L)

TP = Total phosphorus (µg/L)

The Eq. (2.6) showed the TSI value is the average TSI of TP, chlorophyll-a and SD. Then, the lake was classified as oligotrophic (low productivity) with is the value of TSI less than 40, while mesotrophic (moderate productivity) in between 40 to 50, and eutrophic (high productivity) above 50. The CTSI values and classification of lake can be represent according to Table 2.1.

Table 2.1: CTSI value and classification of lakes (Devi Prasad, 2012 and Carlson, 1977)

TSI	SD	TP	Chl-a	Trophic Status	Attributes
<30	<8	<6	<0.94	Oligotrophic	Clear water, oxygen throughout the year in the hypolimnion
30-40	8-4	6-12	0.94-2.6	Oligotrophic	A lake will still exhibit oligotrophy, but some shallower lakes will become anoxic during the summer
40-50	4-2	12-24	2.6-6.4	Mesotrophic	Water moderately clear, but increasing probability of anoxia during the summer
50-60	2-1	24-48	6.4-20	Eutrophic	Lower boundary of classical eutrophic; Decrease transparency, warm-water fisheries only
60-70	1-0.5	48-96	20-56	Eutrophic	Dominance of blue-green algae, algae scum probable extensive aquatic plant problems
70-80	0.5-0.25	96-192	56-154	Hypereutrophic	Heavy algal blooms possible throughout the summer, often hypereutrophic
>80	>0.25	>192	>154	Hypereutrophic	Algal scum, summer fish kills, few aquatic plants

2.4.2 New Trophic Index

New Trophic Index (TRIX) developed by Vollenweider (1998) to characterize the trophic state of a water body, based on chlorophyll-a, oxygen saturation, nutrients such as total phosphorous (TP) and total nitrogen (TN). This method is applicable to coastal marine water. The index is ranging from 0 to 10 numerically, covering of trophic lake status from oligotrophic (low productive) to eutrophic (high productive). TRIX included a turbidity index (TRBIX), both TRIX and TRBIX served as the complementary in water quality index (Vollenweider et al., 1998). The following Eq. (2.7) showed that the TRIX equation.

$$\text{TRIX}= \frac{\log_{10}(\text{Chl-a x DO\% x TN x TP}) - (-1.5)}{1.2} \tag{2.7}$$

Where:

Chl-a = chlorophyll-a (mg/L)

DO%= oxygen as absolute (%)

TN= total nitrogen (mg/L)

TP= total phosphorus (mg/L)

The new trophic index (TRIX) has trophic range level where less than 4 to be considered low trophic level, range from 4 to 5 moderate trophic level, 5 to 6 high trophic level, and more than 6 very high trophic level (high nutrient content, low transparency, and hypoxia bottom of the water). Water transparency is an important quality parameter as the transparency cause by three factor that resultant light absorption and scattering of light; water contains high amount of dissolved substances and biomass. The transparency has a relationship between chlorophyll-a has derived in terms of chlorophyll-a showed in Eq. (2.8) and the limit range for chlorophyll-a was 0.2 to 300 mg/m^3; TRSP 48 to 0.3 m.

$$\text{TRSP (p)} = \frac{30}{\text{Chl-a}^{0.7}} \tag{2.8}$$

Turbidity/Chlorophyll-a ratio can be defined the ratio between the potential (p) and actual (a) transparency as displayed Eq. (2.9). In addition, the turbidity index calculated as the log to the basic two of TRBR showed in Eq. (2.10). The Table 2.2 illustrated a simple interpretation of TRIX.

$$TRBR = TRSP(p)/TRSP(a) \quad (2.9)$$

$$TRBIX = \log_2 (TRBR) \quad (2.10)$$

Where:

TRSP = Transparency (m)

TRBR = Turbidity (NTU)

Chl-a = Chlorophyll-a (mg/m^3)

TRBIX = Turbidity Index

Table 2.2: Turbidity Index value and its conditions (Vollenweider et al., 1998).

TRBIX	Condition
0	Biomass saturated
1	Chlorophyll and other turbidity would be equal
2	Chlorophyll would make out about 1/4

2.4.3 Eutrophication Index

Eutrophication index (E.I.) is principal component analysis applied including a set of nutrient data of nitrate, nitrite, ammonia, and phosphate and chlorophyll-a concentrations (Pavlidou et al., 2015). This method origin and the most appropriate to describe eutrophication in Mediterranean (in between Europe and Africa). The range of characterizing the lake and defining the lake range index by oligotrophy, mesotrophic, and eutrophication. The five variables participate to form from the first principal component and propose E.I into Eq. (2.11).

$$E.I. = 0.279C_{PO_4} + 0.261C_{NO_3} + 0.296C_{NO_2} + 0.275C_{NH_3} + 0.214C_{chla\text{-}a} \quad (2.11)$$

Where:

C_{PO_4} = concentration of phosphate (mg/m^3)

C_{NO_3} = concentration of nitrate (mg/m^3)

C_{NO_2} = concentration of nitrite (mg/m^3)

C_{NH_3} = concentration of ammonium (mg/m^3)

C_{chl-a} = concentration of phytoplankton (mg/m^3)

The E.I. can be divided into five classes according to the requirement of European Water Framework Directive according to the Table 2.3. As for chlorophyll-a with the mean value of 0.11, 0.65, and 1.43 mg/L can be characterized as Good, Moderate, and Poor water quality respectively.

Table 2.3: Trophic status, range, and its conditions for Eutrophication Index (Pavlidou et al., 2015).

Trophic status	Range	Condition
Oligotrophy	<0.04	High
Oligotrophy	0.04-0.38	Good
Mesotrophic	0.38-0.87	Moderate
Eutrophic	0.87-1.51	Poor
Eutrophic	>1.51	Bad

2.5 Study of Eutrophication

Eutrophication was a global issue since the 1900s, ever since civilization introduced to this world. Human activities influence most major aquatic ecosystem, relating nutrient loading discharged into water body. Unfortunately, these nutrients produced by human activities promote a negative effect on the water quality of the water surface. Agriculture fertilizer released more than 10 million metric tonnes of nitrogen in 1950, by 2030 predicted to exceed 135 million metric tonnes of nitrogen only in agriculture fertilizer alone (Smith, 2003).

2.5.1 Global Studies

Eutrophication is a global aquatic environmental problem due to ecological consequences. The Figure 2.6 showed that the red dots were signifying hypoxia – less or no DO containing in the water body while yellow dots were representing eutrophication, symptom of hypoxia. This interactive map of eutrophication and hypoxia represents 762 coastal sites impacted by eutrophication or hypoxia. There were 479 sites were experiencing hypoxia, but there were 55 sites hypoxia were improving. About 228 sites that experienced eutrophication including algae blooming, loss of habits, and impacts to coral reef. The stored data started from 1850s to 2010s. During the 1850s to 1950s, there were approximately 20 case reported about hypoxia and eutrophication, mostly located at America, Europe and Australia. It all began in 1950s, a rapid increase of cases reported all around the world, when civilization, industrialized and developing countries were introduced, most number of reported cases were North America, Europe, Australia, China and Japan (WRI, 2018).

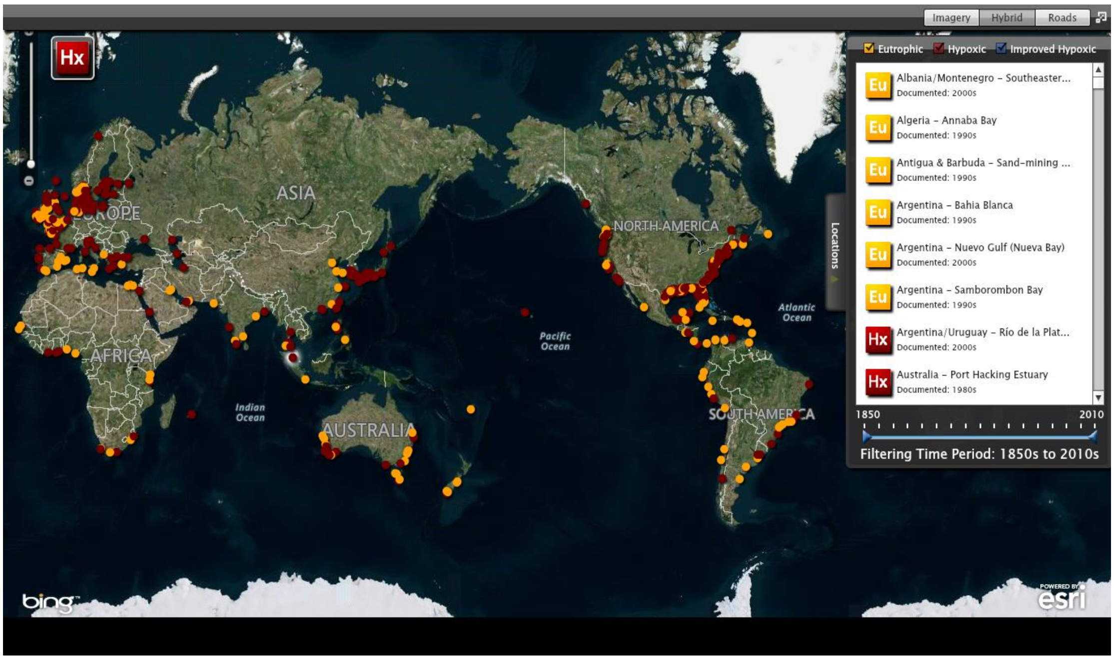


Figure 2.6: Interactive map of eutrophication and hypoxia from 1850s to 2000s (WRI, 2018).

During the 2000s, high number of papers reported to World Resources Institute about the body of water status. Tracadie and Winter Bays, Canada were locating on Prince Edward's island, extensive fish farming occurs in the areas and created hypoxia event on the bays. Tees Estuary located in United Kingdom, England empties into the North Sea, the Europe's Urban Waste Water Treatment Plant said that the Tees Estuary classified as sensitivity, eutrophic area, and enrichment of nutrient to support primary growth due to industrialization of its drainage basin. Tees Estuary was reported that it was suffering with hypoxia condition. Lake Brullus, Egypt was a shallow lagoon in the Nile delta area. The lake received large amount of nutrient loading from agriculture causing algal bloom during summer. This lake was reporting that eutrophication happened and depletion oxygen have blamed for fisheries death. Caroline Beach Lake, USA faced agriculture, urban, suburban runoff and other nutrient loading source. In this case, the BOD negatively correlated with ammonia and water temperature, and the condition of this lake was reported as hypoxia.

2.5.2 Asia

There were 24 eutrophic coastal areas and approximately 40 cases reported with documented hypoxia, and nine areas of concern within area (Figure 2.7). About forty-two percentages of these reported cases were from Japan, Japan was the first developing country in Asia. However, China did not report their water quality status as a single point might represent more than a single case because of insufficient information. Rapid increase agriculture methods, industrial development, and population growth in Asia for the past 20 years. This map was underrepresenting the greatly of eutrophication and hypoxia (WRI, 2018).

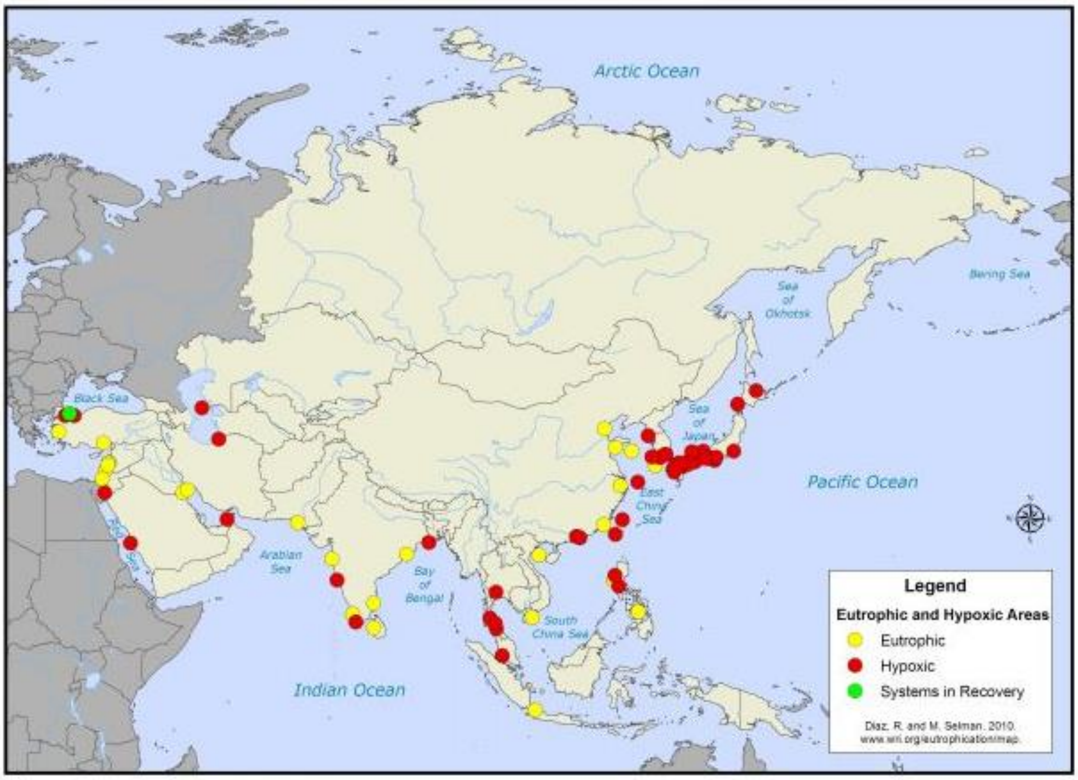


Figure 2.7: Eutrophic and hypoxic coastal areas of Asia (WRI, 2018).

Ariake Sea, Japan was a body of salt water, and Isahaya Bay was a branch of the Ariake Sea. About 240 square kilometre was suffering with seasonal hypoxia because of construction for the farmland prevent from flooding. The dike – sort of embankment causes the weakening current of Ariake Sea, leading nutrient loading and increase of toxic algal bloom and hypoxia condition. Fisheries, aquaculture, and seaweed harvesting operation experienced a sharp decline. The lowest DO was recorded 0.53 mg/L. This lake was suffering with hypoxia and eutrophic (Hodoki and Murakami, 2006). In China, Pearl River Estuary about 31.6 x 10^8 m^3 of wastewater discharge yearly, mainly from developed cities. It was reporting that it was hypoxia because of the agriculture industry and population growth at upstream Pearl River Estuary contained high concentration of nitrate to phosphate ratio of 200:1 in the surface layer, with a rapid increase of harmful algal bloom (Dong et al., 2006). Mekong River – longest rivers in Asia, located in Vietnam through it course China, Burma, Laos, Thailand, and Vietnam discharging into South China Sea. The river basin influenced by the increase of population and agriculture crop production causing a nutrient runoff for the last few decades. This river was suffering with a moderate eutrophic even though rich in nutrients, harmful algal bloom, oil and grease, and increase of algal production (WRI, 2008)

2.5.3 Malaysia

Port Klang was the only reported case to WRI (2018) from Malaysia in 2006 (Figure 2.8). The water sample collected monthly at the mouth of the Klang River, near to the Southport. *In-situ* measured pH (7.08 - 7.86) and temperature (29.2 - 30.1 ℃) with a pH meter. For DO determined by Winkler titration method (3.20 mg/L). As for chlorophyll-a and suspended solid using the trichromatic method (0.00358 mg/L) and APHA 2540D with the range of 260 to 290 mg/L respectively. There were several tests for dissolved inorganic nutrient (DIN) such as nitrate, nitrite, ammonia and phosphorous by using APHA methods – ultraviolet spectrophotometric method, colorimetric method, phenete method, and ascorbic acid method with the result of 0.173 mg/L, 0.110 mg/L, 0.213 mg/L, 0.539 mg/L. The growth primary production and community respiration results proved that the nature of Port Klang was eutrophic (Lee and Bong, 2006).

