AN EVALUATION OF WATER QUALITY OF SEPANG KECIL RIVER IN SELANGOR

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KUALA LUMPUR

2017

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DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF TECHNOLOGY

INSTITUTE OF BIOLOGICAL SCIENCES
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UNIVERSITY OF MALAYA
KUALA LUMPUR

2017

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ABSTRACT

This study was conducted once a month from May 2014 to February 2015 at five sampling stations. This study was carried out to determine the water quality of the Sepang Kecil River based on the Water Quality Index (WQI) and the diversity of phytoplankton. A total of 19 parameters were analyzed which were the water temperature, pH, total dissolved solid (TDS), conductivity, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solid (SS), turbidity, salinity, ammoniacal nitrogen (NH_3-N), chlorophyll *a* and including seven anions of fluoride, chloride, nitrite, bromide, nitrate, phosphate, and sulphate. Based on the National Water Quality Standard of Malaysia (NWQS), the result showed that DO, BOD, NH_3-N and SS fall under Class III while pH, conductivity and TDS were categorized under Class I. Other than that, the turbidity and the COD were classified under Class II and Class IV respectively. Based on the NWQS for Malaysia, only fluoride and chloride were classified under Class I and Class II respectively while the rest of the anions fall under Class V. Based on the ANOVA analysis from the SPSS (Statistical Package for the Social Sciences) programme, it was found that the DO, BOD, NH_3-N and the salinity shown a significant difference in between the five stations and the nine months. Overall, the WQI for the Sepang Kecil River was recorded as slightly polluted which was classified into Class III with the value of 69.0. A total of 37 species from four divisions namely Bacillariophyta, Chlorophyta, Cyanobacteria, and Pyrrophyta were recorded during this study. Division of Chlorophyta and Bacillariophyta were dominated in this study. The results from the water quality classification based on overall H' values showed slightly polluted level and high diversity of phytoplankton was found in the downstream of the Sepang Kecil River. Phytoplankton has a positive correlation with BOD, COD, NH_3-N, conductivity, salinity and chlorophyll *a*, nitrite, bromide, phosphate and sulphate.

ABSTRAK

Kajian ini dijalankan sekali setiap bulan bermula dari bulan Mei 2014 sehingga Februari 2015 di lima stesen. Kajian in dijalankan untuk menentukan kualiti air Sungai Sepang Kecil berdasarkan Indeks Kualiti Air (WQI) dan kepelbagaian fitoplanton. Sebanyak 19 parameter telah dijalankan dan dianalisis yang merupakan suhu air, pH , jumlah pepejal terlarut (JPT), konduktiviti, oksigen terlarut (OT), keperluan oksigen biokimia (KOB), keperluan oksigen kimia (KOK) , pepejal termendap, kekeruhan, kemasinan, nitrogen ammoniakal , klorofil *a* dan termasuk tujuh anion fluorida, klorida, nitrit, bromida , nitrat ,fosfat dan sulfat. Berdasarkan NWQS untuk Malaysia, keputusan menunjukkan bahawa OT, KOB , nitrogen ammoniakal dan pepejal termendap berada di Kelas III manakala pH, konduktiviti and JPT berada di Kelas I. Selain daripada itu, kekeruhan dan KOK masing-masing diklassifikasikan dibawah Kelas II dan Kelas IV. Berdasarkan NWQS untuk Malaysia, hanya fluorida dan klorida diklassifikasikan dibawah Kelas I dan Kelas II manakala anion yang lain di bawah Kelas V. Berdasarkan analisis ANOVA dari SPSS (Statistical Package for Sains Sosial) yang diprogramkan , didapati bahawa OT, KOB, nitrogen ammoniakal dan kemasinan pula telah menunjukkan perbezaan signifikasi antara lima stesen dan sembilan bulan. Secara keseluruhan , WQI untuk Sungai Sepang Kecil menunjukkan tahap sedikit tercemar yang dikategorikan berada di dalam Kelas III dengan nilai 69.0. Sebanyak 37 spesies daripada empat kumpulan iaitu Bacillariophyta , Chlorophyta , Cyanobacteria, dan Pyrrophyta telah direkodkan semasa kajian ini. Chlorophyta dan Bacillariophyta mendominasi dan kebanyakannya ditemui dalam kajian ini. Keputusan dari klassifikasi kualiti air berdasarkan keseluruhan nilai H' menunjukkan tahap pencemaran sedikit dan nilai kepelbagaian spesis yang tinggi di jumpai di kawasan bawah sungai. Fitoplankton mempunyai hubungan yang positif dengan KOB, KOK, nitrogen ammoniakal, konduktiviti, kemasinan, klorofil *a*, nitrit, bromida, fosfat dan sulfat.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my deepest and greatest appreciation to my supervisor, Assoc. Prof. Dr. Rozainah Mohamad Zakaria and Dr. Pozi Millow for their continuously supporting, guide, spending time, giving their knowledge and expertise, advising me throughout the dissertation process and also supported me in terms of funding (Research Grant No: RU006G - 2014). Secondly, I would sincerely express my special thanks to the Department of Environment, laboratory assistant, university drivers, boatman (Encik Edy), who directly or indirectly helped me for providing information and guidance about the research.

Besides that, I would like to deeply thank to my fellow closest friend (Farahin, Adibah and Masitah) and also fellow MTECH classmates for their support and motivation that encouraged me to complete my masters. Without their encouragement and supportive word, I may have not able to finish and complete my entire dissertation writing process.

Moreover, I would like to express a lot of thanks to my beloved parents (Masnaliza Abdul Hamid and Abdul Raof Ismail) for all the financial support, their understanding and support throughout my study and research. Lastly, a big appreciation to my family for all their encouragement towards me is completing this study. I truly and sincerely offer my deepest gratitude to all people that I mention above.

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LIST OF SYMBOLS AND ABBREVIATIONS

BOD	:	Biochemical oxygen demand
Br^-	:	Bromide
Cl^-	:	Chloride
COD	:	Chemical oxygen demand
CO_2	:	Carbon dioxide
DO	:	Dissolved oxygen
DOE	:	Department of Environment
F^-		Fluoride
IC	:	Ion chromatography
km		Kilometer
L or l	:	Liter
m	:	Meter
mg	:	Milligram
ml	:	Milliliter
NH_3-N	:	Ammoniacal nitrogen
nm	:	Nanometer
NO_2^-	:	Nitrite
NO_3^-	:	Nitrate
NTU	:	Nephelometric turbidity units
NWQS	:	National Water Quality Standard
PO_4^-	:	Phosphate
SI	:	Sub-index
SO_4^{2-}	:	Sulphate
sp	:	Species

TDS	:	Total dissolved solid
SS	:	Suspended solid
µg	:	Microgram
µS	:	MicroSiemens
WQI	:	Water quality index
°C	:	Degree celcius

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

Water is one of the most important substances on earth. All living organism need water to survive. Rivers are vital resource for life (Amneera *et al.*, 2013). A river is a natural freshwater that flows towards a larger body of water such as an ocean, a sea, a lake or another river. Rivers are an important part of the hydrological cycles or water cycle. Rivers have been used as source of water by human in many ways ranging from recreational activities such as fishing and boating to more commercial applications such as transportation, crop irrigation, drinking water, bathing, and many more. Also, for animal and plants, rivers provide source of water and home or hunting ground for many organism. Additionally, the rivers play an important role in assimilating municipal and industrial effluent as well as runoff from agricultural land and the surrounding area in a watershed (Sigua and Tweedale, 2003)

Water quality models are often implemented in order to quantify biological, physical, and chemical transformation of constituents of interest, and to investigate the impact of altered boundary conditions on aquatic ecosystems (Wagenschein and Rode, 2008). “Water quality” is a term used here to express the suitability of water to sustain various uses or processes. Any particular use will have certain requirement for the physical, chemical or biological characteristics of water (Bartram and Balance, 1996). Water quality changes rapidly in response to a number of influences. Consequently, water quality can be defined by a range of variables which limit water use (Bartram and Balance, 1996). Water quality can be measured and analyzed chemically, biologically and physically. Water quality changes over time, necessitating repeated measurements to characterize variations in quality adequately.

To know the quality of water, there are many parameter involve where by conducting this parameters such as pH, dissolved oxygen (DO), turbidity, conductivity, Total Dissolved Solid (TDS), Total Suspended solid (TSS), salinity, temperature and others we can see any changes of the rivers have occurred over times. These parameters can be measured to determine and monitor the quality of water of rivers. It is also important to monitor water quality in combination with other parameters as they may be used to help explain biological responses such as chemical and biological parameter. The methods of collecting water quality data depend upon the property or parameter to be measured, the scale of the study, and the questions to be addressed (Bierman *et al.*, 2011). Furthermore, according to Bartram and Balance (1996), efforts to improve or maintain a certain water quality often compromise between the quality and quantity demands of different users.

However, human intervention has also significantly effects on water quality (Bartram and Balance, 1996). Water pollution is the contamination of water bodies such as rivers, lakes, oceans and groundwater. Significantly, urbanization is major contribution to the increase in water pollution. Rivers in urban areas also have been associated with water quality problems because of the practice of discharging of untreated domestic and industrial waste into the water bodies which leads to the increase in the level of metals in river water (Khadse *et al.*, 2008; Venugopal *et al.*, 2009). Land use is the primary factor causing habitat degradation and poor water quality (Wear *et al.*, 1998). The threat of rapid and often devastating changes to water quality through both anthropogenic and natural mechanisms is often increased as a result of the connection to the land. Changes in water quality can be potentially catastrophic for marine ecosystems as species are threatened by conditions which are no longer suitable for their survival. These changes in water quality also pose threats to humans through changes in waters utilized for recreation, fishing and industry. It is clear that human reliance on these precious resources requires regulatory interventions and that robust and reliable ecosystem condition indicators are needed for decision making (Pinto *et al*., 2009).