Figure 2.8: The only reported case in Malaysia (WRI, 2018).

Although, WRI reported only one coastal marine ecosystem (Port Klang) was suffering with hypoxia, the following discussion will be more focusing on freshwater ecosystem monitoring the river from the local researchers. The Table 2.4 showed that all of the cases were related to the water body of river or lake except for Port Klang case.

Varsity Lake located in University Malaya has a water body of river and lake, two rivers (Sungai Pantai and Sungai Anak Air Batu) streams pass through the campus and they were not joining to the lake. The main reason to conduct these studies because the surrounding area packed with urbanization and pollutions. During 2013, Varsity Lake was landmark for UM campus where water activities were held such as kaya and recreational activities. However, the lake closed due to serious eutrophication (Chee Mood et al., 2017). To overcome such problem, the water warriors constructed an underground pipeline to diverge the sewage from urbanization. The monitoring period began November 2014 to October 2015 with nine station and nine water samples monthly. Three samples from the Varsity Lake, two samples from Sungai Anak Air Batu, and four samples from Sungai Pantai. *In-situ* measurements were pH (6.8 - 8.1), temperature (29.4 - 32.4 ℃), and DO (3.3 - 8.0 mg/L). After sampling, the samples kept in 4 ℃ to reduce any chemical reaction in the raw water. BOD, COD, TSS, DIN (nitrate, nitrite, and phosphorus) were testing in the laboratory with the method of Winkler's method (1.2- 4.2 mg/L), open reflux method (21.5 - 52 mg/L), gravimetric process (9.0 - 18.8 mg/L), kjedahl method (0.3 - 3.9 mg/L), ultraviolet spectrophotometric screening method (1.8 - 2.1 mg/L), and ascorbic method (0.1-1.3mg/L) respectively. The method used to determine the trophic index was NLWQCS. In conclusion, Varsity Lake case, the trophic index was reporting that it was suffering high nutrient loading because pollution associated with eutrophication condition (Chee Mood et al., 2017).

The Sibu Laut River, the 8 km long river located in northwest region of Kuching. The sampling method was focusing on eutrophication study with 13 stations and water samples collection (monthly) in the middle of the river with approximately 1 m below the water surface. Among the 13 stations, only one of the station readings has taken as the following content because the specific station was suffering with eutrophication. *In-situ* test, the measurements were pH with pH meter (7.8), temperature with temperature probe (30 ℃), DO with DO meter (5.5 mg/L) and SD (0.53 m). In the laboratory, TSS method was the difference between the initial and final weight of the filter paper (0.7 µm Whatman GF/F), after filter the sample volume and drying in the oven at 105 ℃. The filter water samples used to determine the DIN such as inorganic phosphorous (IP) with colorimetric ascorbic acid method, ammonia and nitrite determined by phenate method and colorimetric diazotization method, and nitrate tested with ultraviolet spectrophotometric method. As for the TP and TN dissolved in potassium persulfate digestion to determine as IP and nitrate. As for the organic phosphorus and nitrogen calculated by the differences between the TP and IP, and the differences between the TN and IN (inorganic nitrogen-nitrate, nitrite, ammonia). The method indicated trophic status was judging and comparing with other publication paper by Smith, 1998. Thus, it concluded that the river was suffering with eutrophic-hypertrophic (Soo et al., 2014).

Bukit Merah Reservoir (BMR) the oldest manmade lake in Malaysia located in Perak, the main purpose of the reservoir was to provide supply water and agriculture such as paddy field, palm oil industry, and breeding farming industry. There were total of 10 stations with two-water samples per station to be collected. *In-situ* test, the measurements were DO (6.2 mg/L), temperature (29.9 ℃), pH (8.2), total dissolved solid (0.01 mg/L), and conductivity (17.7 µS/cm) were measuring by using the YSI multi-parameter probe. The indication of trophic state was CTSI with parameters TP (0.16 mg/L), chlorophyll-a (0.046 mg/L) and transparency (0.80 m) by using acid persulfate digestion method, fluorometric method, and SD respectively. BMR was reported that the reason of eutrophication eventually by aging process (Yaccob, 2017). However, human activities play a role that actively boost the eutrophication process by excessive nutrient input.

Sembrong Lake located in Johor, were manmade lakes for the purpose of water supply to the local community from 1984. *In-situ* measurements of temperature, pH, DO, salinity, turbidity and conductivity were conducted by using multi-parameter probe with the results of 30.3℃, 8.2 mg/L, 0.14 ppt, 25.5 mg/L, and 0.12 mS/cm respectively. Additionally, water transparency was measured by using SD with the value of 0.3 m. In the laboratory, TP (0.125 mg/L), chlorophyll-a (0.0654 mg/L) and nitrate-nitrogen were measured by using ascorbic acid method, APHA10200H fluorometric method, and ultraviolet spectrophotometric method respectively. It was reported that the Sembrong Lake dominated by blue-green algae even as eutrophic-hypereutrophic condition (Sharip, 2016).

2.6 Summary

Eutrophication is where a water body enrich with nutrients either natural or anthropogenic. Eutrophication may hazard to the environmental, the ecosystem, humans and animals. Eutrophication can be proven by using the CTSI that determines the productivity of the lake which can indicate the level of trophic state. Malaysia is a developing country that will increase the number of eutrophication cases with the existing cases shown in Table 2.4. Trophic state test should be conducted for lakes in Malaysia, which is as important as water quality index for identifying the trophic level.

Table 2.4: Summary of eutrophication studies for lakes and river in Malaysia from 2004 to 2016.

Studied location and type of water body	Parameter	Method used	Result	Period	Frequency	No. of stations and sample	Method used for trophic index	Trophic State	Reference
Varsity Lake, University Malaya (River and lake)	pH	-	6.8-8.1	Nov 2014 to Oct 2015.	Monthly	9 & 9	NLWQCS	Eutrophic	(Chee Mood et al., 2017).
	Temperature	-	29.4-32.4℃						
	DO	-	3.3 - 8.0mg/L						
	Turbidity	-	-						
	BOD	Winkler's method	1.2 – 4.2mg/L						
	COD	Open reflux method	21.5 - 52mg/L						
	TSS	Gravimetric process	9.0 - 18.8mg/L						
	NH_3^--N	Kjedahl method	0.3 -3.9mg/L						
	NO_3^--N	Ultraviolet Spectrophotometric Screening method	1.8 – 2.1mg/L						
	PO_4^{3-}	Ascorbic Method	0.1 – 1.3mg/L						
Sibu Laut River, Sarawak, Malaysia (River)	pH	pH meter	7.8	Feb 2010 to Apr 2010	Monthly	13 & 13	Compare standards with APHA limits	Eutrophic-hypertrophic	(Soo et al., 2014)
	Temperature	Temperature probe	30℃						
	DO	DO meter	5.5mg/L						
	Transparency	Secchi disk	0.56m						
	Turbidity	Turbidity meter	High						
	Chl-a	EPA Method 445.0 by Fluorescence	0.0059mg/L						
	BOD	Dilution method 8043	1.34mg/L						
	TSS	APHA 2540D TSS Dried	Low						
	TDS	Multi-parameter meter	Low						
	IP	Colorimetric ascorbic acid	0.043mg/L						
	TP	IP after potassium persulfate digestion of samples.	0.014mg/L						
	OP	Differences of TP and IP	-						
	NH_3^--N	Phenate method	0.054mg/L						
	NO_2^--N	Colorimetric diazotization method	0.179mg/L						
	NO_3^--N	Ultraviolet spectrophotometric method	0.415mg/L						
	TN	NO_3^--N after potassium persulfate digestion of the sample.	1.177mg/L						
	Org-N	Difference TN and IN (NH_4^+-N, NO_2^--N, and NO_3^--N)	-						

Table 2.4: Summary of eutrophication studies for lakes and river in Malaysia from 2004 to 2016 (continued).

Studied location and type of water body	Parameter	Method used	Result	Period	Frequency	No. of stations and sample	Method used for trophic index	Trophic State	Reference
Bukit Merah Reservoir, Perak (Lake and reservoir)	DO	Multi-parameter probe	6.2mg/L	Dec 2016	-	10 & 20	Carlson’s Trophic state index	Eutrophic	(Yaccob, 2017)
	Temperature	Multi-parameter probe	29.9℃						
	TDS	Multi-parameter probe	0.01mg/L						
	pH	Multi-parameter probe	8.2						
	Conductivity	Multi-parameter probe	17.7µS/cm						
	Transparency	Secchi depth	0.80m						
	Chl-a	APHA 10200H fluorometric method	0.046mg/L						
	TP	Acid Persulfate digestion method	0.16mg/L						
Sembrong Lake, Johor (Lake)	Transparency	Secchi disk	0.3m	Dec 2014 to Aug 2015	Monthly	-	Carlson’s Trophic state index	Eutrophic-hyper-eutrophic	(Sharip, 2016)
	Temperature	Multi-parameter probe	30.3℃						
	DO	Multi-parameter probe	8.2mg/L						
	pH	Multi-parameter probe	8.2						
	Salinity	Multi-parameter probe	0.14ppt						
	Conductivity	Multi-parameter probe	0.12mS/cm						
	NO_3^--N	Ultraviolet spectrophotometric method	-						
	TP	Ascorbic Acid method	0.125mg/L						
	Turbidity	Multi-parameter probe	25.5mg/L						
	Chl-a	APHA 10200H fluorometric Method	0.0654mg/L						
Port Klang, Peninsular Malaysia (Estuary)	pH	pH meter	7.08–7.86	Sep 2004 to Feb 2005	Monthly	1 & 1	Determination of Gross primary production and community respiration	Eutrophic	(Lee and Bong, 2006)
	Temperature	pH meter	29.2 – 30.1℃						
	DO	Winkler titration method	3.20mg/L						
	Chl-a	Trichromatic method	0.00358mg/L						
	TSS	APHA 2540D TSS Dried	260–290 mg/L						
	NO_3^--N	Ultraviolet spectrophotometric method	0.173mg/L						
	NO_2^--N	Colorimetric method	0.110mg/L						
	NH_3^--N	Phenete method	0.213mg/L						
	PO_4^{3-}	Ascorbic acid method	0.539mg/L						

*American Public Health Association (APHA)
*National Lake Water Quality Criteria and Standards (NLWQCS)

CHAPTER 3

RESEARCH METHODOLOGY

In this chapter, research methods and apparatus set-up were shown. In details, it consists of four sub-topics. In section 3.1 will be discussed the background of sampling location, water sample collection procedure and *in-situ test* measurements. Section 3.2 will be discussed on the chemicals used, equipment used and parameters test conduct in the laboratory includes digestion method, phosphorus, chlorophyll-a, ammonia, nitrate and chemical oxygen demand. Lastly, section 3.3 will be focusing on the selection of trophic index

3.1 Study Area

The sampling site for the determination for primary production was an ex-tin mining located at Lake 18, University Tunku Abdul Rahman (UTAR), Kampar, Perak, 31900 with the area of 232,171 m^2. Kampar located in North coast of peninsular Malaysia with the coordinate of 4.3º North latitude, 101.14º East longitude, and 63 m elevation above sea level. Kampar has a rainforest environment surrounded with ex-tin mine lakes and mountains.

3.1.1 Sampling Location

According to the Figure 3.1, there were total of five water sampling locations started on October 2018 until March 2019. The water samples were collected every month.

The sampling sites were selected because site 3 and site 5 were water inlet or outlet; site 3 has small stream (between UTAR library and Faculty of Engineering and Green Technology) that connected with East Lake which surrounded with student hostel. Site 5 was connected with West Lake which surrounded with housing. At site 4, the Student Pavilion 1 (cafeteria) has a wastewater treatment plant, which discharge treated water into the Lake 18. Site 2 located in the center of the lake that determine the overall productivity of the lake since it was away from the all inlet, outlet, drainage, and other sources. The productivity of lake affects the lake biology as a whole (Naumann, 1929). The main purpose of selecting site 1 because well distribution of selecting site point, and obtain more data input.

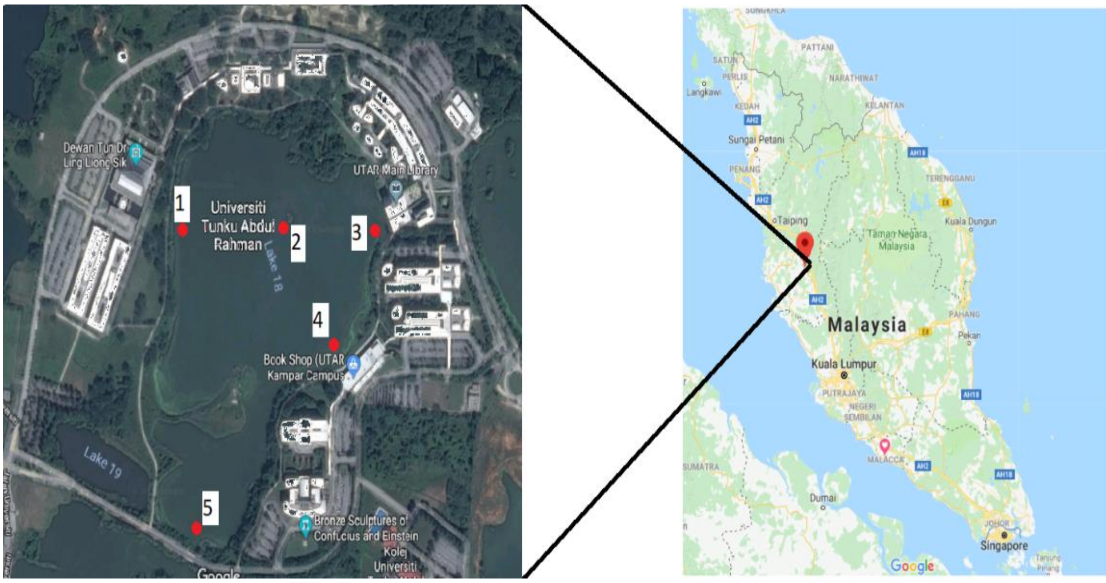


Figure 3.1: The sampling location at UTAR Lake.

3.1.2 Sampling Method

The water sample collection procedure was showed in Figure 3.2. Firstly, polyethylene bottles were acid-washed with a drop of concentrated sulphuric acid and rinsed with deionized water. The polyethylene bottles must not wash with detergent and do not store the water sample in bottles that containing any phosphorus or nitrogen compounds (Rice et al., 2017). The Secchi Dish transparency was tested at the site by using Secchi Disk (Figure 3.3) - a circular plain black and white disk about 20 cm in diameter that used to measure water transparency by lowering down the disk in water bodies until when the disk invisible from sight and the measurement was taken in meter. Before the water was collected by a worker from Department of General Services, the polyethylene bottle rinsed with the lake water for 3 times with the bottle cap on before collecting water sample, then lake water was scooped approximately 0.5 m below the water surface until the shoulder of the bottle. The water sample was conducted for parameter measurements by using *HI-98703 Portable turbidity meter* for turbidity and *PCD650 meter kit* to obtain dissolved oxygen (DO), pH and water temperature. The water bottle was immediately labelled and the water sample was stored into the icebox to slow down the chemical reaction, no preservation needed as long it is store in icebox or refrigerator at 4℃ until analysis for several weeks (Rice et al., 2017). All the steps were repeated at different sites.

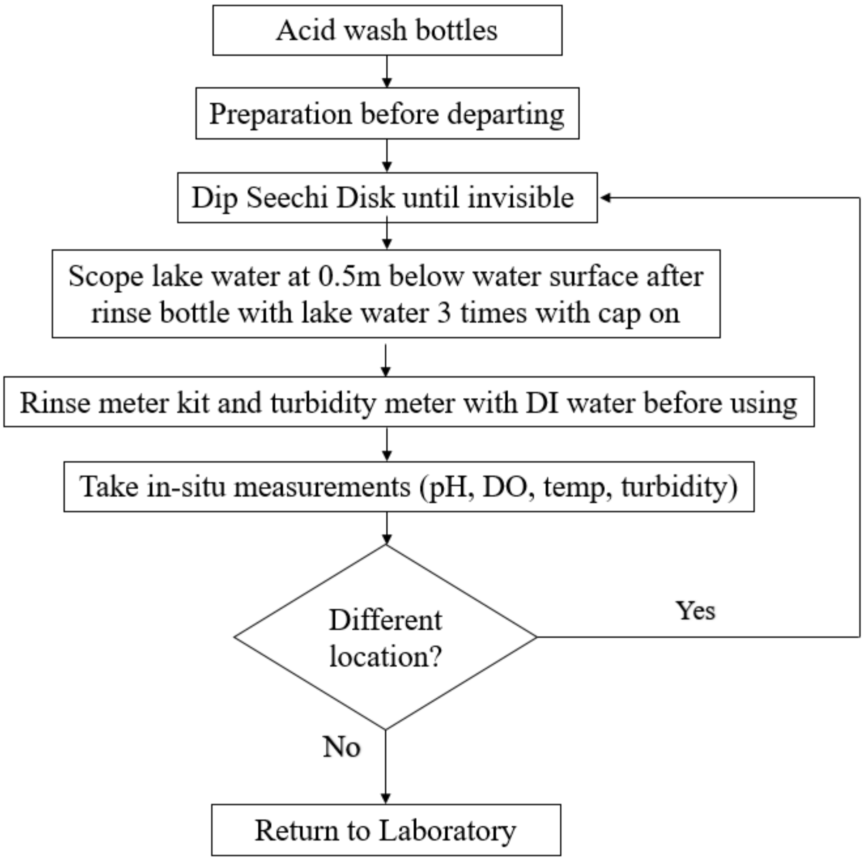


Figure 3.2: Water sample collection procedure flow chart

Figure 3.3: Secchi Disk apparatus

3.2 Parameters test

3.2.1 Chemicals and Reagents

The chemicals and reagents were prepared for each of the parameters showed in Table 3.1.

Table 3.1: List of chemicals and reagents used.

Parameter	Chemical
Digestion of Total Phosphorus and Total Nitrogen	5.25 N Sulphuric acid solution
	5.0 N Sodium Hydroxide solution
	HACH potassium persulfate powder pillow
Total Phosphorus	HACH PhosVer3 Phosphate Reagent Powder Pillow
Chlorophyll-a	Saturated magnesium carbonate (1 g finely powdered $MgCO_3$ + 100 mL distilled water)
	Aqueous acetone solution (90% acetone and 10% Saturated magnesium carbonate)
Ammonia	Nessler Reagent, Mineral Stabilizer and Polyvinyl Alcohol Dispersing Agent
Total Nitrogen	HACH NitraVer Nitrate 5 Reagent powder pillow
Chemical Oxygen Demand (COD)	COD digestion low range (LR) vials

3.2.2 Equipment and Apparatus

The apparatuses were used for each of the parameters displayed in Table 3.2.

Table 3.2: List of apparatus used.

Parameter	Apparatus
Digestion of Total Phosphorus and Total Nitrogen	*HTS-2013 Digital Hotplate Stirrer*
Total Phosphorus	*HACH 6000 UV-Vis Spectrophotometer* (program 490 P React. PP)
Chlorophyll-a	*HACH 6000 UV-Vis Spectrophotometer* (optical density readings at 664, 647, and 630 nm)
Ammonia	*HACH 6000 UV-Vis Spectrophotometer* (program 380 N, Ammonia Ness)
Total Nitrogen	*HACH 6000 UV-Vis Spectrophotometer* (program 353 N Nitrate MR PP)
Chemical Oxygen Demand	*HACH DRB200 Reactor digester* *HACH 6000 UV-Vis Spectrophotometric (*program of 430 COD LR)

3.2.3 Analytical Procedure

Figure 3.4 showed a brief section of the research methods include parameters such as total phosphorus, total nitrogen, chlorophyll-a, ammonia and chemical oxygen demand

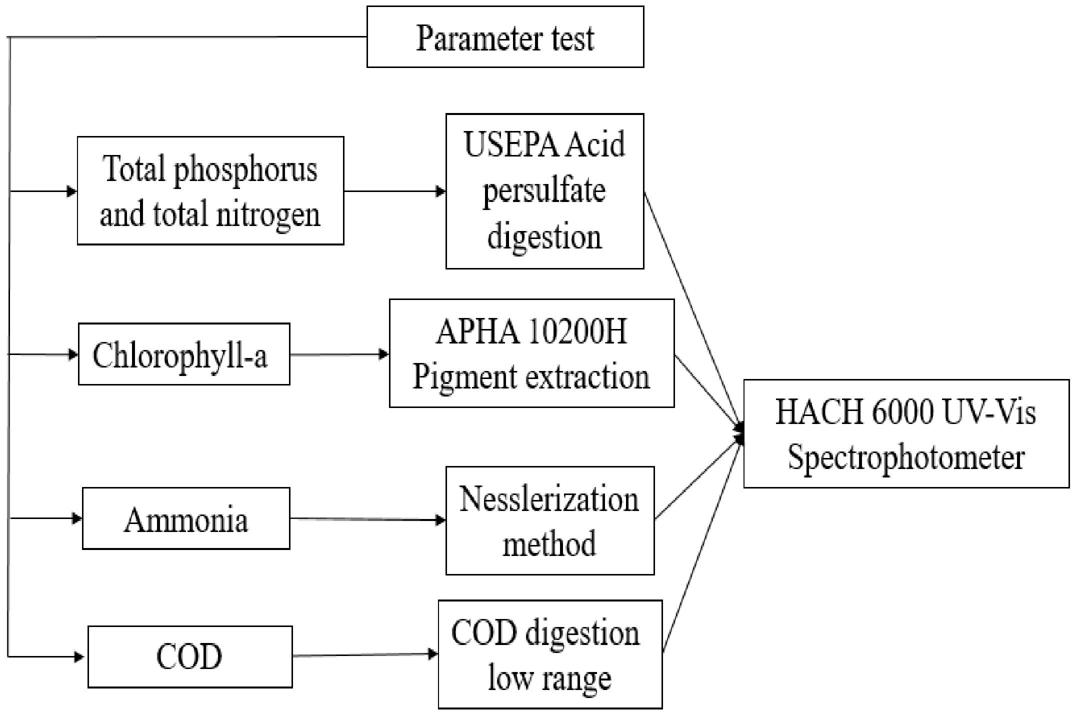


Figure 3.4: Overview of Parameters Test.

3.2.3.1 Digestion of Total Phosphorus and Total Nitrogen

The determination of total phosphorus (TP) and total nitrogen (TN) by oxidation under acidic conditions. To measure all particular matter and dissolved matter necessary to use TP test in digestion to convert particular to dissolved phosphate or orthophosphate (Dabkowski and White, 2015). Phosphates organic and inorganic (meta-, pyro- or other polyphosphates) must converted to the reactive orthophosphate which is essential nutrients for algae growth (Howell, 2010).

TN is all the nitrogenous compounds by oxidation such as organic nitrogen, ammonia, nitrite and nitrate converted to nitrate. This method concept referred to APHA Method 4500-N C (Persulfate method), APHA method 4500-P J (Persulfate Method for Simultaneous Determination of Total Nitrogen and Total Phosphorus). It allows test for water, wastewater and seawater.

This method was referred to USEPA Acid persulfate digestion method. The Persulfate method cannot analysis with samples preserved with any acid. The hotplate apparatus was preheated at 100 ℃. 25 mL of sample was added into a conical flask and one pack of potassium persulfate powder pillow was added. Next, 2 mL of 5.25 N Sulphuric acid was added into the solution and the cell was swirled to mix. The sample was boiled gently for 30 minutes. 2.0 mL of 5.0 N Sodium Hydroxide solution was added to cool down the solution. The digested sample may proceed to the next test.

3.2.3.2 Total Phosphorus

Phosphorus is essential nutrient for algae blooming and limiting nutrient for primary productivity of a body water. The most common test for phosphorus is to determine the orthophosphate that can be measure directly. Previously, Persulfate method digest the TP or particular phosphorus into dissolved phosphorous (inorganic phosphorous) or in the form of orthophosphates (Dabkowski and White, 2015). Orthophosphates commonly found in agricultural or residential cultivated land as fertilizers or household waste. This method referred to HACH Method 8048 PhosVer3 (Ascorbic Acid) powder pillow method. It allows to test drinking water, wastewater and seawater with the concentration range of 0.02 to 2.50 mg/L PO_4^{3-}.

10 mL of digested solution and one PhosVer 3 Phosphate Reagent Powder Pillow were pour into a sample cell. The sample cell was shake vigorously for 30 seconds and let the colour to develop for 10 minutes. Blur colour was developed as phosphate was present. The sample cell was placed into the spectrometer and the phosphate concentration was recorded in mg/L.

3.2.3.3 Chlorophyll-a

The chlorophylls are unique pigments with green colour that contains in plants, algae and cyanobacteria. Chlorophyll-a can be found in all photosynthesize organisms that have light harvesting complex (Figure 3.5), it normally absorbs red light from solar spectrum with the adsorption peak of 420 nm to 660 nm (Pareek et al., 2017). Before determination of chlorophyll, a pigment extraction procedure required. The concentration of photosynthetic pigments used to estimate phytoplankton biomass. The method is referring to APHA method 10200 H Chlorophyll with pigment extraction and spectrophotometric determination of chlorophyll.

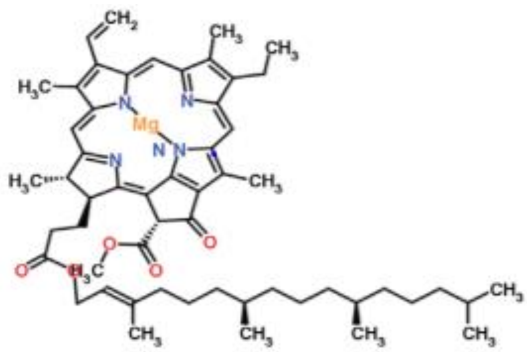


Figure 3.5: Structural formula of Chlorophyll (Pareek et al., 2017).

The algae concentrate was separated and filtered 100 mL water sample. The algae concentrated was transferred into the mortar and grind manually by adding 2 to 3 mL of aqueous acetone solution. The acetone solution function was to extract greenish colour of the plankton concentrate. Continuously grind for a few minutes, a few drops of aqueous acetone solution was added. The sample was filtered and transferred to 15 mL screw-cap centrifuge, the mortar was rinsed with aqueous acetone and total volume to 10 mL was adjusted with aqueous acetone. The sample was left at least 2 hours at 4 ℃ in dark. Finally, the sample was filtered to reduce retention of extract. The sample was extracted to a 1 cm cell and measured optical density (OD) at 664, 647 and 630 nm. The concentration of chlorophyll a was calculated in the extract by inserting the corrected optical densities showed in Eq. (3.1). After determining the concentration of pigment in the extract, calculate the amount of pigment per unit volume as displayed in Eq. (3.2)

$$C_a = 11.85(OD664) - 1.54(OD647) - 0.08(OD630) \quad (3.1)$$

$$\text{Chl a} = \frac{C_a \text{ x extract volumne, L}}{\text{volume of sample, m}^3} \quad (3.2)$$

Where:

C_a= concentration of chlorophyll-a (mg/L)

OD664, OD647, OD630 = corrected optical densities (with a 1-cm light path) at the respective wavelengths

Chl-a = Chlorophyll a (mg/m^3)

3.2.3.4 Ammonia

Ammonia can be analysis by using Nesslerization method, it is a classic standard water quality measurement for more than a century. It method referred to USEPA Nessler Method 350.2 that applicable for water, wastewater and seawater with the concentration range of 0.02 to 2.50 mg/L NH_3-N.

The 25 mL of water sample was prepared by adding 3 drops of Mineral Stabilizers, 3 drops of Polyvinyl Alcohol Dispersing Agent and 1 mL of Nessler Agent. The mixture was set aside for 1 minute to let the yellow colour to develop. The 10 mL of mixture was transferred to sample cell and the result was taken in mg/L by using spectrophotometer. The procedure was repeated by using blank solution.

3.2.3.5 Total Nitrogen

All of these form of nitrogen state nitrate, nitrite, ammonia and organic nitrogen are biochemically interconvertible in the nitrogen cycle. In the water sampling, TN is the sum of the kjeldahl nitrogen including ammonia, organic and reduced nitrogen and nitrate-nitrite (Rice et al., 2017). To determine TN, the persulfate method introduced at section 3.2.1, to determine the TN by oxidation of all nitrogenous compounds into nitrate. Ammonia, nitrate, and nitrite can conduct experiment individually while organic nitrogen can be obtained by difference of TN and inorganic nitrogen (ammonia, nitrite and nitrate). This technique only applies for sample that containing low organic matter content. This method referred to HACH Method 8171 Cadmium Reduction Method Powder Pillow method. It allows to test for water, wastewater and seawater with the concentration range of 0.1 to 10 mg/L NO_3^{-}–N for spectrophotometer.