Rivers are polluted from point (PS) and non point sources (NPS). Point sources refer to contaminants that enter a waterway from a single source. Point sources mainly include discharge from the industrial sewage treatment plant or municipal sewage from the residential areas. Meanwhile, non point source defined as diffuse contamination from a wide area that does not originate from a single location. Non point source occurs when rainfall, snowmelt water or irrigation water runs over land, carrying and depositing pollutants into rivers, lakes, and coastal waters (Wu and Chen, 2013).

Rainfall runoff as storm water is one of the major non point sources especially from the urban areas. As the runoff moves, it washes away contaminant from the urban such as oil, grease, dust, or chemical substances and finally carries them into lakes, rivers, and other water bodies. Also, non point sources which from farming area include pesticides, fertilizers, animal waste can be washed through the soil by rain and runoff into rivers. However, if large amount of fertilizers or farm waste deposit into river, it will lead to pollution due to nutrient enrichment. Water quality is affected by a wide range of natural and human influences. The most important of the natural influences are geological, hydrological and climatic since these affect the quantity and the quality of water available (Bartram and Balance, 1996).

Rivers also play important role to other ecosystem as they support vegetative growth such as mangrove habitat as mangrove forest thrive near the mouths of large rivers where river deltas provide lots of sediment (sand and mud). Mangroves forest is a type of unique forest ecosystem which can be found along the sheltered coast where they grow abundantly in saline soil and brackish water. Mangroves are defined by the presence of trees that mainly occur in the intertidal zone, between land and sea, in the (sub) tropics (Nagelkerken *et al*., 2008). Mangrove forests and their inhabitants are therefore fairly robust and highly adaptable (or tolerant) to life in waterlogged saline soils within warm, subtropical and tropical seascapes (Alongi, 2008). Many studies have demonstrated that mangroves have made a significant contribution to the removal of nutrients and organic matter from waste water (Sansanayuth *et al.*, 1996; Wong *et al*., 1997; Chu *et al*., 1998; Tilley *et al.*, 2002) and to the maintenance of estuarine water quality (Saenger, 2002).

Mangroves play an essential role in protecting water quality and in the coastal tropic chain (Day *et al.*, 1996). Increased sediment loads in runoff from catchments affect mangrove distributions within estuaries as well as water quality (Duke *et al.*, 2003). Although the natural ecosystem is in harmony with natural water quality, any significant changes to water quality will usually disruptive to the ecosystem (Bartram and Balance, 1996). Although degradation of water quality is almost invariably the result of human activities, certain natural phenomena can also result in water quality falling below the requirement for particular purposes (Bartram and Balance, 1996). According to Bartram and Balance (1996), natural events such as torrential rainfall and hurricanes has lead to excessive erosion and landslides, which in turn increased the content of suspended material in affected rivers and lakes.

Living organisms play major roles in many aspects of water quality control and thus the assessment of the biological characteristic of water is often of great significance (Tebbutt, 1992). Algae can be found in almost every environment such as the oceans, freshwater rivers, lakes, ponds, hot springs, snow, soil, trees, rocks and even or certain animals, including sea anemones, corals, worms or on the shell of bivalve (Salleh and Tajuddin, 2006). Generally, the distribution and abundance of phytoplankton in tropical waters varied remarkably due to the environmental fluctuations during season and these variations are well pronounced in the sheltered costal systems like mangroves (Rajkumar *et al.*, 2009). Too many algae and other organism can reduce water quality, block rivers and canals (Salleh and Tajuddin, 2006). Phytoplankton can be classified according to their division. There are four main division of phytoplankton which are Bacillariophyta (Diatom), Chlorophyta (Green Algae), Cyanobacteria (Blue-green Algae), Pyrrophyta (Dinoflagellate).

1.2 Problem Statement

In Malaysia, water quality deterioration of rivers is one of the most common issues. Lately, clean fresh water has become scarce. In the last few decades, the accelerated pace of industrial development and progressive growth of population caused in tremendous increase in the demand of fresh water (Ramakrishnaiah *et al.*, 2009). Sepang Kecil River has been chosen for this water quality studies because of its importance and function to the communities. Sepang Kecil River serves as very important resources for all aspects of human and ecosystem living around this area. Rivers comprise the most important water resources for irrigation, domestic water supply, industrial, and other purposes in a watershed, thereby tending to stimulate serious hygienic and ecological problems. Consequently, prevention and controlling of river pollution and reliable evaluation of water quality are an imperative stipulation for effective management (Chen *et al.*, 2003).

Sepang Kecil River is surrounded by various residential area, plantation and tourism places. Besides that, this river is known as one of the recreation destination for mangrove tour and fishing activities in Sepang. Due to the rapid development and urbanization process around the area made Sepang Kecil River vulnerable to human activities and susceptible to water quality degradation. Anthropogenic pollutants related to land use result in drastic deterioration of aquatic systems in watersheds (Gasim *et al.*, 2002). Apart from that, the discharge of excessive nutrients from urban and industrial wastewaters, or rural and agricultural runoff contributes to the enrichment of inorganic and organic material in marine waters (Soo *et al.*, 2016).

Excessive of nutrients into the river also can cause an increase of algal production. Often, the ‘‘bloom’’ or greatly increase of aquatic vegetation or phytoplankton and algal in a water body is the first response to the increased levels of nutrients or the eutrophication (Pan and Rao 1997; Smith *et al*,. 1999). Eutrophication can be defined as the process of increasing nutrients of an ecosystem that causes changes to its nutritional status (Nixon, 1995). Therefore, this water quality study is employed to determine the current status level of pollution of the Sepang Kecil River in order to implement some strategies to solve the problem and to be used for the river basin management in the future.

1.3 Objectives

The main objectives of this study are:

I. To determine the physical and chemical parameters as well as species composition of phytoplankton of Sepang Kecil River

II. To classify Sepang Kecil River based on Water Quality Index (WQI)

III. To identify the effects of anthropogenic land use activities on the water quality of Sepang Kecil River

IV. To relate the water quality of Sepang Kecil River and the presence of phytoplankton species according to Shannon-Wiener Diversity Index.

Therefore, the aim of this study is to provide detailed information on the evaluation of current status of water quality of Sepang Kecil River. This water quality data collection in this research could be useful for the river monitoring efficiently in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 River Water Quality

Major rivers especially in developing countries continuously face a severe degradation of water quality. As a result, it becomes a threat to the ecosystem and also to human health. The water quality status of rivers in Malaysia has always been a cause for concern to government as well as the public. According to Department of Environment (2013), out of the 473 rivers monitored, 275 (58.1%) were asserted to be clean, 173 (36.6%) were slightly polluted and another 25 (5.3%) were found to be polluted.

Conducting water quality assessment plays a major role to know the condition of the river ever since anthropogenic activities has caused river ecosystem to change at a more rapid rate. This is because the water in a river is always moving and mixing. Pollutants that enter the river will flow to some distance before they are throughout mixed. The quality of receiving waters is affected by human activities in water bodies through point source pollution, such as wastewater treatment facilities and non point source NPS) pollution, such as runoff from urban areas, mining and farmlands (Lenat and Crawford, 1994)

According to Bartram and Balance (1996) also state that more obvious are the polluting activities, such as the discharge of domestic, industrial, urban and other wastewaters into the water-course (whether intentional or accidental) and the spreading of chemicals on agricultural land in the drainage basin. Examples of non point sources of pollution include urban land use, agricultural practices, and transportation infrastructures (Tong and Chen, 2002; Ribolzi *et al.*, 2011; Liu *et al.*, 2009). Other non point sources example includes sediment runoff such as from forest land and construction site. NPS pollution is more diffuse and harder to identify, isolate, and control compared to point source pollution (Dzikiewicz, 2000; Ouyang *et al.*, 2009). Urban growth and the concentration of people could increase environmental problems related to soil degradation which have important implications on water quality (Young *et al.*, 1989). Common sources of pollution to streams include agricultural activities, municipal dischargers and urban runoff such as from city streets or parking lots. Moreover, the range of deterioration in water quality in the river varied depending on the percentage of change in land use. (Al-Badaii *et al*., 2013)

In 2013, the Department of Environment (DOE) continued with the river water quality-monitoring programme, to determine the quality of river water and to detect any changes in quality of the river. There are many studies conducted recently to evaluate the water quality of rivers or lakes in Malaysia. Mostly, all studies using WQI calculation method to classify the quality of the river based on the physical and chemical properties and some of the example of river water quality in Malaysia can be seen in Amneera *et al*., (2013) and Al-Badaii *et al*., (2013).

The study by Amneera *et al*., (2013) was carried out on water quality of Perlis River at three sampling stations. The three stations marked as Kangar City (Station 1), Department of Irrigation and Drainage (DID) monitoring station at Esplanade Pengkalan Asam (Station 2) and Kangar wet market (Station 3). There were residential areas nearby all the three stations and also only station 1 nearby the commercial area. It was found that station 2 was categorized as slightly polluted where it class of classification in range of 60 to 80 whereas station 1 and station 3 were categorized into polluted range as in range of 0 to 59 where station 1 to station 3 of WQI as 58.30, 61.87 and 41.64 respectively. Station 3 was the lowest in quality compared to others due to wastewater produced from nearby activity, namely wet market. The overall WQI for three months recorded as slightly polluted which has class range from 60 to 80. The study by Al-Badaii *et al*., (2013) was carried out to determine the Semenyih River water quality. This study indicated that the river water quality is slightly polluted and can be used for irrigation with precaution, and it is in need for any form of treatment to be used for domestic purposes

Usually, the studies on the water quality are mainly based on the effect of rapid development nearby the rivers. For example, the study by Gandaseca *et al*., (2011) was carried out on river water quality at Sibuti Wildlife Sanctuary, Miri based on the physicochemical properties. This river study at Sibuti Wildlife Sanctuary was conducted because of the rapid development and other land uses in the mangrove areas over the years had negatively affected the ecological functions and its ecosystem.

2.2 Water Quality Index

Knowledge on the water quality of a particular river is of upmost in determining the suitability of the river water to be used for domestic purpose as well as for providing suitable habitat for aquatic organism (Zulaikha-Othman *et al*., 2009). In Malaysia, the Department of Environment of Malaysia (DOE) has developed a Water Quality Index (WQI) (also referred DOE-WQI) system to evaluate the status of the water quality of rivers in country. The Water Quality Index (WQI) was used to indicate the level of pollution and the suitability in terms of water uses according to the Interim National Water Quality Standards for Malaysia (INWQS) (Department Of Environment, 2013). The WQI takes into consideration six important parameters which are Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH3-N), Suspended Solids (SS) and pH (Department of Environment, 2013). Calculations are performed based on their sub-indices where The Best Fit Equations were used for the estimation of the six sub-index values as shown in Appendix A. The sub-indices are named SIDO, SIBOD, SICOD, SIAN, SISS and SIpH.

The water quality parameter data that obtained were used to classify the river and its uses either in Class I, II, III, IV or V based on National Water Quality Standards for Malaysia (NWQS) as shown in Table 2.1 and Table 2.2. The value of water quality index also was used to determine the status of river water quality weather in clean, slightly polluted or polluted category (Table 2.3). Generally, WQI is a unitless number varies between 0 and 100. A higher index value represents good water quality. Therefore, a numerical index is used as a management tool in water quality assessment (Avvannavar and Shrihari, 2008).

Table 2.1: National Water Quality Standards for Malaysia

Parameter	Unit	Class					
		I	IIA	IIB	III	IV	V
DO	mg/l	<7	5-7	5-7	3-5	1-3	<1
BOD	Mg/	<1	1-3	1-3	3-6	6-12	>12
COD	Mg/l	<10	10-25	10-25	25-50	50-100	>100
NH3-N	Mg/l	<0.1	0.1-0.3	0.1-0.3	0.3-0.9	0.9-2.7	>2.7
TSS	Mg/l	<25	25-50	25-50	50-150	150-300	>300
pH	-	>7	6-7	6-7	5-6	<5	<5
Temperature	°C	-	Normal ± 2	-	Normal ± 2	-	-
TDS	Mg/l	500	1000	-	-	4000	-
Conductivity	umhos/cm	1000	1000	-	-	6000	-
Salinity (%)	%	0.5	1	-	-	2	-
Turbidity	NTU	5	5-50	5-50	-	-	-
F	Mg/l	Natural levels or absent	1.5	1.5	10	1	Levels above IV
Cl	Mg/l		200	200	-	80	
NO_2	Mg/l		0.4	0.4	0.4(0.03)	-	
NO_3	Mg/l		7	7	-	5	
SO_4	Mg/l		250	250	-	-	
WQI	-	>92.7	76.5-92.7		51.9-76.5	31.0-51.9	<31.0

Sources: (Department Of Environment, 2013)

Table 2.2: Water Classes and Uses

Class	Uses
Class I	Conservation of natural environment water supply 1 – practically no treatment necessary Fishery I – very sensitive aquatic species
Class IIA	Water supply II – conventional treatment required Fishery II – Sensitive aquatic species
Class IIB	Recreational use with body contact
Class III	Water supply III – Extensive treatment required Fishery III – Common, of economic value and tolerant species, livestock drinking
Class IV	Irrigation
Class V	None of the above

Sources: (Department Of Environment, 2013)

Table 2.3: DOE Water Quality Classification based on Water Quality Index

SUB INDEX & WATER QUALITY INDEX	INDEX RANGE		
	CLEAN	SLIGHTLY POLLUTED	POLLUTED
Water Quality Index (WQI)	81 - 100	60 - 80	0 - 59

Sources: (Department Of Environment, 2013)

2.3 Water Quality Parameter

It is important for a healthy river to have a good water quality. In order to determine the health of the river water, various water quality parameters need to be measured so that it is safe to use for any purpose. In order to develop a water quality or river index, there are several physical and chemical parameters that need to be conducted. The water temperature is a measure of the heat content in the water. Temperature can influences the growth rate of aquatic life. Different species of fish have different needs for an optimum temperature and tolerances of extreme temperatures (Davis and McCuen, 2005).

Total dissolved solid (TDS) indicates measurement of solid (usually mineral salts) that are dissolved in water. This total dissolved solid has close connection with conductivity. Hence it can influence the conductivity of water. The more dissolved salts are dissolved in the water, the higher the value of conductivity. The ions from the dissolved solids in water create the ability for that water to conduct an electric current. Conductivity is a measure of the ability of water to conduct an electric current. Also, conductivity can be affected by the temperature where an increase in temperature can increase the conductivity. Moreover, conductivity is related to suspended solid and dissolved solid. Water shows significant conductivity when dissolved salts are present. Generally, most of the freshwaters conductivity is ranging from 10 to 1000 μS/cm. Nevertheless, the concentration can exceed about 1000 μS/cm in the water that receiving pollution (Harun *et al.*, 2010).

Turbidity measurements are important in the field of the water supply because of aesthetic point of view reasons to people. Higher turbidity can increase the temperature of water because suspended materials will absorb more heat. Thus, this will reduce the concentration of dissolved oxygen (DO) as water hold less DO than cold water. Also, higher turbidity can reduces the amount of sunlight penetrating into the water which can affect the photosynthesis process. High concentrations of particles can damage the habitats for fish and other aquatic organisms (Said *et al*., 2004). Turbidity can come from suspended sediment such as silt or clay, inorganic materials, or organic matter such as decaying material. Turbidity expressed in nephelometric turbidity units (NTU). Salinity is a measure of the content of dissolved salt in water. Salts are highly soluble in surface and groundwater and can be transported by movement of water. Too much amount of dissolved salt in water can affect agriculture, drinking water supplies and also to ecosystem health. However, some of aquatic life can adapt too many range of salt concentration.

Chlorophyll *a* is a main green photosynthetic pigment that can be found in all plants and also algae. It is a sensitive indicator of algal biomas. Chlorophyll *a* concentration has been used to assess nutrient environmental of streams, even in regional-scale studies (Leland, 1995; Pan *et al*., 1999). Measuring chlorophyll *a* concentration in water is a surrogate for an actual measurement of algae biomass (Tong et *al*., 2003). Chlorophyll concentrations represent a simple and integrative measure of the phytoplankton community response to nutrient enrichment or succession (Devlin *et al*., 2007; Harding, 1994). The value of concentration of Chlorophyll *a* may be influenced by anthropogenic effects and evidenced by its positive correlation with salinity and may also be due to the fresh water discharges from the rivers, causing turbidity and less availability of light (Kawabata *et al*.. 1993; Rajasekar *et al*., 2005).

Dissolved Oxygen (DO) is defined as the amount of oxygen that dissolved in water. This oxygen can get into water by diffusion from the surrounding air, by aeration which has rapid movement and as a waste product of photosynthesis. Dissolved oxygen also can be a good indicator of aquatic health as all respiring organisms require oxygen

(Bong and Lee, 2008). The presence of natural organic matter, waste discharge from domestic, agricultural and industrial effluent also depletes the DO content (Yang *et al*., 2007; Yayintas *et al*., 2007). Yayintas *et al*., (2007) stated that DO values less than 3 mg/L indicate the occurrence of water pollution. Numerous scientific studies suggest that 4–5 mg/l of DO is the minimum amount that will support a large, diverse fish population and typically DO levels less than 2 mg/l will kill fish (Ching *et al*., 2015).

The biochemical oxygen demand (BOD) is defined as the amount of oxygen required by the bacteria to stabilize the organic matter under aerobic conditions. If there is a large quantity of organic matter, the rate of decomposition process increases because the rate of oxygen consumption in the water increases. Eventually, the BOD levels become high due to oxygen demand increasing. When BOD levels become high, the dissolved oxygen decreases because is being consumed by bacteria. If the concentration of BOD is higher, hence the water is considered to be polluted. 5 days BOD (BOD_5) is the most widely used parameter of organic pollution applied to wastewater and surface water (APHA, 1992). This test is used by taking an initial dissolved oxygen reading and a second reading after five days of incubation at 20 ^{o}C. The BOD value is expressed as in milligram per liter (mg/l) which indicates the oxygen consumed per liter of sample during 5 days of incubation at 20 ^{o}C.