One NitraVer Nitrate 5 Reagent powder pillow and 10 mL of digested sampled were pour into a sample cell. The sample cell was shake vigorously for 1 minute and an amber colour was developed for 5 minutes because nitrate was present. The sample cell was inserted into the spectrophotometer and the result was taken in mg/L.

3.2.3.6 Chemical Oxygen Demand

The chemical oxygen demand is to digest sample by using dichromate ion oxidizes COD material in the sample. From the state of hexavalent chromium (VI) state to trivalent (III) state. The dichromate ($Cr_2O_7^{2-}$) absorb the spectrometer light at 400 nm when the chromic (Cr^{3+}) absorption is less. However, absorb strongly at 600 nm region when chromate has nearly zero absorption. However, COD value lower than 90 mg/L can determine the decrease in dichromate at 420 nm. Higher value of COD can be obtained by sample dilution. This parameter was tested by using HACH Method 8000 Reactor Digestion Method that applicable for water and wastewater. The HACH method has a different concentration range but low range was selected as the concentration range 3 to 150 mg/L.

DRB200 Reactor Digester was pre-heated at 150°C. 2 mL of filtered water sample was transferred into COD vial. The cap of the vial was tight and shake for several time. The COD vials was placed into the Reactor for 2 hours. COD vials was cooled to room temperature and the result was taken by using spectrophotometer in mg/L.

3.2.3.7 Quality Assurance and Quality Control

Throughout the whole procedure, the glassware was acid washed with one drops of concentrated sulphuric acid with distilled water. All the glassware and reagent storage must be detergent-free to avoid inaccurate phosphorous reading. When handling chlorophyll-a, the test was conducted in a dim or away from sunlight area to avoid any chemical reaction of the concentrated algae. When water collection, ensure that the Secchi Disk was conducted at 10:00 am to 5:00 pm and conducted at a sunny side of the boat to obtain clearer reading. The sensor of *PCD650 Meter Kit* and *Turbidity Meter* were rinsed with distilled water every time after used. Lastly, the sample cells were properly washed with distilled water because the residual from previous usage will stay on the bottom surface that may affect the results especially TP and TN.

3.3 Selection of Trophic State Index

Any eutrophication in Malaysia lake can be conducted by using Carlson's Trophic State Index (CTSI) (NAHRIM, 2015). In this research, UTAR Kampar Lake was conducted by using CTSI method to classify and monitor the lake from the period October 2018 to March 2019. CTSI used as an indicator of eutrophication level of Malaysia's lake and the main parameter for CTSI are Chlorophyll-a, TP and SD. CTSI is develop to indicate the condition lake in temperate countries, to validate the value of the Carlson Index using data from Malaysia lakes. The following table shows a judgemental and predication of Trophic Status Index (TSI) with the associated parameters of SD in meter, TP in µg/L and Chlorophyll-a in µg/L. The calculation, equations and trophic state identification can refer to Section 2.4.1.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter presents all the collected data, results and information about this research study. The contents of the chapter have four subsections. The overview results, general information such as water sampling period and monthly precipitation rate will be discussed in section 4.1. The trophic state index will be discussed in section 4.2 to determine the productivity of lake with the parameters of Carlson's Trophic State Index (CTSI) and compared with National Lake Water Quality Criteria and Standards (NLWQCS). Section 4.3 will be focused on the National Water Quality Index (WQI) with the supporting water parameters and the last Section 4.4 will be the summary of this chapter.

4.1 Overview results

This study investigated the overall trophic state of University Tunku Abdul Rahman (UTAR) lake, Kampar Campus Lake by using CTSI. Water sampling was taken from five collection points with different inlet and outlet from other sources (lakes or drains). Several parameters had been examined such as in-situ test (dissolved oxygen, water temperature, pH value, turbidity and water transparency) and laboratory tests (Total Nitrogen, total phosphorus, Chlorophyll-a, ammonia, and chemical oxygen demand).

The data collection began on October 2018 to March 2019 including the precipitation rate (Figure 4.1). The rainy season began on October 2018 until December 2018 and the dry season began on January 2019 until March 2019. October 2018, November 2018 and December 2018 had a high average rainfall rate which were 834.6 mm, 823.4 mm and 654 mm respectively (World Weather Online, 2019). West Malaysia monsoon season began on the end of September 2018 until November 2018, it was reported that heavy rain and thunderstorms occurred in a short interval followed by strong wind especially in the afternoon until evening (Perimbanayagam, 2018). The dry season began January 2019 onward and a slight increased precipitation rate until March 2019. January 2019, February 2019 and March 2019 have the average rainfall rate of 179.9 mm, 274.5 mm and 258.8 mm, respectively (World Weather Online, 2019). The average rainfall for six months were 504.2 mm.

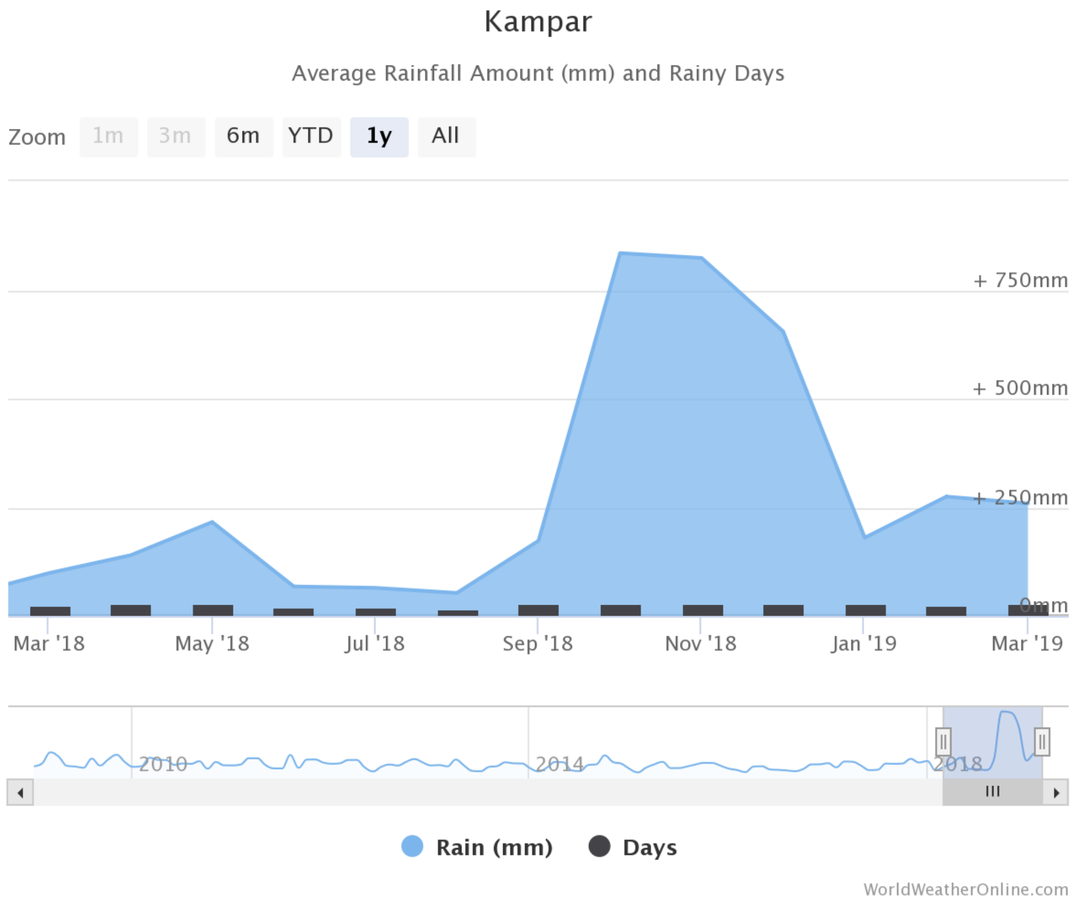


Figure 4.1: Average rainfall in Kampar from October 2018 to March 2019 (World Weather Online, 2019).

All the water samples were collected at the beginning on the month during sunny day after 10:00 am except for February 2019 and March 2019 with a cloudy day. All the parameters were tested within a few days and the results were discussed at the following respective topics. The parameters involved in CTSI were compared with National Lake Water Quality Criteria and Standards (NLWQCS) by National Hydraulic Research Institute of Malaysia (NAHRIM) and re (NRE). Meanwhile, the other parameters were compared with National Water Quality Index for Malaysia (WQI) Classification and National Water Quality Standards (NWQS) for Malaysia. The main reason for using two different standards to compare is because NLWQCS indicates the productivity and condition of the lake with the Carlson's parameters and total nitrogen. Meanwhile, the other water parameters were compared with WQI to indicate the quality standard of the water supply.

4.2 Trophic State Index

This subtopic would discuss the determination of trophic state by using CTSI the correlation of the parameter was Secchi Disk transparency (SD), total phosphorus (TP) and Chlorophyll-a, and compare the results with NLWQCS. Total nitrogen (TN) was discussed in this subtopic because the results comparable with NLWQCS and correlate with TP.

4.2.1 Secchi Disk Transparency

Figure 4.2 shows that sites 1 and 2 have the SD value of 1.21 ± 0.11 m and 1.24 ± 0.05 m, respectively. Sites 1 and 2 have high water transparency (greater than 1 m) as predicted due to absent of discharge source. According to the Table 2.1, SD exceed 1 m indicated that the lake status was mesoeutrophic-eutrophic, while sites 3, 4 and 5 have the SD value of 0.80 ± 0.03 m, 0.81 ± 0.03 m and 0.81 ± 0.04 m, respectively which indicated that the lake status was eutrophic. The transparency correlated with increase algae density (Chlorophyll-a) and decrease light penetration along the water depth (Mazumder and Havens, 1998). The sites 3, 4 and 5 showed the low transparency due to connection of inlet and outlet sources resulting higher presence of suspended solids and excessive algae bloom (Shekha, 2017). From the Malaysia cases Table 2.4, the water transparency for UTAR Kampar lake was higher than Bukit Merah, Sembring Lake and Sibu River with the SD value of 0.8 m, 0.3m and 0.6m, respectively. Thus, UTAR Kampar lake considered high transparency and indicated that the algae biomass lesser extent.

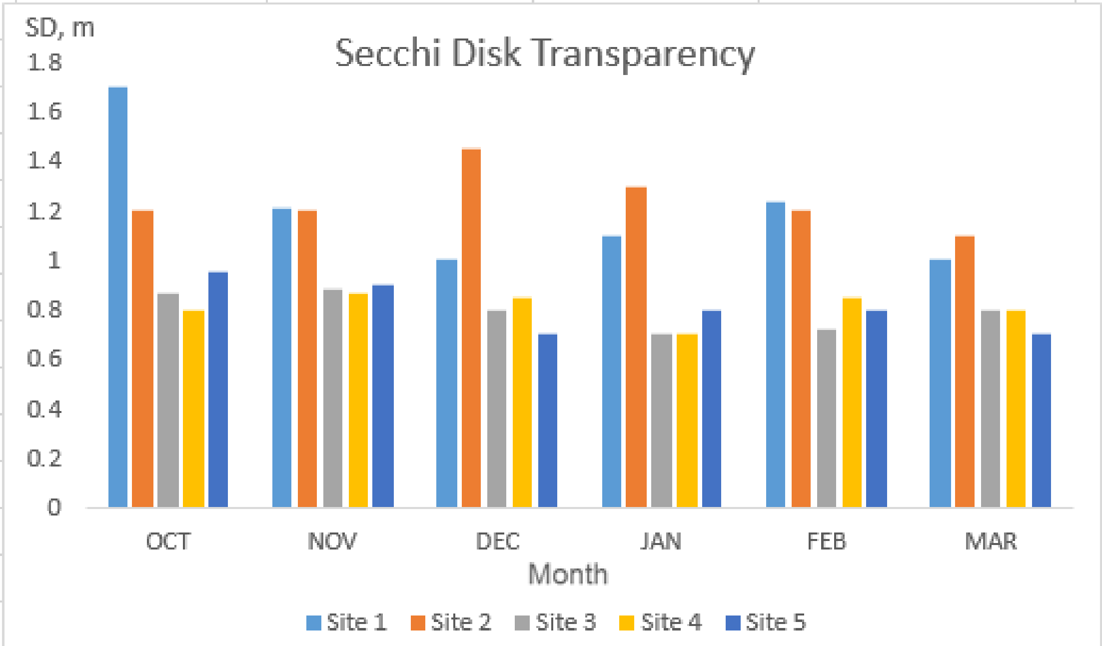


Figure 4.2: Monthly water transparency at different sites.

4.2.2 Total Phosphorus

The highest TP was in November 2018 (95 ± 5.7 µg/L) and March 2019 (89 ± 12 µg/L), while the lowest TP was October 2018 (14 ± 1.7 µg/L) (Figure 4.3). The data for October 2018 was taken slightly before the rainy season resulting a significant low nutrients concentration in the waterbody. As for November 2018 and March 2019 followed by December 2018 (48 ± 4.1 µg/L) have a higher TP concentration due to precipitation cause a greater runoff. The possible sources contain in the UTAR runoff were cow dung, dead leaf and fertilizers (Appendix H). The site 4 has the most frequency of highest TP concentration because of the cafeteria discharged dishwashing detergent may contribute to the high concentration. In dishwashing detergent formulation builders which contain sodium phosphates used to control water hardness and improve cleaning efficiency (Geetha and Tyagi, 2016). The lake water exceeds about 50 µg/L indicated the trophic state is eutrophic (Table 2.1). October 2018, December 2018, January 2019 (39 ± 5.3 µg/L) and February 2019 (28 ± 4.9 µg/L) were under the limit. According to Mcclain and Bilby (2011), nutrients decrease in the dry season because nutrient accumulated in the forest surface, and upper soil horizons and assimilation of the nutrients by algae, with that the increase vegetation produced more oxygen and decrease nutrient concentration (Silvino and Barbosa, 2015). TP concentration for Sibu River was 14 µg/L, Bukit Merah was 160 µg/L and Sembrong Lake was 125 µg/L. The lake has greater TP concentration because accumulation of fine particles rich in organic material and phosphorus (Clarke, 2002). TP concentration for rainy season in UTAR Kampar lake was relatively high as compare to those lakes, but low at dry season.