The chemical oxygen demand (COD) test is a useful measure of water quality as it is used to determine the amount of organic pollutant that found in surface water. If the concentration of COD is higher, the water considered to be polluted. Ammoniacal nitrogen (NH_3-N) may be present in solution as either ammonia or ammonium ion which it depending on the temperature and pH. Ammonia is an inorganic form of nitrogen that can be found in fertilizers, animal waste and also sewage. This form can be toxic to aquatic organisms. The main sources of NH_3-N were found to be from livestock farming and domestic sewage (Department Of Environment, 2013). Ammonia is oxidized to nitrite and then oxidized to nitrate through nitrification process under anaerobic conditions. Ammonia also a nutrient for algae and other forms of plant life, however if this amount of ammonia overload can cause pollution. NH_3-N is an important parameter for water quality analysis; as water quality degradation due to ammoniacal nitrogen remains a crucial environmental and public concern worldwide; because it can cause eutrophication (Wang *et al.*, 2010)

Suspended solids (SS) usually referred to as small particles of solid in water which remain as suspension either as a colloid or due to the motion of the water. Suspended solid that presence in the river water usually consist of clay, silt, fine particles of organic and inorganic matter, plankton, algae and other particulate matter. This suspended solid is not good especially for the aquatic habitat. High suspended solid will prevent the sunlight to penetrate into water which can cause the aquatic plant unable to do photosynthesis process and eventually will die. Furthermore, this suspended solid has close related with turbidity as both can cause the water to be milky or muddy looking.

pH is a measure of the acidity or alkalinity strength in the water. pH express the intensity of the acidity and alkalinity of water where it is associated with the hydrogen ion in water. The lower the pH, the higher the H+ activity and the more acidic is the water (Davis and McCuen, 2005). Most aquatic lives are sensitive to pH variations, leading to fish kills and reduction and changes in aquatic communities when the pH is altered outside their tolerance limits of pH 5–9 (Ching *et al.*, 2015). High value of pH is recorded in waters with high organic content and eutrophic condition (Kalff, 2002).

Fluoride (F^-) is a form of salts where the element of fluoride combines with minerals in soil or rocks. Generally, fluorides can enter the water from fertilizer runoff or aluminum factories. Fluorides can be present in water and usually higher concentration is associated with underground sources. Fluoride is used in certain industrial processes and consequently occurs in the resulting wastewater (Bartram and Balance, 1996). Insecticides and herbicides containing fluorides reach water sources through agricultural runoff (Benefield *et al.*, 1982).

Chlorides (Cl^-) can be present in both freshwater and saltwater. Chloride ions occur mostly as sodium chloride or other salts form such as potassium chloride, calcium chloride and magnesium chloride. These chloride ions can come into the water from ground aquifers or geological formation such as groundwater. Moreover, chloride compound are highly soluble in water. Factors such as road salt, sewage contamination, and water softeners are mainly the sources of chloride. Furthermore, high concentration of chloride in freshwater can harm the aquatic life by interfering with their osmoregulation where this process involve the maintaining of proper salt concentration in their body. By disturbing this process, it can affect their survival, growth and reproduction. Fish and other aquatic life forms cannot survive in high levels of chlorides (Sulaiman *et al.,* 2014).

Bromide (Br^-) is the anion of the element bromine. Commonly, bromide can be found in nature along with the sodium chloride but in smaller quantities. Bromine is a naturally occurring element that can be found in many inorganic substances. Usually bromide comes from runoff water from the agricultural activities and has very negative health effect to the aquatic life. Nitrates (NO_3^-) and nitrites (NO_2^-) are forms of nitrogen. Nitrite is an unstable, intermediate stage in the nitrogen cycle and is formed in water either by the oxidation of ammonia or by the reduction of nitrate (Bartram and Balance, 1996). The possible way of entering nitrate into the estuarine water is through oxidation of ammonia form nitrate to nitrite formation (Rajasegar, 2003). Nitrites can also cause serious illnesses in fish (Davis and McCuen, 2005). Meanwhile, nitrates can be found in terrestrial and aquatic ecosystem. However, if the amount is excess, it can cause significant water quality problems although they are essential for plant as nutrients.

Apart from that, excess of nitrates can cause eutrophication. Hence, it will affect other indicator such as dissolved oxygen and temperature. Also, excessive of nitrates can hypoxia (low levels of dissolved oxygen) and can become toxic to warm-blooded animals. The NO_3^- ion is usually derived from anthropogenic sources like agricultural fields, domestic sewage and other waste effluents containing nitrogenous compounds (Das and Acharya, 2003). However, nitrate is much less toxic than ammonia and nitrite (Romano and Zeng, 2007).

Phosphorus (PO_4^-) is naturally present in water mainly as inorganic and organic phosphates. The major contribution of the presence of phosphorus in streams are soil erosion where a lot of phosphorus being transport during flood. Also, rainfall can cause many amount of phosphate to wash from farm soil for example into the nearby waterways. Rainfall causes varying amounts of phosphates and phosphorus to wash from farm soils and soils treated with certain pesticides into waterways (Sulaiman *et al.,* 2014).

Phosphorus is an essential element to plant but if in excess it can cause eutrophication. They may cause a decrease in the DO levels of the water, and in some cases temperature rise. This can result in a fish kill and the death of many organisms (Said *et al*., 2004). Excess phosphates, however, may cause an excessive growth in algae and aquatic plants, choking waterways and using up large amounts of oxygen, referred to as eutrophication (Sulaiman *et al.,* 2014).

Naturally, sulphate (SO_4^{2-}) is a substances that containing sulphur and oxygen. Sulphate can be present in various mineral salts that are found in soil. Sulphate are soluble in water. The sources of sulphate in the water are mainly from the decaying plant and animal matter. Also, sources from the chemical product such as fertilizers. Sulphate fertilizers are identified as a major source of sulphate to ambient waters (Kellogg *et al*. 1972).

2.4 Phytoplankton

Microscopic algae, called phytoplankton, float or swim in lakes and oceans which comprise a wide range of size, from the largest forms which are visible to naked eye to the smallest that are microscopic (Salleh and Tajuddin, 2006). Phytoplankton contains chlorophyll and they require sunlight in order to live and grow where they also carry out photosynthesis process. This phytoplankton also contributes to the production of oxygen to the Earth's atmosphere other than the terrestrial plant. Moreover, phytoplankton is the basis of the several food chains for freshwater and marine organism. As phytoplankton grow and multiply, zooplankton (small invertebrate animals that swim), aquatic insects, small fish and other animals eat them as food (Salleh and Tajuddin, 2006).

As phytoplankton play an important role for providing source of food to fishes, this phytoplankton can be harmful to them also. When there are too many nutrients available, this phytoplankton can be rapidly increase in growth and eventually form algal blooms. Excessive loads of nutrients to lakes and streams negatively affect ecosystem structure and function by changing dissolved oxygen regimes, increasing algal biomass, altering biological communities, food webs, rates of nutrient and carbon cycling (Smucker *et al.*, 2013). According to Salleh and Tajuddin (2006), there are two divisions of microscopic algae commonly predominant in marine ecosystem; Bacillariophyta (diatoms) and Pyrrophyta (dinoflagellates). Meanwhile in freshwater, the dominant species are Chrysophyta, Cyanobacteria, Chlorophyta, and Bacillariophyta.

Bioindicator is defined as living organism or species that can be used to monitor the health of an environment or ecosystem. Algal communities quickly reflected environmental stressors because of their short life cycles (McCormick & Cairns Jr, 1994). Phytoplankton community structure as bioindicator provides unique information about the ecosystem. This information is potentially useful as an early warning sign of deteriorating condition and thus gives insight into the overall ecology of lakes and will assist in the future conservation and management of this lentic ecosystem (Maznah and Makhlough, 2015). Algae can respond rapidly to changes in environment. Phytoplankton is an efficient indicator of changes in nutrient loads, but is also effective in evaluating responses to many other environmental stressors, due to its fast population response to changes in water quality, hydrology or climate (Domingues *et al.*, 2008).

Using phytoplankton as bioindicator give rapid information of water quality changes due to their short life spans and also they give quick response to pollutants that presence in water. The uses of algal communities correlated to water pollution (Sonneman *et al.*, 2001). According to Pawar *et al.*, (2006), the phytoplankton study is a very useful tool for the assessment of biotic potential and contributes to overall estimation of basic nature and economic potential of water body. Hence, bio monitoring based on algal studies is necessary to provide sufficient information in water quality deterioration in reservoirs (Swaminathan, 2003; Yap, 1997).

Species diversity is the number of species and abundance of each species that live in a particular given area. The nature of species diversity in relation to species composition and phytoplankton density is a notable feature in any aquatic ecosystem (Chandran, 1985). Phytoplankton community descriptors such as total abundance, species richness and diversity were considered indicators of the system's health condition. High phytoplankton concentrations could decrease the amount and quality of light along the water column and serve as an indicator of conditions (Herrera-Silveira and Morales-Ojeda, 2009). Many studies have phytoplankton abundance and also species composition as indicator of the water quality. For example, one study conducted

Maznah and Makhlough in (2015) has assessed the water quality of Mengkuang Reservoir, Penang, Malaysia, by its biological parameters using Shannon–Wiener diversity index (H’). As a result show in this study, the classification of Mengkuang Reservoir’s water quality based on diversity index (H’) of phytoplankton showed that water was slightly polluted. Yap, (1997) also conducted on water quality studies in relation to diversity index.