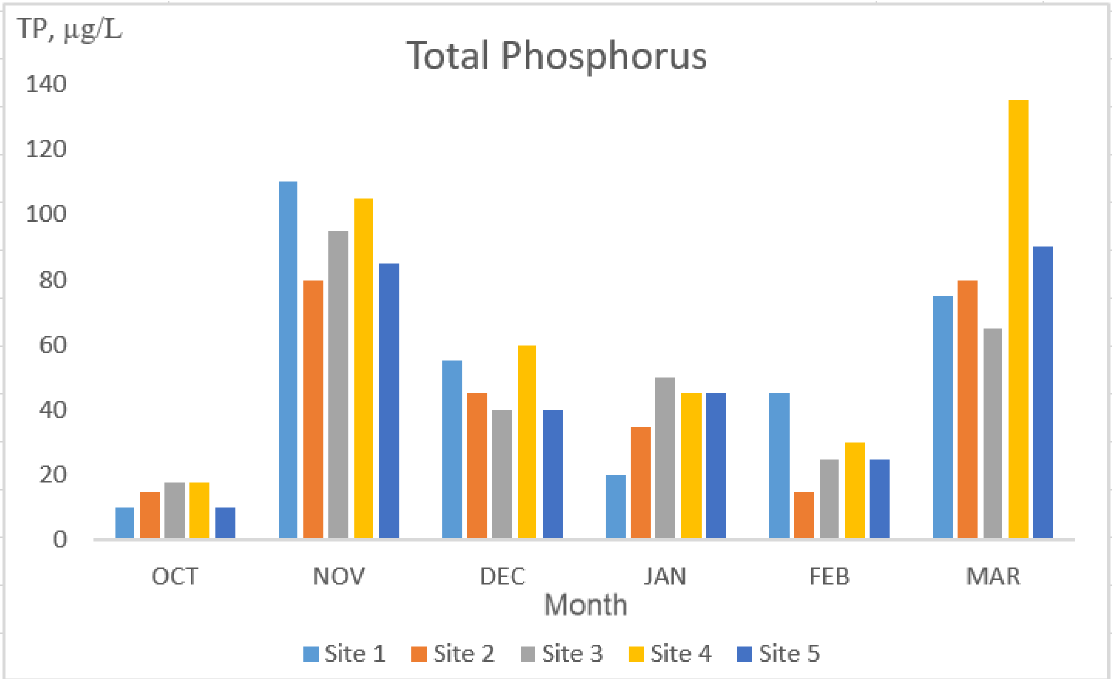


Figure 4.3: Monthly total phosphorus concentration at different sites.

4.2.3 Total Nitrogen

The following Figure 4.4 indicates the results for TN in October 2018 has the lowest concentration (0.58 ± 0.05 mg/L) while November 2018 and March 2019 have a higher concentration (1.31 ± 0.13 mg/L and 2.30 ± 0.62 mg/L) because of greater precipitation rate shown in Figure 4.1. December 2018 (0.77 ± 0.06 mg/L), January 2019 (0.91 ± 0.14 mg/L) and February 2019 (0.63 ± 0.02 mg/L) have a lower concentration compared to November 2018 and March 2019 because dry season has reduced the runoff rate (Mcclain and Bilby, 2011). By comparison of all the sites, the sites 3 and 5 have the most frequency of highest concentration because contribution of the connection of lakes. The possible nitrogen sources were cow dung and sewage discharged because East lake and West lake were surrounded with student hostels. The site 2 has the lowest concentration throughout the whole month because it located in the centre of the lake. The results showed that the TN and TP have similar outcome. The concentration of TN in lake water clearly increase with lake trophic state for lake with TP concentration (Quirós, 2003).

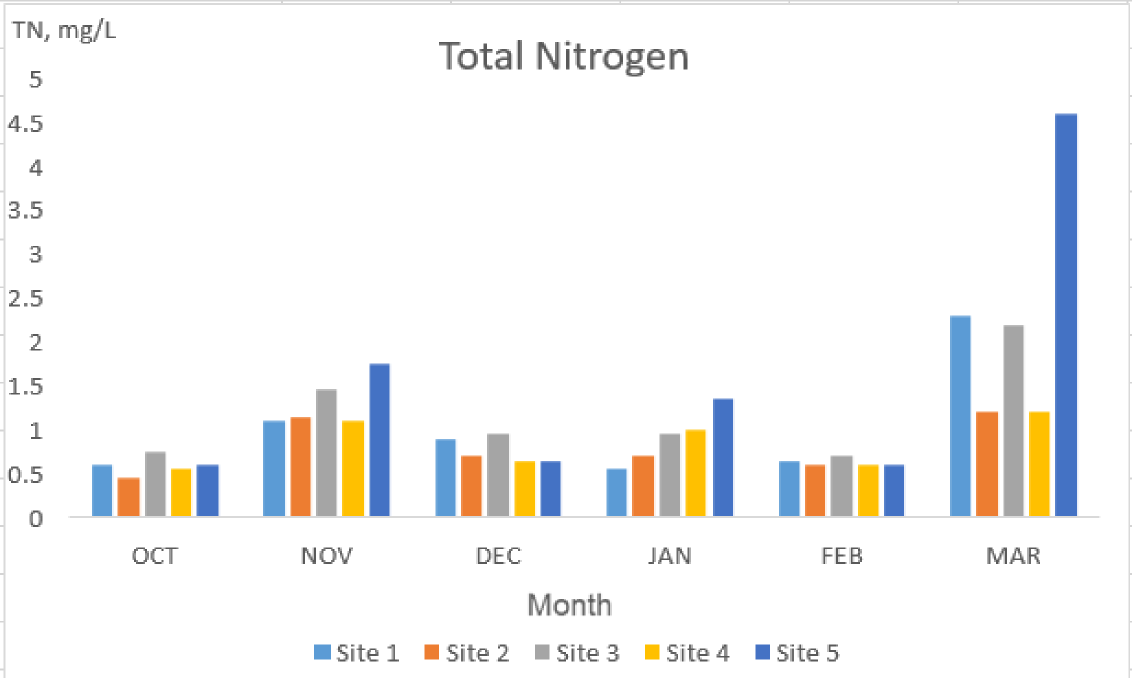


Figure 4.4: Monthly total nitrogen concentration at different sites.

4.2.4 Chlorophyll-a

According to the Figure 4.5, chlorophyll-a concentration was highly dependent on site with or without discharge inlet or outlet. The sites 3, 4 and 5 have a higher average chlorophyll-a concentration than sites 1 and 2. Chlorophyll-a concentration for all the sites have surpass 20 µg/L that indicated trophic state is eutrophic (Table 2.1). The concentration for sites 1 and 2 were 21.20 ± 0.96 µg/L and 23.07 ± 2.28 µg/L, respectively. Meanwhile, site 4 has the highest concentration 41.03 ± 5.27 µg/L, followed by site 3 (35.53 ± 1.99 µg/L) and site 5 (32.97 ± 4.72 µg/L) due to continuous discharge from cafeteria and West and East lake. SD was inversely proportional to the chlorophyll-a concentration, SD per unit chlorophyll-a (Mazumder and Havens, 1998). For example, site 1 has the water transparency greater than 1 m, as the chlorophyll-a concentration decreased indicated that low algae biomass. Thus, water transparency is the best to indicates the algae biomass (North American Lake Management Society, 2018). The chlorophyll-a concentration for Bukit Merah was 46 µg/L, Sembrong lake was 66 µg/L and Sibu river 5.9 µg/L, the river concentration definitely lower than the lake because the river diverts the nutrients flows (Zhang et al., 2015). Thus, those lakes were higher concentration than UTAR Kampar lake.

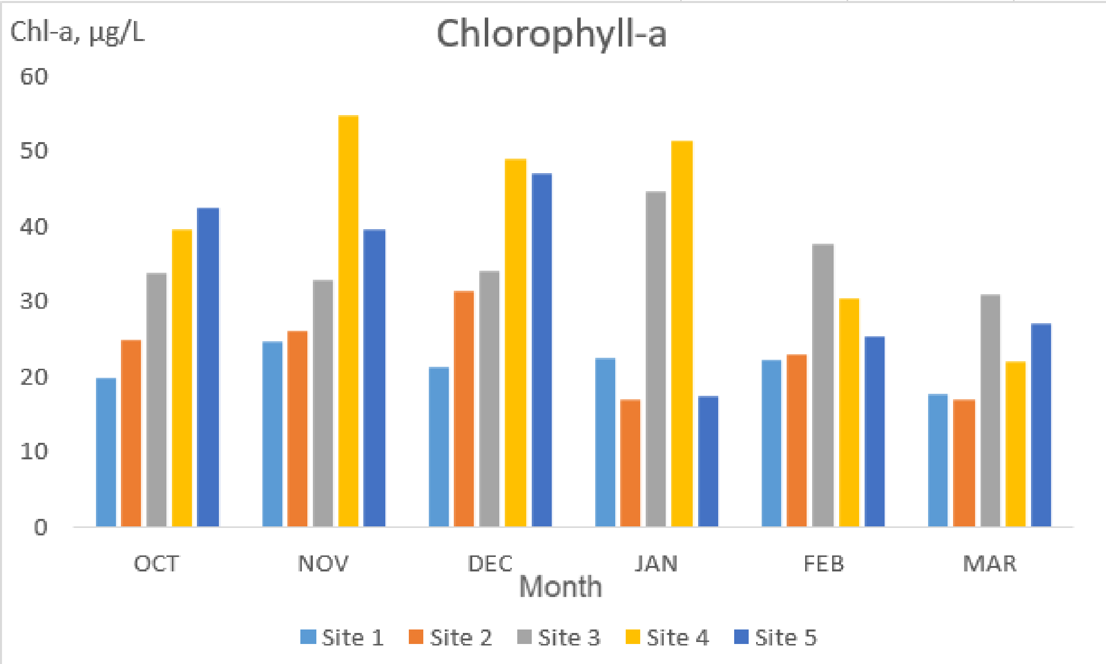


Figure 4.5: Monthly chlorophyll a concentration at different sites.

4.2.5 Carlson's Trophic State Index

CTSI was calculated based on the parameters chlorophyll-a (µg/L), TP (µg/L) and SD (m) from Eq. (2.3) till (2.5). After obtained the TSI value for each parameters, the average TSI was calculated based on Eq. (2.5). The average TSI value was justify by using the Table 2.1 to identify the lake status. The results showed that almost all the sites have eutrophic condition, except for October 2018 site 1 has a trophic state of mesoeutrophic-eutrophic (Table 4.1).

Table 4.1: Monthly average TSI and lake status for each site.

CTSI	Oct 18	Nov 18	Dec 18	Jan 19	Feb 19	Mar 19	Average	Lake Status
Site 1	50	64	61	56	59	62	59	E
Site 2	56	63	59	57	54	61	58	E
Site 3	58	66	62	65	60	64	63	E
Site 4	58	68	65	64	60	66	64	E
Site 5	58	65	64	60	59	66	62	E
Average	56	65	62	60	58	64		
Lake Status	E	E	E	E	E	E		

*E = Eutrophic

November 2018 and March 2019 have the higher average TSI 65 and TSI 64, respectively, because of high rainfall rate during the months while December 2018, January 2019 and February 2019 have a moderate TSI value of 62, 60 and 58, respectively. October 2018 has the lowest TSI value of 56. From all the sites, the lowest TSI value was 59 at site 2, followed by site 1 with TSI value of 58. The highest TSI value was 64 at site 4. Meanwhile, sites 3 and 5 have TSI value of 63 and 62. The previous results such as water transparency, TP and chlorophyll-a showed that site 4 was ranked top at every of the parameters. This showed that the cafeteria discharge at site 4 may contributed the highest to the lake eutrophication. Bukit Merah was eutrophic and Sembrong lake was hypereutrophic because both lakes TSI parameters concentration was higher than UTAR Kampar lake.

4.2.6 National Lake Water Quality Criteria and Standards

The NLWQCS was to indicate and provide information to user needs specification of water quality required different protection uses. The criteria provide the information in making judgmental as the lake water suitable for human activities, recreational purposes and ecosystem health.

The NLWQCS SD for Category A do not exceed 0.6 m, all the sites have exceeded the limit. The TP limit for Category D was 50 µg/L, only November 2018 and March 2019 have exceeded the limit because of rapid runoff during the months. Thus, TP was categorise as Category D. Meanwhile, TN for all the sites throughout the whole months have exceed the NLWQCS for Category D which is 0.35 mg/L. The NLWQCS chlorophyll-a limit for Category D was 25 µg/L as sites 3, 4 and 5 have exceeded, while sites 1 and 2 were slightly under the limit. In overall, the chlorophyll-a was categorise as Category D. In summary, UTAR Kampar lake was suffering nutrient pollution that caused eutrophication and categories as Category D which the lake managed for the minimum preservation of good aquatic life in the lake.

4.3 Other Water Quality Parameters

This subtopic discussed the other water quality parameters such as pH, water temperature, dissolved oxygen (DO), turbidity, ammonia and chemical oxygen demand that may contributed to trophic state index. The parameters were equally important to justify the condition of the lake as well as the water quality. The parameters were compared with WQI to classify the lake with standards.

4.3.1 pH

The Figure 4.6 shows October 2018, November 2018 and December 2018 have the pH value of 7.02 ± 0.02, 8.38 ± 0.09 and 7.80 ± 0.15, respectively. Meanwhile, January 2019, February 2019 and March 2019 have the pH of 8.62 ± 0.19, 8.76 ± 0.16 and 9.04 ± 0.15, respectively. January 2019 to March 2019 have the greater pH value than October 2018 to December 2018 because of rain fall drops from atmosphere, it absorbs carbon dioxide and form carbonic acid. The average acidify rainfall has a pH of 5.0 to 6.0 (Mesner and Geiger, 2005). Pollutants and atmospheric fallout particles landed on the land surface will washed by the rainwater cause pH decrease because most pollutants such as heavy metals are acidic (Harper, 2015). Sites 3 and 5 have the most frequency of highest pH due to high algae growth diverted from the West and East lake. Site 4 has a lower pH value because death algae decomposed by bacteria that consumed oxygen and produced carbon dioxide by lowering the pH. However, site 4 has the greatest chlorophyll-a concentration among all the sites. All the months were in alkalinity environment, as freshwater ecosystem with an alkalinity environment has a high photosynthetic activity by algae (Sharip, 2014). The Malaysia cases from Table 2.4 shows the pH for Varsity Lake (8.1), Bukit Merah (8.2) and Sembrong Lake (8.2). Those cases with the pH of 8 and slightly identical to UTAR Kampar lake scenario with high photosynthesis activity by the algae.

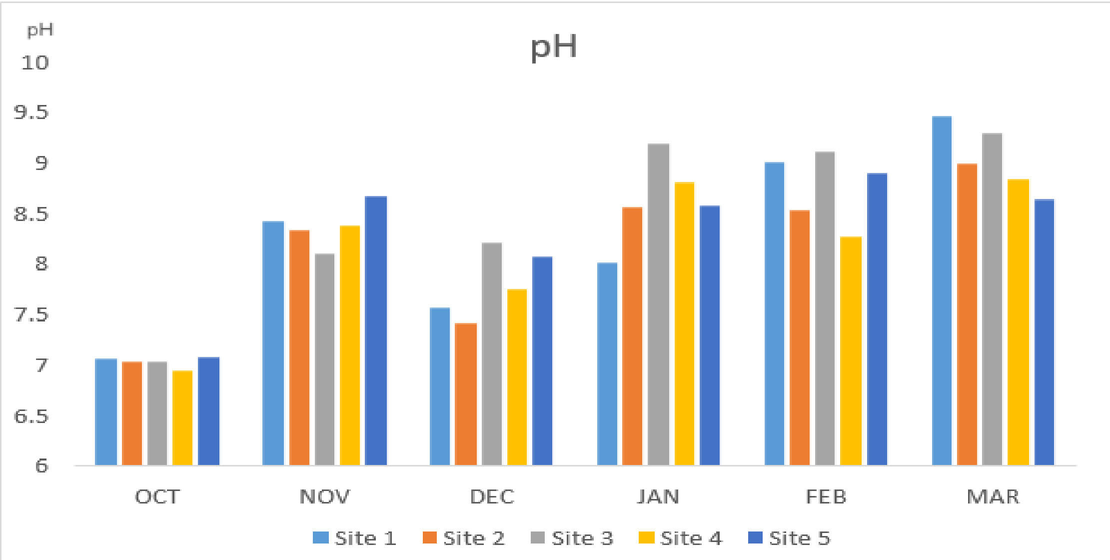


Figure 4.6: Monthly pH concentration at different sites.

The alkalinity of water involved the effect of eutrophication where high photosynthesis occurs and consumed carbon dioxide by the reaction of bicarbonate ions and hydrogen ions produced carbonic acid shown in Eq. (4.1). Any existing carbonate ions will react with hydrogen ions to replace the bicarbonate consumed displayed in Eq. (4.2). Both reaction consumed hydrogen ions resulting production of hydroxyl ion and increase the overall pH value presented in Eq. (4.3). Extensive photosynthesis activity to produce high pH value that may cause serious damage to the aquatic organisms as well a

$$H^+ + HCO_3^- \rightarrow H_2CO_3\ [H_2O + CO_2] \quad (4.1)$$

$$H^+ + CO_3^{--} \rightarrow HCO_3^- \quad (4.2)$$

$$H_2O \rightarrow H^+ + OH^- \quad (4.3)$$

4.3.2 Temperature and Dissolved Oxygen

The water temperature is the control for all chemical reaction. Temperature affects the DO content in the water, the relationship between temperature and DO were inversely proportional. Throughout all the months, the water temperature was 29.0 ± 0.5 ℃. The maximum limit DO for freshwater at 28 ℃ to 30 ℃ were 7.81 mg/L to 7.54 mg/L (Wilde and Radtke, 1998). The lowest dissolved oxygen was October 2018 (3.39 ± 0.09 mg/L). The low DO indicate the algae died and composed by microbial that consumes DO (Viet et al., 2016). November 2018 and December 2018 have the DO of 6.43 ± 0.12 mg/L and 5.83 ± 0.59 mg/L respectively. As for the dry season began on January 2019 (6.85 ± 0.04 mg/L), February 2019 (6.63 ± 0.13 mg/L) and March 2019 (6.53 ± 0.21 mg/L) has greater DO than the wet season. The high DO indicate high photosynthesis activity by algae and cyanobacteria during daylight period, resulting production of oxygen which may lead to increase DO (EPA, 2001). Sites 2 and 4 have lower DO due to decomposition of death algae, while sites 3 and 5 have the higher DO due to greater photosynthesis activity.

4.3.3 Turbidity

The highest turbidity was site 5 (20.32 ± 7.08 NTU), followed by site 3 (19.84 ± 6.91 NTU). Sites 3 and 5 have the highest turbidity because of algae and sediment runoff from the connected lakes. The factor effecting high turbidity were suspended solids, solid particles and abundance algae showed in Figure 4.7 (EPA, 2001). The lowest turbidity was site 1 (12.21 ± 1.37 NTU), followed by site 2 (13.20 ± 1.62 NTU). The low turbidity was predicted at sites 1 and 2 because of absent of inlet and outlet discharge point. Lastly, turbidity for site 4 was 16.02 ± 2.04 NTU.

Figure 4.7: Remaining particles (green algae and suspended solids) after filtered water sample.

4.3.4 Ammonia

The Figure 4.8 presents the highest ammonia concentration was February 2019 (0.723 ± 0.125 mg/L), followed by December 2018 (0.437 ± 0.049 mg/L), January 2019 (0.378 ± 0.019 mg/L) and October 2018 (0.343 ± 0.046 mg/L). All the months mentioned above were the lowest concentration for TN (Figure 4.4), the relationship between ammonia and TN was the nitrate reduced rapidly into organic compounds within organisms and produced high concentration of ammonia (Quirós, 2003). The similar concept for the low ammonia concentration, the lowest ammonia concentration was March 2019 (0.075 ± 0.014 mg/L), followed by November 2018 (0.207 ± 0.021 mg/L). Both March 2019 and November 2018 have the highest TN concentration but lowest ammonia concentration because ammonia oxidized rapidly to nitrate in aerobic water (Quirós, 2003).

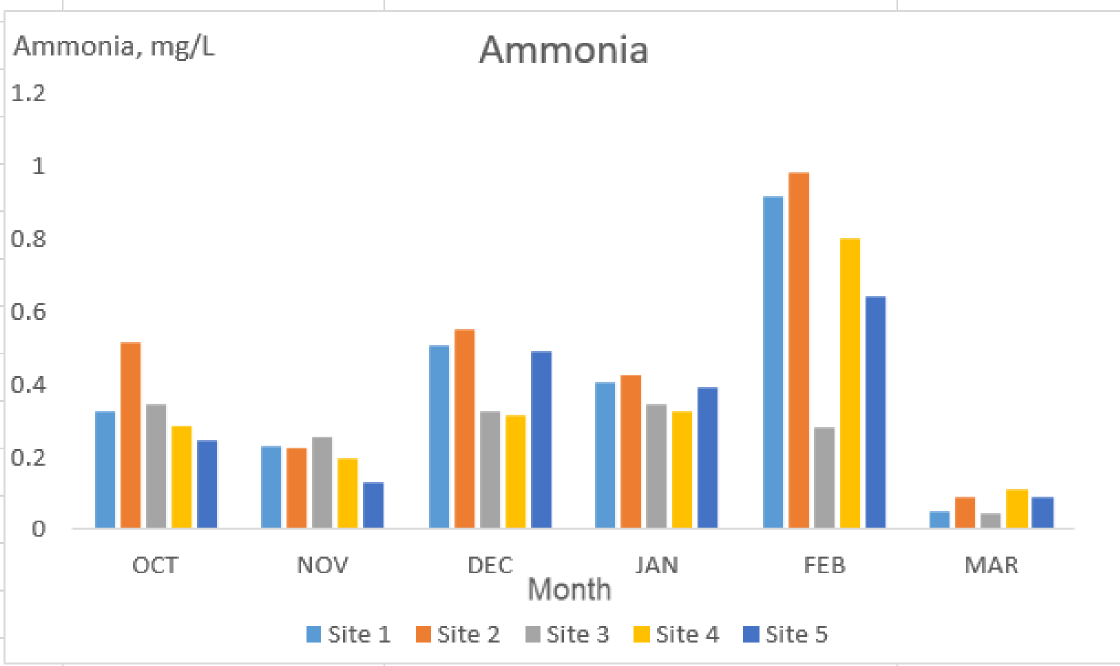


Figure 4.8: Monthly ammonia concentration at different sites.

4.3.5 Chemical Oxygen Demand

The COD value were obtained to further understand and provide more information about UTAR Kampar lake situation. The highest COD value obtained was site 4 (19.94 ± 1.25 mg/L), followed by site 5 (19.78 ± 1.79 mg/L) and site 3 (18.25 ± 2.96 mg/L) because of discharge sources and runoff containing large portion of pollutants used to attach vehicles and washed off from the road (Harper, 2015). Meanwhile, site 1 has 17.23 ± 1.49 mg/L and site 2 has the lowest COD value of 16.83 ± 1.81 mg/L as predicted due to absent or some discharge sources.

4.3.6 Water Quality Index

The National Water Quality Standard (NWQS) for Malaysia was used to determine the water quality. The only parameters can be compared were pH, temperature, DO, turbidity, ammonia and COD.

The mean pH for each of the months were ranging 7.0 to 9.0 that fall into Class IIB (6-9 pH). The mean temperature was ranging 28 ℃ to 30 ℃ classify as Class III while the dissolved oxygen was ranging 5.8 mg/L to 6.8 mg/L except for October 2018 (3.4 mg/L) fall into Class IIB (5-7 mg/L) and Class III (3-5 mg/L) respectively. The mean turbidity was ranging 10 NTU to 20 NTU which fall into Class IIA (<50 NTU). The mean ammoniacal-nitrogen for six months was 0.36 mg/L that fall into Class III (0.3-0.9 mg/L). The average COD was ranging 16 mg/L to 20 mg/L classify as Class II (10-25 mg/L).

UTAR Kampar lake was classified as Class III (Moderate clean) where water supply required go through advanced treatment system, fishery with common of economic value and tolerant species and water suitable for livestock drinking. Class III specifies the water quality enable to sustain aquatic life regardless degree of sensitivity. Thus, UTAR Kampar lake was not polluted at a moderate level.

4.4 Chapter Conclusion

To conclude this chapter, the average SD was 0.8 m to 1.2 m where site 1 have the highest value. TP was ranging 14 µg/L to 95 µg/L with the highest concentration was November 2018 and March 2019 because of high rainfall rate. Meanwhile, the chlorophyll-a concentration was ranging 21 µg/L to 41 µg/L where site 4 has the highest concentration. From the CTSI found that all the months were under eutrophic condition and site 4 has the highest average score 64. The mean pH for each of the months were ranging 7.0 to 9.0 and the mean temperature was ranging 28 ℃ to 30 ℃. The DO was ranging 5.8 mg/L to 6.8 mg/L except for October 2018 3.4 mg/L. The mean turbidity was ranging 12 NTU to 20 NTU. TN and ammonia has the range of 0.63 mg/L to 2.3 mg/L and 0.33 mg/L to 0.46 mg/L, respectively. The average COD was ranging 17 mg/L to 20 mg/L. Thus, water transparency and chlorophyll-a were highly dependent on the sites where inlet and outlet located. Meanwhile, the dissolved inorganic nutrients such as TP, TN and ammonia were dependent on rainy season.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusions

In conclusion, after six months of monitoring the lake in University Tunku Abdul Rahman (UTAR) Kampar, it was showed that the lake was suffering with eutrophication and Carlson's Trophic State Index value proved that site 4 was the greatest contribution in eutrophication due to cafeteria discharge that may contain high in nutrients. Not forgetting sites 3 and 5 contributed in eutrophication as well. The parameters such as water transparency and chlorophyll-a indicated that both were highly dependent on different site locations. Meanwhile, the dissolved inorganic nutrients such as total phosphorus, total nitrogen and ammonia were highly dependent on the rainy season – began on October 2018 until December 2018. The results were compared with National Lake Water Quality Criteria and Standards that UTAR Kampar lake felt into Category D – lake that contains some pollutants and minimum preservation of good aquatic organisms. Lastly, National Water Quality Index for UTAR Kampar lake was classified as Class III – moderate level where water required advanced treatment before consume. Thus, UTAR Kampar lake was nutrient pollution that causes eutrophication.

5.2 Recommendations

There are several recommendations to further improve the situation.

1. The possible ways to treat the existing algae blooming condition in UTAR Kampar lake - installation of advanced treatment system at the Block C cafeteria to reduce the nutrients concentration and increase the number of tree plantation near the discharge points as the trees assimilate the nutrients
2. To enable to collect rainfall and runoff rate manually to have more accurate readings at the specific area.
3. To conduct a test on biotoxin produced by cyanobacteria or algae that hazardous to environment and aquatic organisms.

REFERENCES

Afroz, R. and Rahman, A., 2017. Health impact of river water pollution in Malaysia. *International Journal of Advanced and Applied Sciences*, 4(5), pp.78–85.

Afroz, R., Masud, M.M., Akhtar, R. and Duasa, J.B., 2014. Water pollution: Challenges and future direction for water resource management policies in Malaysia. *Environment and Urbanization Asia*, 5(1), pp.63–81.

Alves Da Costa, J. et al., 2018. Eutrophication in aquatic ecosystems: a scientometric study. *Acta Limnologica Brasiliensia*, 30(2).

Balasubramanian, A., 2016. Aquatic Ecosystems-Freshwater Types. *University of Mysore*, pp. 1-8.

Balasubramanian, A., 2016. Aquatic Ecosystems-Marine Types. *University of Mysore*, pp. 1-9.

Bell, P.R.F., 1992. Eutrophication and coral reefs—some examples in the Great Barrier Reef lagoon. *War. Res.*, 26(5), pp.553–568.

Bista, S., 2016. *Eutrophication Tervalampi of Lakes Huhmarjärvi and Tervalampi*. Bachelor. Helsinki Metropolia University of Applied Sciences.

Callisto, M., Molozzi, J. and Etham Barbosa, J.L., 2014. Eutrophication of Lakes. *Eutrophication: Causes, Consequences and Control*, pp.55–71.

Carlson, R.E., 1977. A trophic state index for lakes. *Limnology and Oceanography*, 22(2), pp.361-369.

Chee Mood, N., Othman, F., Amin, F. and Adham, I., 2017. Effectiveness of Lake Remediation towards Water Quality: Application in Varsity Lake, University of Malaya, Kuala Lumpur. *Sains Malaysiana*, 46(8), pp.1221–1229.

Clarke, S. J., 2002. Vegetation growth in rivers: Influences upon sediment and nutrient dynamics. *Progress in Physical Geography*, *26*(2), 159–172.

Dabkowski, B. and White, M., 2015. Understanding the Different Phosphorus Tests. *HACH*, pp.1–4.

Dalrymple, O.K. et al., 2013. Wastewater use in algae production for generation of renewable resources: a review and preliminary results. *Aquatic biosystems*, 9(1), p.2.

Devi Prasad, A.G., 2012. Carlson's Trophic State Index for the assessment of trophic status of two Lakes in Mandya district. *Pelagia Research Library Advances in Applied Science Research*, 3(5), pp.2992–2996.

Diana, N., 2018. *National Geographic Society - Save the Plankton, Breathe Freely*. [online] Available at: <https://www.nationalgeographic.org/activity/save-the-plankton-breathe-freely/> [Accessed 27 Jun. 2018].