CHAPTER 3

MATERIALS AND METHODS

3.1 Description and Background of Study Area

The Sepang Kecil River is situated in the state of Selangor (Figure 3.1). There are some mangrove trees lining the river. The areas nearby of the Sepang Kecil River are mostly covered by agriculture activities, recreational activities, tourist spots, humans' settlements and plantations. The town nearby is Kampung Sungai Pelek. Kuala Lumpur International Airport and the Sepang International Circuit are also nearby to this area of study. The location of the study area is at of 2°36'36.10"N and 101°41'6.80"E. The area of study received a total rainfall of 2132 mm from May 2014 to February 2015. In this sampling period of study, October, November and December are the months with maximum rainfall while February, June and July are months of minimum rainfall based on Appendix B by Malaysian Meteorological Department. This rainfall data collection is used to relate and compare to the water quality index of river. The water samples are collected from five sampling stations along the Sepang Kecil River. Sepang Kecil River is 10 kilometers long with about 3 to 3.5 meters of depth. The total length of the study area is 7 kilometers and the distance between the stations is about 1.4 kilometers.

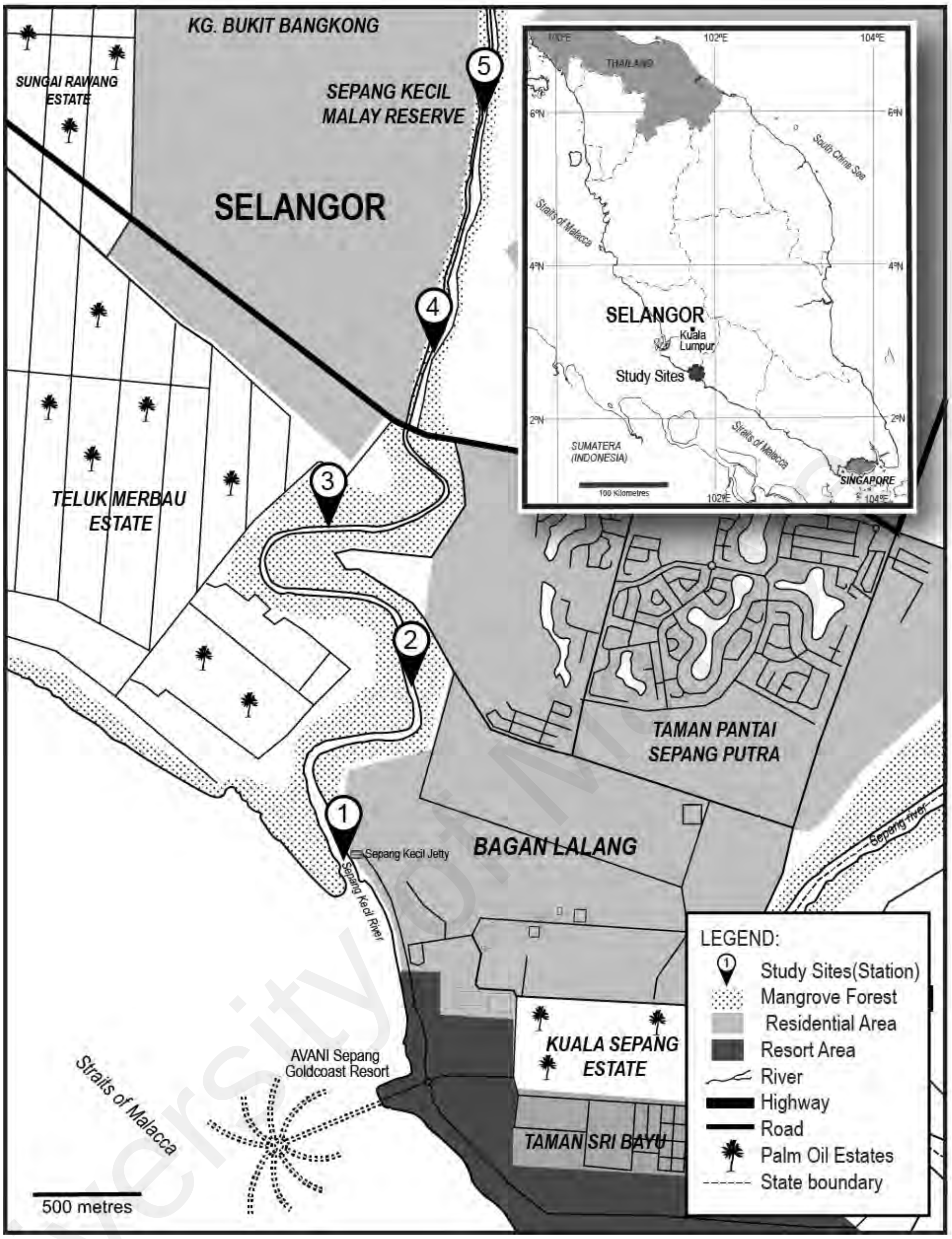

Figure 3.1: Map of Sepang Kecil River showing the five sampling station (Insert: Map of Peninsular Malaysia) (Source: Sepang Municipal Council)

There are a few activities carried out near the station. Station 1 (Plate 3.1) located at the main jetty port and is located near the river mouth. There are also recreational area, tourism activities, residential areas and plantation areas nearby station 1. Station 3 (Plate 3.3) located near to the bridge where people who live nearby this bridge use it to cross the river. Meanwhile in station 2 (Plate 3.2), there is no main activity seen nearby. Station 4 (Plate 3.4) and station 5 (Plate 3.5) which are more upstream, mostly there are densely populated areas in which the residential places and plantation areas are nearby.

Plate 3.1: Location of Station 1 at Sepang Kecil River

Plate 3.2: Location of Station 2 at Sepang Kecil River

Plate 3.3: Location of Station 3 at Sepang Kecil River

Plate 3.4: Location of Station 4 at Sepang Kecil River

Plate 3.5: Location of Station 5 at Sepang Kecil River

3.2 Water Sample Collection, Preservation and Storage

Water samples were collected from the five stations along the river by dipping the bottles just below the surface of the water. Three replicates of the water samples were taken from each station. The sampling of water was conducted once in every month starting from May 2014 until February 2015. No sampling was conducted in the month of August 2014 due to the technical problem. The water samples were collected using the polyethylene plastic bottles (500 ml) and the BOD bottles (Plate 3.6). Standard procedures were followed for the water samples collection and the water samples analysis (APHA, 1992). Measurements of the physical parameters were recorded *in situ* at all sampling stations. Samples for the chemical analysis were immediately kept in a cool place and were carried out in the laboratory. Samples for the chemical analysis were brought back and analyzed in the analytical laboratory within 24 hours after the sample collection. Water samples were analyzed within 24 hours because its quality changes by long storage duration (Bartram and Balance, 1996).

Plate 3.6: BOD bottles used for BOD test

3.3 Measurement of Physical and Chemical Parameter

3.3.1 *In Situ* Water Sampling

Temperature, total dissolved solid (TDS), pH, salinity and conductivity were measured by using the YSI handheld multimeter (Plate 3.7). Meanwhile, dissolved oxygen (DO) was measured using YSI 550A DO meter (Plate 3.8). The probe was dipped into the water about 1 m below its surface to obtain the reading. Three reading were recorded to find average reading.

Plate 3.7: YSI handheld multimeter

Plate 3.8: YSI 550A DO meter

3.3.2 Suspended Solid, Turbidity and Ammoniacal Nitrogen

Suspended solid and turbidity measurement were taken by using the Spectroquant Pharo 300 MERCK spectrophotometer in the laboratory. Ammoniacal nitrogen is done by using the test kit and measurement was taken by using Spectroquant Pharo 300 MERCK spectrophotometer (Plate 3.9).

Plate 3.9: Spectroquant Pharo 300 MERCK spectrophotometer

3.3.3 Biochemical Oxygen Demand (BOD)

To measure the BOD value in the water samples, BOD_5 test was conducted according to Standard methods for the examination of water and wastewater (APHA, 1992). The BOD bottles were filled with the water samples to the rim to avoid trapped gas bubbles. At least one bottle was analyzed for dissolved oxygen (DO_0) immediately with the DO meter. The OD bottles were incubated at 20 C for 5 days. After 5 days incubated, the DO_5 were determined. To get the BOD value of the water, this equation was used;

$$BOD_5 = DO_0 - DO_5 \times 1.0 \text{ (dilution factor)}$$

3.3.4 Chemical Oxygen Demand (COD)

HI 839800 COD reactor and HI 83099 COD meter were used for COD test. The cap from a reagent vial was removed and by using the supplied syringe, 2 ml of water sample were added into the vial, while keeping the vial at 45-degree angle and tightly cap. The cap was replaced tightly and mixed by inverting the vial a couple of times. Using the other clean syringe, deionized water was added to another reagent vial repeating the first and second step. This is the blank. Then, the vials were inserted into the HI 839800 COD reactor (Plate 3.10) and heat them for 2 hours at 150°C. After 2 hours of digestion period, allowed the vials to wait for twenty minutes to cool to about 120°C. The vials were left in the tube rack to cool to room temperature and then the COD reading were determined by using HI 83099 COD meter (Plate 3.10).