Diaz, R. J., 2010. Agriculture's impact on aquaculture: Hypoxia and eutrophication in marine waters. *Advancing the Aquaculture Agenda: Workshop Proceedings, pp. 275-319.*

Dong, L.X., Su, J.L., Li, Yan., Xia, X.M. and Guan, W.B., 2006. Physical Process and Sediment Dynamics in the Pearl River. *The Environmental in Asia Pacific Harbours*, pp.127-137.

Earth Eclipse, 2018. *Causes and Effects of Eutrophication | Earth Eclipse*. [online] Available at: <https://www.eartheclipse.com/ecosystem/causes-and-effects-of-eutrophication.html> [Accessed 13 Jul. 2018].

EPA, 2001. *Parameter of Water Quality: Interpretation and Standards.* Wexford: Environmental Protection Agency.

Geetha, D., & Tyagi, R., 2016. Consumer behavior and fascinating challenges on household laundry and dishwashing. *Carl Hanser Publisher, Munich*, *53*(6), 568–575.

Gibson, G., Carlson, R. and Simpson, J., 2000. *Nutrient Criteria Technical Guidance Manual: Lake and Reservoirs*. Washington, DC: United States Environmental Protection Agency.

Harper, H.H., 2015. Stormwater chemistry and water quality. Ph.D. University of Central Florida.

Helmer, R. and Hespanhol, I., 1997. *Water Pollution Control – A Guide to the Use of Water Quality Management Principles.* London: United Nations Environment Program.

Henny, C. and Nomosatryo, S., 2016. Changes in water quality and trophic status associated with cage aquaculture in Lake Maninjau, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 31(1), pp.1-9.

Heshani, S., Handapangoda, K. and Athukorala, S., 2015. Socio-economic impacts of eutrophication in Beira Lake in Colombo, Sri Lanka. *Proceedings of the Second Undergraduate Research Symposium on Environmental Conservation and Management*, pp.29–30.

Hodoki, Y. and Murakami, T., 2006. Effects of tidal flat reclamation on sediment quality and hypoxia in Isahaya Bay. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 16(6), pp.555–567.

Howell, J.A., 2010. The distribution of phosphorus in sediment and water downstream from a sewage treatment works. *Bioscience Horizons*, 3(2), pp.113–123.

Jenny, J. et al., 2016. Urban point sources of nutrients were the leading cause for the historical spread of hypoxia across European lakes. *Cross Mark*, pp.1–6.

Lazzari, R. and Baldisserotto, B., 2008. Nitrogen and Phosphorus Waste in Fish Farming. *Boletim do Instituto de Pesca*, 34(4), pp.591–600.

Lee, C.W., Bong, C.W. and Hii, Y.S., 2009. Temporal variation of bacterial respiration and growth efficiency in tropical coastal waters. *Applied and Environmental Microbiology*, 75(24), pp.7594–7601.

Lee, C.W., Bong, C.W. and Hii, Y.S., 2009. Temporal variation of bacterial respiration and growth efficiency in tropical coastal waters. *Applied and Environmental Microbiology*, 75(24), pp.7594–7601.

Lee, CW. and Bong, CW., 2006. Carbon Flux Through Bacteria in a Eutrophic Tropical Environment: Port Klang Waters. *The environment in Asia Pacific Harbours*, pp.329-345.

Lindsey, R. and Scott, M., 2010. *What are Phytoplankton?*. [online] Available at: <https://earthobservatory.nasa.gov/features/Phytoplankton> [Accessed 8 Apr. 2019].

Macklin, M., 2017. *Animal Agriculture – Killing More than Just Cows. How Farm Run-Off Threatens Marine Life*. [online] <Available at: https://www.onegreenplanet.org/environment/how-factory-farm-run-off-threatens-marine-life/> [Accessed 9 Jul. 2018].

Mazumder, A. and Havens, K.E., 1998. Nutrient-chlorophyll-Secchi relationships under contrasting grazer communities of temperate versus subtropical lakes. *Canadian Journal of Fisheries and Aquatic Sciences*, 55.

Mcclain, M. E., Bilby, R. E., & Triska, F. J. (2011). River Ecology and Management. *River Ecology and Management*, 347–372.

Mesner, N. and Geiger, J., 2005. *Understanding Your Watershe is pH?*. Utah State: Utah State University.

Michigan Department of Environmental Quality, 2008. *Cooperative Lakes Monitoring Program.* Michigan: Michigan Clean Water Corps.

NAHRIM, 2015. *National Lake Water Quality Criteria and Standards. Malaysia*. Malaysia: National Hydraulic Research Institute of Malaysia.

Nakai, Y., 2001. Animal Waste Management and Microorganisms. *Animal Science Journal*, 72(1), pp.1–3.

National Taiwan Museum, 2007. *Morphology and Taxonomy-Introduction*. [online] Available at: <http://formosa.ntm.gov.tw/seaweeds/english/b/b1_01.asp#top> [Accessed 8 Apr. 2019].

Naumann, E., 1929. The Scope and Chief Problems of Regional Limnology. *Internationale Revue der gesamten Hydrobiologie und Hydrographie*, 22(1), pp.423–444.

North American Lake Management Society, 2018. *Defining Trophic State*. [online] Available at: <http://www.secchidipin.org/index.php/monitoring-methods/defining-trophic-state/> [Accessed 9 Apr. 2019].

North American Lake Management Society, 2018. *Trophic State Equations*. [online] Available at: <http://www.secchidipin.org/index.php/monitoring-methods/trophic-state-equations/> [Accessed 9 Apr. 2019].

Othman, N. Bin et al., 2016. Parametric investigation in Malaysian separate sewer systems. *Proceedings of the Institution of Civil Engineers - Municipal Engineer*, 170(2), pp.90–96.

Paerl, H.W. et al., 2006. Anthropogenic and climatic influences on the eutrophication of large estuarine ecosystems. *Limnology and Oceanography*, 51(1), pp.448–462.

Pareek, S. et al., 2017. Chlorophylls: Chemistry and biological functions. *Fruit and Vegetable Phytochemicals: Chemistry and Human Health: Second Edition*, 1(2), pp.269–284.

Pavlidou, A. et al., 2015. Methods of eutrophication assessment in the context of the water framework directive: Examples from the Eastern Mediterranean coastal areas. *Continental Shelf Research*, 108, pp.156–168.

Perimbanayagam, K., 2018. *Monsoon transition phase begins today*. [online] Available at: <https://www.nst.com.my/news/nation/2018/09/415613/monsoon-transition-phase-begins-today> [Accessed 13 Mar. 2019].

Qin, B. et al., 2006. Mechanism and control of lake eutrophication. *Chinese Science Bulletin*, 51(19), pp.2401–2412.

Quirós, R., 2003. The relationship between nitrate and ammonia concentrations in the pelagic zone of lakes. *Limnetica*, 22(1–2), pp.37–50.

Rabalais, N.N. et al., 2010. Dynamics and distribution of natural and human-caused hypoxia. *Biogeosciences*, 7(1), pp.585–619.

Rice, E.W., Baird, R.B. and Eaton, A.D., 2017. *Standard Methods for the Examination of Water and Wastewat*er. 23rd Edition. Washington, DC: American Public Health Association.

Saad, A. and Atia, A., 2014. Review on freshwater blue-green algae (cyanobacteria): Occurrence, classification and toxicology. *Biosciences Biotechnology Research Asia*, 11(3), pp.1319–1325.

Sharip, Z. and Zakaria, S., 2008. Lakes and Reservoir in Malaysia: Management and Research Challenges. *The 12th World Lake Conference*, pp.1349–1355.

Sharip, Z. et al., 2014. Lakes of Malaysia: Water quality, eutrophication and management. *Lakes and Reservoirs: Research and Management*, 19(2), pp.130–141.

Sharip, Z., 2016. Trophic state characterisation for malaysian lakes. *Proceedings The 16th World Lake Conference*. pp. 442–447.

Shekha, Y., 2017. Assessment of Water Quality and Trophic Status of Duhok Lake Dam. *Baghdad Science Journal*, 14(2), pp.335–341.

Silvino, R. and Barbosa, F., 2015. Eutrophication potential of lakes: an integrated analysis of trophic state, morphometry, land occupation, and land use. *Braz. J. Biol*, 1(1).

Smith, V., 2003. Eutrophication of freshwater and coastal marine ecosystems a global problem. *Environmental Science and Pollution Research*, 10(2), pp.126–139.

Smith, V.H., Joye, S.B. and Howarth, R.W., 2006. Eutrophication of freshwater and marine ecosystems. *Limnology and Oceanography*, 51(2), pp.351–355.

Smith, V.H., Tilman, G.D. and Nekola, J.C., 1998. Eutrophication: Impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. *Environmental Pollution*, 100(1–3), pp.179–196.

Soo, C.L., Ling, T.Y., Nyanti, L. and Apun, K., 2014. Assessment of the characteristic of nutrients, total metals, and fecal coliform in Sibu Laut River, Sarawak, Malaysia. *Apple Water Science*, 6, pp.77–96.

Sterner, R.W., 2009. Nutrient Stoichiometry in Aquatic Ecosystems. *Encyclopedia of Inland Waters*, pp.820–831.

U.S Department of Agriculture, 2007. *Food (Meat, Poultry, and Egg Products) and Agriculture*. Washington, D.C.: Homeland Security.

U.S National Library of Medicine, 2017. *Runoff*. [online] Available at: <https://toxtown.nlm.nih.gov/text_version/locations.php?id=1> [Accessed 9 Jul. 2018].

Viet, N.D., Huong, T. and Hoang, T., 2016. Dissolved Oxygen as an Indicator for Eutrophication in Freshwater Lakes Dissolved Oxygen as an Indicator for Eutrophication in Freshwater Lakes. *Proceedings of International Conference on Environmental Engineering and Management for Sustainable Development*, pp.1–6.

Viman, O. V., Oroian, I. and Fleşeriu, A., 2010. Types of water pollution: Point source and nonpoint source. *AACL Bioflux*, 3(5), pp.393–397.

Vollenweider, R.A., Giovanardi, F., Montanari, G. and Rinaldi, A., 1998. Characterization of the trophic conditions of marine coastal waters with special reference to the nw adriatic sea: proposal for a trophic scale, turbidity and generalized water quality index. *Envrionmentrics*, 9, pp.329–357.

Wilde, F.D. and Radtke, D. B., 1998. *Handbooks for water-resources investigations*. Washington, D.C.: U.S Geological Survey.

World Health Organization, 2010. *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans.* Lyon, France: International Agency for Research on Cancer.

World Weather Online, 2019. *Kampar Weather Forecast*. [online] Available at: <https://www.worldweatheronline.com/kampar-weather/perak/my.aspx> [Accessed 18 Mar. 2019].

WRI, 2008. *World Hypoxia and Eutrophic Coastal Areas.* [online] Available at: < https://www.wri.org/resource/world-hypoxic-and-eutrophic-coastal-areas> [Accessed 10 Sep 2018].

WRI, 2018. *About Eutrophication | World Resources Institute*. [online] Available at: <http://www.wri.org/our-work/project/eutrophication-and-hypoxia/about-eutrophication> [Accessed 15 Aug 2018].

WRI, 2018. *Coastal Eutrophic and Hypoxic Areas of Asia | World Resources Institute*. [online] <Available at: http://www.wri.org/resources/maps/coastal-eutrophic-and-hypoxic-areas-asia> [Accessed 17 Aug. 2018].

WRI, 2018. *Impacts | World Resources Institute*. [online] Available at: <http://www.wri.org/our-work/project/eutrophication-and-hypoxia/impacts> [Accessed 13 Jul. 2018].

WRI, 2018. *Sources of Eutrophication | World Resources Institute*. [online] Available at: <http://www.wri.org/our-work/project/eutrophication-and-hypoxia/sources-eutrophication> [Accessed 12 Jul. 2018].

Yaccob, N.S., 2017. Water Quality Assessment of Bukit Merah Reservoir, Perak. *International Conference on Environmental Research and Technology*, pp.91–96.

Yang, X., Wu, X., Hao, H. and He, Z., 2008. Mechanisms and assessment of water eutrophication. *Journal of Zhejiang University. Science. B,* 9(3), pp.197–209.

Zhang, L., Shao, S., Liu, C., Xu, T., & Fan, C., 2015. Forms of nutrients in rivers flowing into lake chaohu: A comparison between urban and rural rivers. *Water, 7*(8), 4523–4536.

APPENDICES

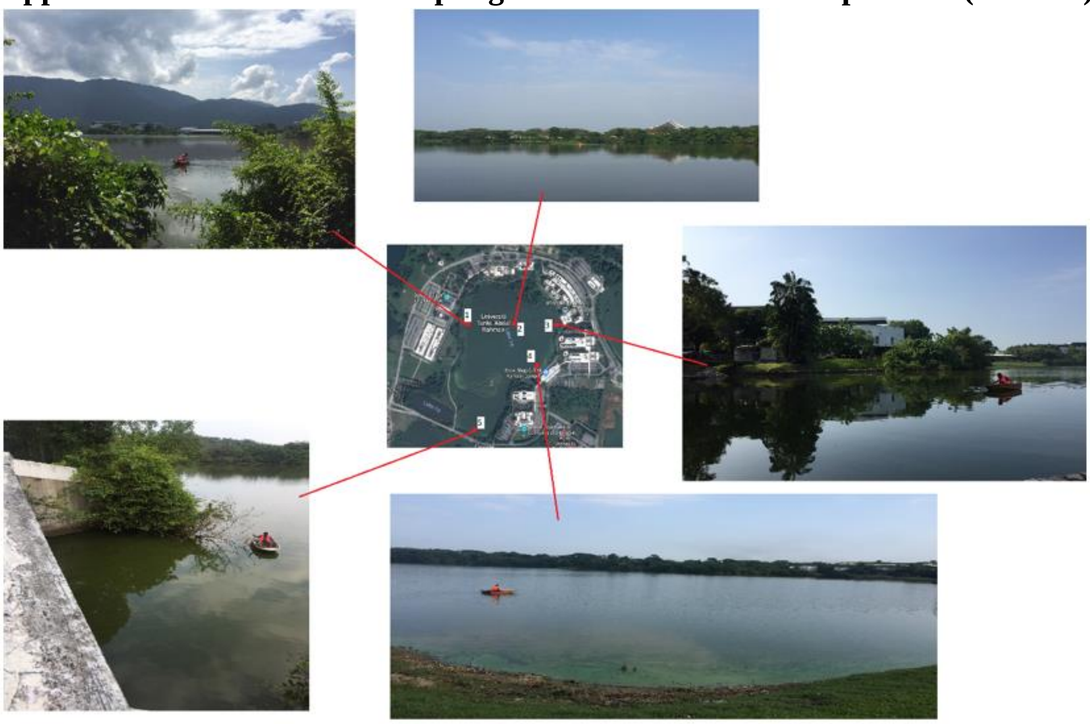
Appendix A: Observation of UTAR Kampar lake eutrophication throughout the months

Appendix A (1): October 2018 (Left), November 2018 (Right)

Appendix A (2): December 2018 (Left), January 2019 (Right)

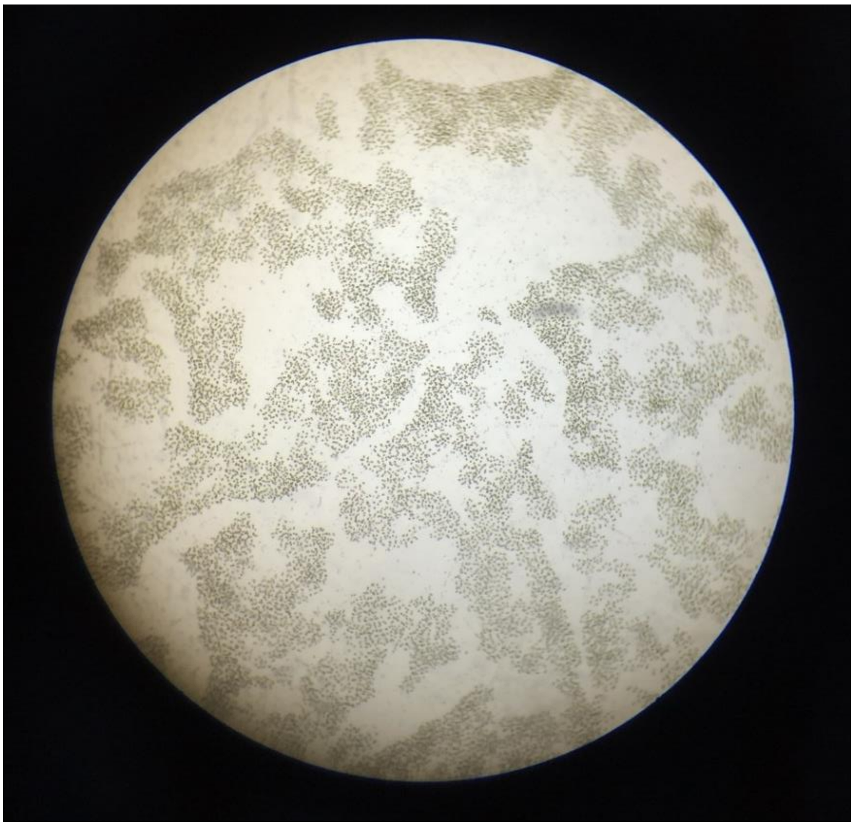
Appendix A (3): February 2019 (Left), March 2019 (Right)

Appendix B: View of water sampling locations at UTAR Kampar lake (Lake 18)



Appendix C: Microscopic view of algae

Appendix C (1): Total magnification of 400x



Appendix C (2): Total magnification of 40x

Appendix D: National Lake Water Quality Criteria and Standards for Category A

PARAMETER	UNIT	CATEGORY A
PHYSICALS		
Colour	TCU	100 - 200
Conductivity	µS/cm	1000
Salinity	ppt	nvd
Floatables	-	NV
Dissolved Oxygen	mg/L	6.3 - 7.8
DO percentage saturation	%	80 -100
Odour	-	NOO
pH	-	6.5 - 8.5
Taste	-	NOT
Temperature	°C	28
Total Suspended Solid	mg/L	<100
Turbidity	NTU	40
Transparency (Secchi)	m	0.6
Oil & Grease	mg/L	1.5
NUTRIENTS		
Ammoniacal Nitrogen (NH_3-N)	mg/L	0.1 [a]
Nitrate-N (NO_3-N)	mg/L	7 [h]
Total Phosphorus	mg/L	0.01 [d]
BIOLOGICAL/MICROBIOLOGICAL		
Chlorophyll-a	µg/L	10 [b]
Biochemical Oxygen Demand (BOD_5)	mg/L	3
Chemical Oxygen Demand (COD)	mg/L	10
Clostridium perfringens (including spores)	-	nd [g]
Total Coliform	Counts/ 100ml	5000 [a]
E. coli	Counts/ 100ml	100 [f]
Giardia sp	-	nd [g]
Leptospira sp.	-	nd [h]
Cryptosporodium sp	-	nd [g]
Enterococci	Counts/ 100ml	33 [h]
Cyanobacteria	Cells/ ml	15 000 [h]

Note: [a] DOE 2006, [b]Carlson 1996, [c]ANZECC 2000, [d]Health Canada 2012, [e]USEPA2012, [f]Donna et al 1993, [g]Perbadanan Putrajaya 2000, [h]MOH 2012, [I]MEEA 2013

NO	CATEGORIES	DESCRIPTION
1	CATEGORY A	• Lakes that are managed in which the water to be used for recreational purposes - primary body contact such as swimming, diving and kayaking.
2	CATEGORY B	• Lakes used for recreational purposes - secondary body contact such as boating and cruising. • Swimming is not allowed in this category of lakes
3	CATEGORY C	• The lakes are meant for the preservation of aquatic life and biodiversity
4	CATEGORY D	• Lakes managed for the minimum preservation of good aquatic life in the lakes. • It applies good management practices of lakes.

Appendix E: National Lake Water Quality Criteria and Standards for Category D

PARAMETER	UNIT	CATEGORY D
PHYSICAL		
Colour	TCU	300
Conductivity	µS/cm	5000
Salinity	ppt	>1
Floatables	-	NV
Dissolved Oxygen	mg/L	3.3 – 10.3
DO percentage saturation	%	40 - 130
Odour	-	NOO
pH	-	5.5 - 9.0
Taste	-	NOT
Temperature	°C	28
Total Suspended Solid	mg/L	>200
Turbidity	NTU	250
Transparency (Secchi disk)	m	0.3
Oil & Grease	mg/L	1.5
BIOLOGICAL/MICROBIOLOGICAL		
Chlorophyll-a	µg/L	25 [b]
CHEMICALS		
Ammoniacal Nitrogen (NH_3-N)	mg/L	2.7 [a]
Nitrate (NO_3-N)	mg/L	10 [c]
Total Phosphorus	mg/L	0.05 [d]

PARAMETER	UNIT	CATEGORY D
BIOLOGICAL/MICROBIOLOGICAL		
Biochemical Oxygen Demand (BOD_5)	mg/L	8
Chemical Oxygen Demand (COD)	mg/L	50
Clostridium perfringens (including spores)	-	nvd
Total Coliform	Counts/ 100ml	5000 [a]
E. coli	Counts/ 100ml	3000 [f]
Giardia sp	-	nvd
Leptospira sp.	-	nvd
Cryptosporodium sp.	-	nvd
Enterococci	Counts/ 100ml	nvd
Cyanobacteria	Cells/ ml	15 000 [h]

Appendix F: National Water Quality Index for Malaysia

National Water Quality Standards For Malaysia

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
Biochemical Oxygen Demand	mg/l	1	3	3	6	12	> 12
Chemical Oxygen Demand	mg/l	10	25	25	50	100	> 100
Dissolved Oxygen	mg/l	7	5 - 7	5 - 7	3 - 5	< 3	< 1
pH	-	6.5 - 8.5	6 - 9	6 - 9	5 - 9	5 - 9	-
Colour	TCU	15	150	150	-	-	-
Electrical Conductivity*	µS/cm	1000	1000	-	-	6000	-
Floatables	-	N	N	N	-	-	-
Odour	-	N	N	N	-	-	-
Salinity	%	0.5	1	-	-	2	-
Taste	-	N	N	N	-	-	-
Total Dissolved Solid	mg/l	500	1000	-	-	4000	-
Total Suspended Solid	mg/l	25	50	50	150	300	300
Temperature	°C	-	Normal + 2 °C	-	Normal + 2 °C	-	-
Turbidity	NTU	5	50	50	-	-	-
Faecal Coliform**	count/100 ml	10	100	400	5000 (20000)a	5000 (20000)a	-
Total Coliform	count/100 ml	100	5000	5000	50000	50000	> 50000

Notes
* = At hardness 50 mg/l $CaCO_3$
# = Maximum (unbracketed) and 24-hour average (bracketed) concentrations
N = Free from visible film sheen, discolouration and deposits

Sourse : EQR2006

DOE Water Quality Index Classification

PARAMETER	UNIT	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 Suspenbed Solid	mg/l	< 25	25 - 50	50 - 150	150 - 300	> 300
Water Quality Index (WQI)	-	< 92.7	76.5 - 92.7	51.9 - 76.5	31.0 - 51.9	> 31.0

Water Classes And Uses

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. Fishery II - Sensitive aquatic species.
Class IIB	Recreational use 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.

Sourse : EQR2006

Appendix G: Monitoring Data

TP, µg/L	OCT	NOV	DEC	JAN	FEB	MAR
Site 1	10±0	110±10	55±5	20±0	45±5	75±15
Site 2	15±2.5	80±10	45±5	35±5	15±5	80±20
Site 3	17.5±2.5	95±5	40±10	50±10	25±5	65±15
Site 4	17.5±1.5	105±5	60±0	45±5	30±0	135±5
Site 5	10±2.5	85±3.5	40±0	45±15	25±5	90±10

TN, mg/L	OCT	NOV	DEC	JAN	FEB	MAR
Site 1	0.55±0.05	1.10±0.30	0.90±0.05	0.55±0.05	0.65±0.05	2.30±0.20
Site 2	0.45±0.05	1.15±0.05	0.70±0.10	0.70±0	0.60±0.10	1.20±0.10
Site 3	0.75±0.05	1.45±0.15	0.95±0.05	0.95±0.25	0.70±0	2.20±0.20
Site 4	0.55±0.15	1.10±0.10	0.65±0.05	1.00±0.20	0.60±0	1.20±0.40
Site 5	0.60±0.10	1.75±0.15	0.65±0.05	1.35±0.15	0.60±0	4.60±0.30

Chla,µg/L	OCT	NOV	DEC	JAN	FEB	MAR
Site 1	19.6±1.0	24.4±0.5	21.2±0.3	22.4±1.0	22.0±2.0	17.6±0.5
Site 2	24.8±1.5	26.0±0.7	31.2±1.0	16.8±0.5	22.8±2.2	16.8±0.5
Site 3	33.6±1.3	32.8±0.8	34.0±0.5	44.4±1.5	37.6±1.8	30.8±1.0
Site 4	39.4±0.5	54.6±0.5	48.8±0.1	51.2±1.0	30.4±0.4	21.8±0.2
Site 5	42.4±2.0	39.4±0.4	46.8±0.1	17.2±1.0	25.2±0.6	26.8±0

SD (m)	OCT	NOV	DEC	JAN	FEB	MAR
Site 1	1.70	1.21	1.00	1.10	1.24	1.00
Site 2	1.20	1.20	1.45	1.30	1.20	1.10
Site 3	0.87	0.88	0.8	0.70	0.72	0.80
Site 4	0.80	0.87	0.85	0.70	0.85	0.80
Site 5	0.95	0.90	0.70	0.80	0.80	0.70

pH	OCT	NOV	DEC	JAN	FEB	MAR
Site 1	7.06±0.03	8.42±0.01	7.57±0.01	8.00±0.07	9.00±0.18	9.46±0.02
Site 2	7.03±0.03	8.33±0.01	7.41±0.01	8.56±0.04	8.53±0.18	8.99±0.03
Site 3	7.03±0.03	8.10±0.01	8.21±0.02	9.18±0.01	9.11±0.41	9.29±0.14
Site 4	6.93±0.05	8.37±0.01	7.75±0.01	8.80±0.31	8.26±0.43	8.84±0.07
Site 5	7.07±0.06	8.67±0.01	8.07±0.10	8.58±0.17	8.89±0.34	8.63±0.02

DO, mg/L	OCT	NOV	DEC	JAN	FEB	MAR
Site 1	3.64±0.03	6.49±0.06	5.78±0.02	6.86±0.03	6.22±0.01	6.61±0.06
Site 2	3.56±0.02	6.72±0.03	3.92±0.02	6.72±0.02	6.81±0.10	5.88±0.08
Site 3	3.28±0.04	6.00±0.03	6.34±0.02	7.00±0.09	6.55±0	7.16±0.02
Site 4	3.23±0.03	6.45±0.02	5.53±0.02	6.85±0.03	6.62±0.02	6.69±0.10
Site 5	3.25±0.03	6.47±0.18	7.56±0.01	6.84±0.03	6.96±0.01	6.31±0.97

Turbidty NTU	OCT	NOV	DEC	JAN	FEB	MAR
Site 1	13.80±0.80	9.61±0.40	10.06±0.15	9.29±0.10	12.47±0.72	18.03±1.04
Site 2	12.17±0.17	9.53±0.25	10.47±0.22	11.57±0.38	20.27±0.49	15.17±1.17
Site 3	12.03±0.09	11.24±0.72	13.67±0.03	54.27±1.72	12.70±0.26	15.13±0.69
Site 4	14.93±0.61	20.71±0.58	23.67±0.81	11.57±0.54	12.97±0.47	12.27±0.79
Site 5	9.62±0.21	10.35±0.72	54.07±4.07	8.84±0.29	16.37±0.47	22.67±0.64

Ammonia	OCT	NOV	DEC	JAN	FEB	MAR
Site 1	0.325±0.005	0.230±0	0.505±0.015	0.405±0.015	0.920±0.005	0.045±0
Site 2	0.515±0.005	0.225±0.01	0.550±0	0.425±0.005	0.980±0.070	0.090±0.01
Site 3	0.345±0.015	0.255±0.05	0.325±0.005	0.345±0.005	0.280±0.020	0.040±0.01
Site 4	0.285±0.005	0.195±0.03	0.315±0.005	0.325±0.015	0.800±0.010	0.110±0.01
Site 5	0.245±0.005	0.130±0.03	0.490±0	0.390±0.010	0.640±0.010	0.090±0.01

COD	OCT	NOV	DEC	JAN	FEB	MAR
Site 1	22.5±2.5	20.0±1.0	16.35±0.65	15.5±4.5	17.0±1.0	12.0±1.0
Site 2	19.5±0.5	20.5±2.5	21.50±2.50	14.5±1.5	15.0±1.0	10.0±2.0
Site 3	17.0±1.0	31.0±1.0	21.50±0.50	12.0±1.0	16.5±1.5	11.5±1.5
Site 4	23.0±1.0	21.5±2.5	19.65±3.35	19.0±5.0	22.0±1.0	14.5±0.5
Site 5	22.5±0.5	24.0±2.0	23.70±0.70	18.5±1.5	13.0±1.0	17.0±1.0

Appendix H: Possible source of nutrients

Appendix H (1): Cow dung around UTAR Kampar lake

Appendix H (2): Fertilizer used for UTAR Kampar lake

Appendix H (3): Detergent used by cafeteria

Appendix H (4): Dead leaves nearby the river connected to East lake (site 3)

Appendix H (5): Residential nearby West Lake