Plate 3.10: Hanna Instrument (HI 839800 COD reactor and HI 83099 COD meter) for COD test

3.3.5 Chlorophyll *a*

Chlorophyll *a* analysis was conducted by the extraction in methanol according to Strickland and Parsons (1968). Water samples were filtered through a glass fiber filter and rinsed with deionized distilled water which then was washed with glass rod in 20 ml methanol. The extracts were left overnight at 4°C in the refrigerator to facilitate the pigment extraction. 40 ml of methanol were then added to the extraction. The absorbance of the extract was measured by using spectrophotometer UV-160A at a wavelength of 665 nm (Plate 3.11) with 100% methanol as "blank". The calculation of chlorophyll *a* concentration was based on the following equation;

$$\text{Chlorophyll } a \text{ concentration} = \frac{C \times 1000}{V}$$

Where,

C = optic absorbance

V = volume of filtered sample (ml)

Plate 3.11: UV spectrophotometer

3.3.6 Chemical Analysis

Nutrients such as flouride, chloride, nitrite, bromide, nitrate, phosphate and sulphate were conducted and quantified by using the ion chromatography (Metrohm 882 Compact IC Plus) (Plate 3.12). The water samples were immediately brought back to the laboratory. Firstly, the process started with the preparation of the anion eluent, preparation of H_2SO_4 for the suppressor regeneration solution and the standard solution for 1 ppm, 2 ppm and 5 ppm. Meanwhile, the ion chromatography must be switched on and let it warm up. After 1 hour, the prepared standard can be run followed by the water samples by injecting the samples through the syringe into the machine. After the last sample is conducted, the ultra-pure water was used to run for the cleaning process. All the readings that appeared from the computer screen were recorded. Lastly, the operation was stopped and all the waste water must be thrown out.

Plate 3.12: Ion chromatography (IC)

3.4 Data Analysis for Water Quality

The following formula was used in the calculation WQI where involve of subindex (SI) of six parameter which are Subindex of dissolved oxygen (SIDO), Subindex of biological oxygen demand (SIBOD), Subindex of chemical oxygen demand (SICOD), Subindex of acidity/alkalinity (SIpH), Subindex of ammoniacal nitrogen (SIAN), and Subindex of suspended solids (SISS). The calculation of this subindex is shown in Appendix A. The value of WQI obtained was classified based on the Table 3.1. According to Department of Environment (2013) the formula are shown as below;

WQI = [0.22 X SIDO]+[0.19 X SIBOD]+[0.16 X SICOD]+[0.15 X SIAN]+[0.16 X SISS]+[0.12 X SIpH]

Table 3.1: DOE Water Quality Classification and Index Range based on Water Quality Index

Analysis	**Class**						**Index Range**		
	I	IIA	IIB	III	IV	V	Clean	Slightly polluted	Polluted
WQI value	>92.7	76.5-92.7		51.9-76.5	31.0-51.9	<31.0	81-100	60 - 80	0 - 59

In addition, statistical analysis was conducted to test any significant difference between stations and months which conducted Analysis of Variance (ANOVA) by using IBM SPSS Statistic version 20 software.

3.5 Water Sampling and Preservation for Phytoplankton

Water samples were collected using the plankton net that is fixed with a collecting vial at the bottom (Plate 3.13). The mesh size of the plankton net is 30 μm. Each water sample was gathered from several scoops to reduce the chance of missing the smaller size and less abundant phytoplankton. The water samples in the collecting vials were transferred into the 500 ml polythene bottles and preserved with 4% of formalin. The samples were examined for further analysis identification of phytoplankton to species level and phytoplanton counts were made using the sedimentation-inverted microscope technique (Salleh and Tajuddin, 2006).

The procedure involved adding 3 drops of Lugol's Iodine Solution into the bottles containing the water sample that was placed in small vials. It was put aside for a while for the settling of phytoplankton, and the sedimentation chamber was prepared. The cover slip was placed at the base which was the lower part of the chamber by spreading the Vaseline at its side to make sure it stick at the base and then the upper part of the sedimentation chamber were placed together with the lower part. 1 ml of the water sample was poured into the sedimentation chamber. Then 1 drop of iodine was inserted using a pipette and it was put aside for 40 minutes. After 40 minutes, the upper part of the sedimentation chamber was removed slowly, and the sample that is left in the base was observed under the inverted microscope (Olympus bx51 model) (Plate 3.14). Results were expressed in the number of phytoplankton in cells/ml.

Plate 3.13: Plankton net

Plate 3.14: Inverted microscope (Olympus bx51 model)

3.6 Data Analysis for Phytoplankton

Statistical analysis was conducted where Pearson's correlation in SPSS software was done to indicate relationship between physical and chemical parameter with phytoplankton. Species diversity of phytoplankton for each station and month was determined using Shannon-Weiner Index (H') (Shannon and Weaver, 1963). The Shannon-Weiner Index formula is as shown below;

$$\text{Shannon-Weiner Index, H'} = -\sum_{i=1}^{n}(pi \ \ln pi)$$

Where;

n = number of species in the sample

P_i = proportion of total sample belonging to i*th* species

ln = natural logarithm

According to the study of Yap (1997), a classification scheme based on the estimated H' was conducted by following a few step procedures. Firstly, grouping the diversity index (H' values) into intervals (cell width) (United States Environmental Protection Agency, 1980). This interval (cell width) is defined as an estimated break point in the range of the H' value of a data set. This estimated is obtained by scoring the maximum H' values and the minimum H' values and then calculating the interval using the relationship ((maximum H'+ minimum H'values) ÷ 5), where 5 denotes five chemical water quality classes (Universiti Malaya-Department of Environment, Malaysia, 1986). Secondly, breaking the range of H' values into five categories and the lowest limit should start with lowest value 0. Lastly, arranging the five categories of H' values in line with the sequence of the five chemical water quality classes (I-V).

CHAPTER 4

RESULTS

4.1 Physical and Chemical Parameters of the Sepang Kecil River

Table 4.1 showed the mean values of the temperature, total dissolved solid, conductivity, salinity, turbidity and chlorophyll *a* of the Sepang Kecil River in five stations. Station 2 recorded the highest temperature with 29.64 ^{0}C while station 4 recorded the lowest mean temperature with 29.30 ^{0}C. Overall, the temperature values do not show much difference between all stations. Meanwhile, Figure 4.1 showed the mean values of the temperature of Sepang Kecil River in nine months. The temperature values started to increase from May (2014) to July (2014) and after that, the values dropped until October (2014). The highest temperature value was recorded in July (2014) with 30.92 ^{0}C and the lowest mean temperature was recorded in February (2015) with 27.22 ^{0}C.

Based on the Table 4.1, the range of the TDS recorded in five stations was between 18 mg/l to 25 mg/l. The TDS values showed that the values were increasing from the downstream at station 1 with 18.9mg/L towards the upstream at station 5 with 25.51 mg/L. Meanwhile, from the Figure 4.2 the TDS value keeps on increasing from 13.64 mg/L in May (2014) to 28.85 mg/L in December (2014) and started to decrease in January (2015). Then, the TDS value increased back in February (2015).

In addition, between all five stations, the highest conductivity value based on the Table 4.1 was from station 1 with 24.76 µS/cm and the lowest was from station 3 with 21.57 µS/cm. The conductivity value started to decline at station 2 until station 3 but increased again at station 4. However, it dropped slightly again at station 5 from 22.87 at station 4 to 23.78 µS/cm. Apart from that, the result from Figure 4.3 showed that

December (2014) has the highest conductivity value recorded with 27.13 µS/cm while June (2014) has the lowest one with 15.94 µS/cm. The salinity value showed that the value was declining from the downstream towards the upstream with the values of 10.87 ppt to 5.55 ppt as shown in Table 4.1. Besides that, Figure 4.4 showed that May (2014) has the highest salinity value recorded with 11.4 ppt while December (2014) has the lowest mean salinity value with 5.58 ppt. The salinity value keeps decreasing starting from July (2014) until December (2014) and after that, increased back until February (2015).

Table 4.1 also showed that the turbidity value became higher towards the upstream. The highest turbidity recorded was at station 5 with 25.35 NTU and the lowest turbidity was at station 2 with 20.08 NTU. From the Figure 4.5, the turbidity values keep increasing from September (2014) until January (2015). Then, the turbidity reading in February (2015) was dropping more from 29.22 NTU to 19.28 NTU.

Lastly, the value of chlorophyll *a* from the five stations showed a small range of 0.4 µg/L to 0.61 µg/L. The highest mean of chlorophyll *a* value was recorded at station 1 with 0.61 µg/L while the lowest mean of chlorophyll *a* value was recorded at station 4 with 0.44 µg/L based on the Table 4.1. Overall, the value of chlorophyll *a* was declining as the values approached the upstream. From the Figure 4.6, June (2014) has recorded the highest mean of chlorophyll *a* value with 0.69 µg/L while February (2015) has recorded the lowest mean of chlorophyll *a* value with 0.3 µg/L. There was a decreasing trend at the end of the sampling month starting from December (2014) until February (2015).

Table 4.1: Mean values of physical and chemical parameters of Sepang Kecil River in five stations from May 2014 to February 2015. The symbol "±" refers to standard deviation.

Station	Parameter					
	Temperature (°C)	TDS (mg/L)	Conductivity (µS/cm)	Salinity (ppt)	Turbidity (NTU)	Chlorophyll *a* (µg/L)
1	29.61±0.99	18.9±7.25	24.76±2.93	10.87±3.67	20.23±5.88	0.61±0.17
2	29.64±1.01	20.58±5.45	22.92±4.19	9.33±2.81	20.08±5.33	0.51±0.16
3	29.54±1.27	22.2±5.32	21.57±5.8	8.04±2.51	21.7±4.37	0.47±0.13
4	29.30±1.27	23.32±5.57	22.87±4.68	6.92±1.96	24.33±3.82	0.44±0.07
5	29.37±1.28	24.51±5.59	23.78±4.98	5.55±1.94	25.35±3.09	0.5±0.14

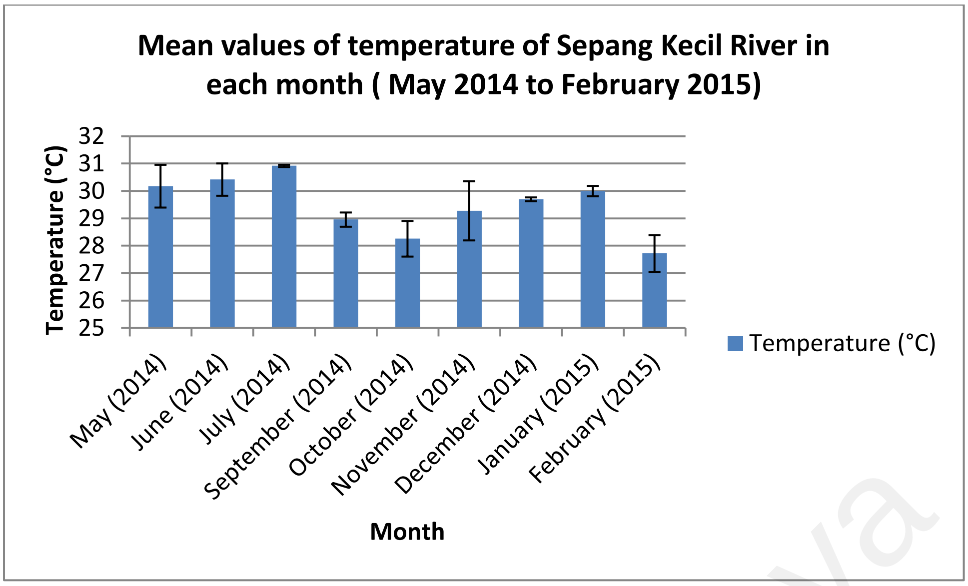

Figure 4.1: Graph of mean values of temperature of Sepang Kecil River in each month from May 2014 to February 2015

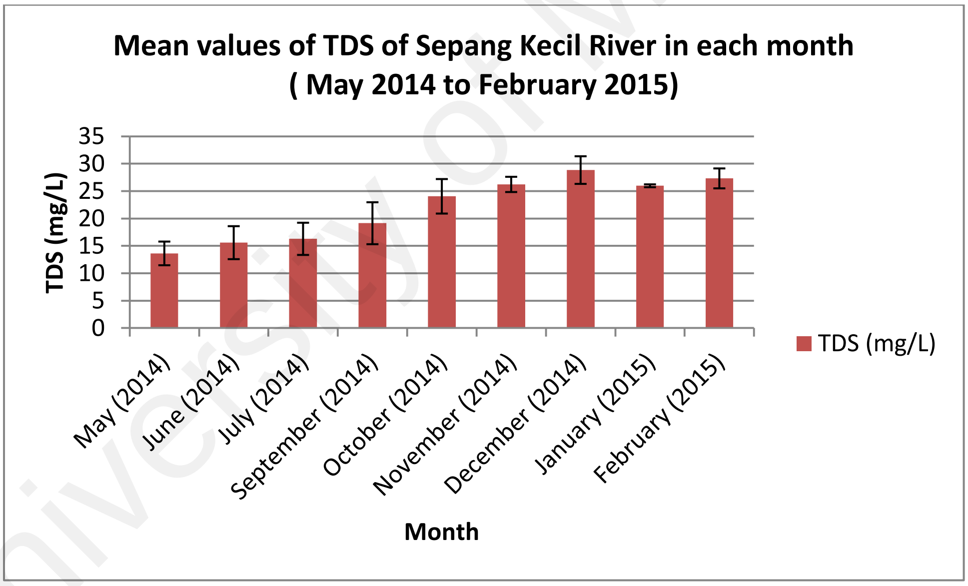

Figure 4.2: Graph of mean values of total suspended solid (TDS) of Sepang Kecil River in each month from May 2014 to February 2015

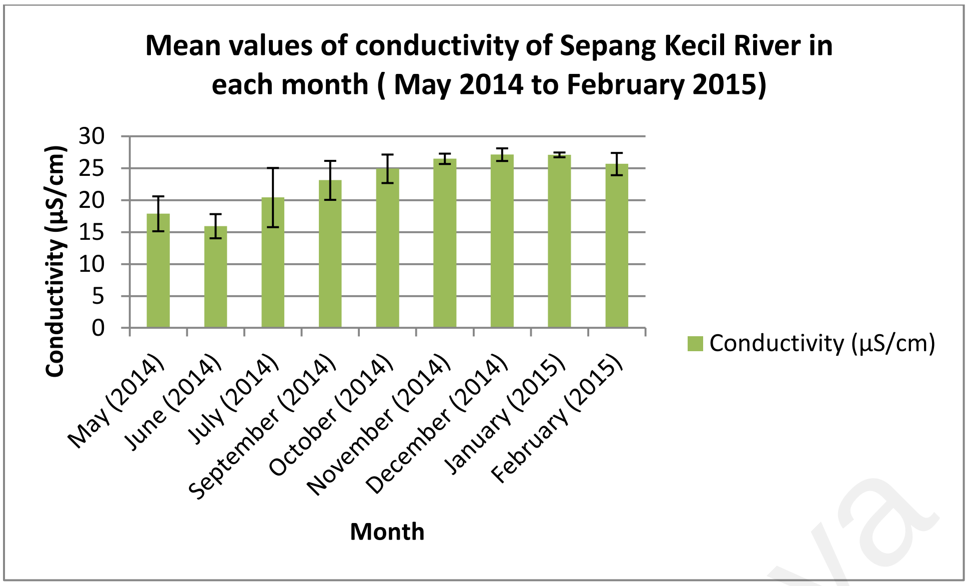

Figure 4.3: Graph of mean values of conductivity of Sepang Kecil River in each month from May 2014 to February 2015

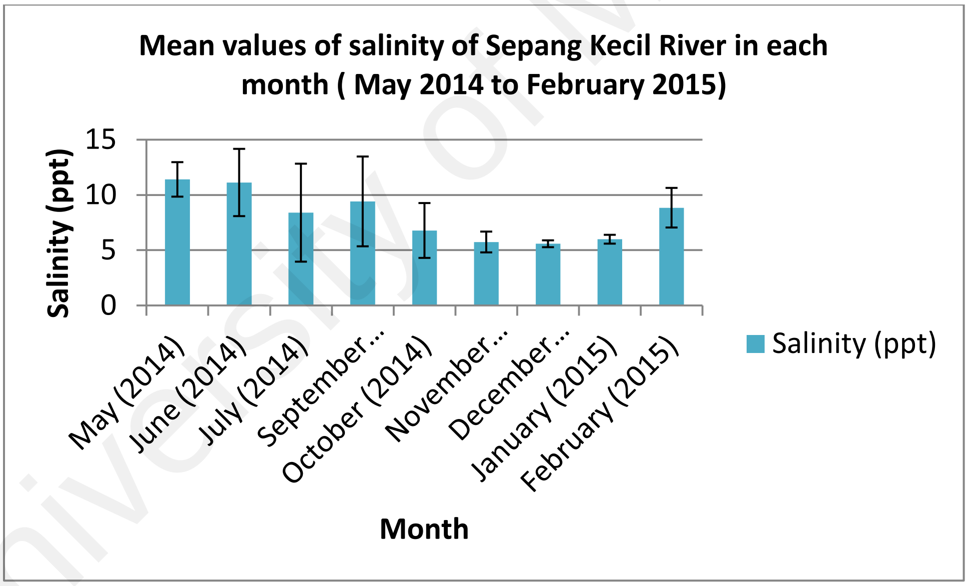

Figure 4.4: Graph of mean values of salinity of Sepang Kecil River in each month from May 2014 to February 2015

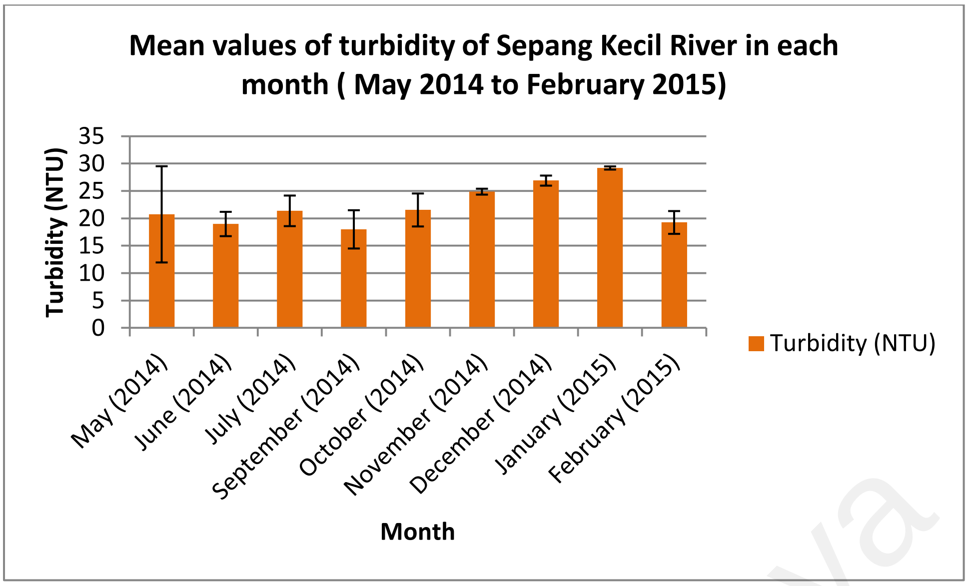

Figure 4.5: Graph of mean values of turbidity of Sepang Kecil River in each month from May 2014 to February 2015

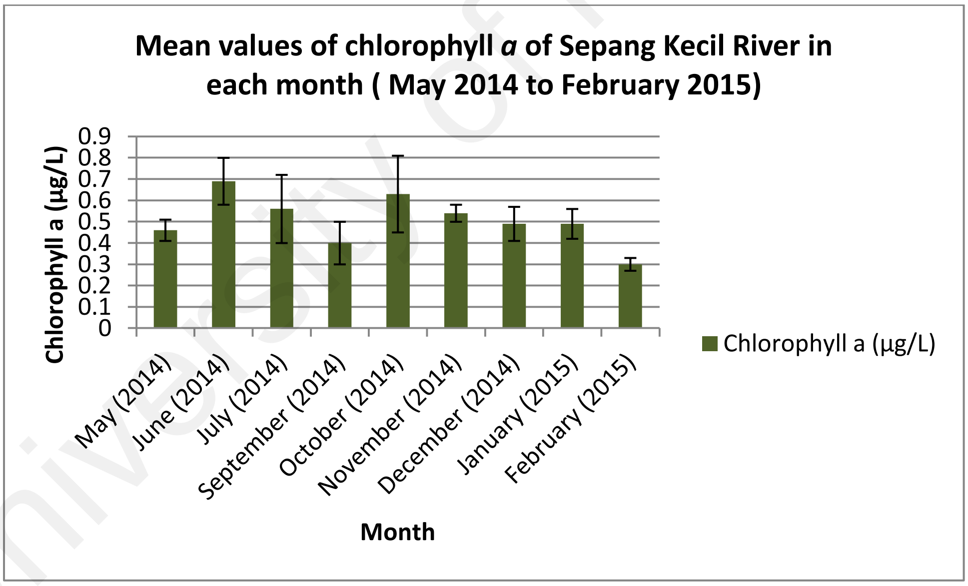

Figure 4.6: Graph of mean values of chlorophyll *a* of Sepang Kecil River in each month from May 2014 to February 2015

As seen in Table 4.2 below, only salinity showed that there was significant difference for station with values of .001. Based on the month, most of the parameters are significantly difference with value of .000 and only salinity showed significant value of .002.

Table 4.2: Significant differences values of physical and chemical parameter from Analysis of Variance (ANOVA)

Parameter	Significant value for station	Significant value for month
Temperature	.961	.000*
TDS	.294	.000*
Conductivity	.669	.000*
Salinity	.001*	.002*
Turbidity	.063	.000*
Chlorophyll *a*	.111	.000*

*. The test result is significant at the 0.05 level

Table 4.3 showed the mean values of the six main parameters of the water quality index of the Sepang Kecil River in five stations. The result showed that the DO value was increasing more at downstream compared to the stations at upstream. The DO value kept on increasing from station 1 until at station 3 and after that the values were declining as it approaches the upstream. The highest DO recorded was at station 2 with 3.76 mg/L while the lowest DO was recorded at station 5 with 3.04 mg/L. Meanwhile, Figure 4.7 showed the mean values of the DO of the Sepang Kecil River in nine months. The highest mean DO value was recorded in February (2015) with 4.41mg/L and the lowest mean DO value was recorded in December (2014) with 2.8 mg/L.

The trend showed that the BOD value became higher at the upstream. The BOD value started to increase more at station 2 with 4.93 mg/L until station 5 with 5.81 mg/L as shown in Table 4.3. On the other hand, from the Figure 4.8 the highest BOD value was recorded in January (2015) with 6.09 mg/L and the lowest BOD value was recorded in June (2014) with 4.57 mg/L.

The range of the COD recorded in five stations was between 52 mg/L to 62 mg/L. Table 4.3 showed that the station 1 recorded the highest mean of COD value with 61.67 mg/l and station 2 recorded the lowest with 52.22 mg/L. The COD concentration was starting to increase from the downstream at station 2 until the upstream at station 5. Meanwhile, based on Figure 4.9, November (2014) recorded the highest COD value with 96.4 mg/L and May (2014) recorded the lowest with 24 mg/L. After that, the COD value decreased to 68.4 mg/l in December (2014) and increased again in January (2015) with 87.6 mg/L. However, it dropped much further in February (2015) from 87.6 mg/l to 38.4 mg/L.

The result from the Table 4.3 showed that the highest NH_3-N value was recorded at station 5 with 0.71 mg/L while the lowest NH_3-N value was recorded at station 3 with

0.48 mg/L. Overall, the NH_3-N values started to decline from station 2 to station 3 but increased again at station 4 until station 5. Based on Figure 4.10, December (2014) recorded the highest NH_3-N value with 0.73 mg/l and May (2014) recorded the lowest NH_3-N value with 0.45 mg/l. The NH_3-N values were increasing from May (2014) until December (2014) and after that, the NH_3-N values started to drop until February (2015)

The highest SS value recorded was at station 5 with 97.82 mg/L while the lowest was at station 2 with 71.1 mg/L based on the Table 4.3. The values showed an increment more towards the upstream. Meanwhile, the highest mean SS value recorded was in November (2014) with 159.6 mg/L and the lowest mean SS value was recorded in May (2014) with 53.5 mg/L as shown in Figure 4.11. After the month of November (2014), the SS values dropped much lower until February (2015).

According to Table 4.3, the pH values for every station showed a similar result and ranged from 7.0 to 8.0. The results showed that the pH value increases more towards the upstream starting from station 2 with pH of 7.64 until station 4 with pH of 7.99. Apart from that, June (2014) recorded the highest mean pH value of 8.06 and September (2014) recorded as the lowest mean pH value with 7.1 as shown in Figure 4.12.

Table 4.3: Mean values of six main parameters of water quality index of Sepang Kecil River in five stations from May 2014 to February 2015. The symbol "±" refers to standard deviation.

Station	Parameter					
	DO (mg/L)	BOD (mg/L)	COD (mg/L)	NH_3-N (mg/L)	SS (mg/L)	pH
1	3.16±0.57	5.67±0.28	61.67±25.93	0.66±0.12	74.29±13.97	7.67±0.27
2	3.76±0.62	4.93±0.77	52.22±19.65	0.52±0.09	71.1±15.15	7.64±0.13
3	3.73±0.65	4.94±0.62	52.89±23.32	0.48±0.11	81.17±38.15	7.69±0.53
4	3.26±0.51	5.48±0.59	54.78±27.28	0.66±0.14	91.57±50.13	7.99±0.54
5	3.04±0.36	5.81±0.59	59.67±31.31	0.71±0.15	97.82±53.76	7.92±0.73

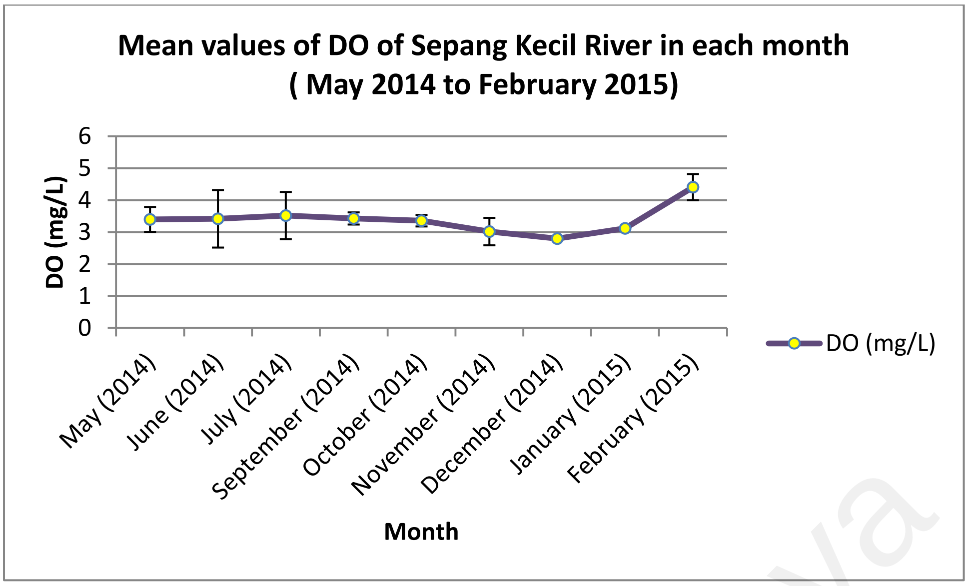

Figure 4.7: Graph of mean values of dissolved oxygen (DO) of Sepang Kecil River in each month from May 2014 to February 2015

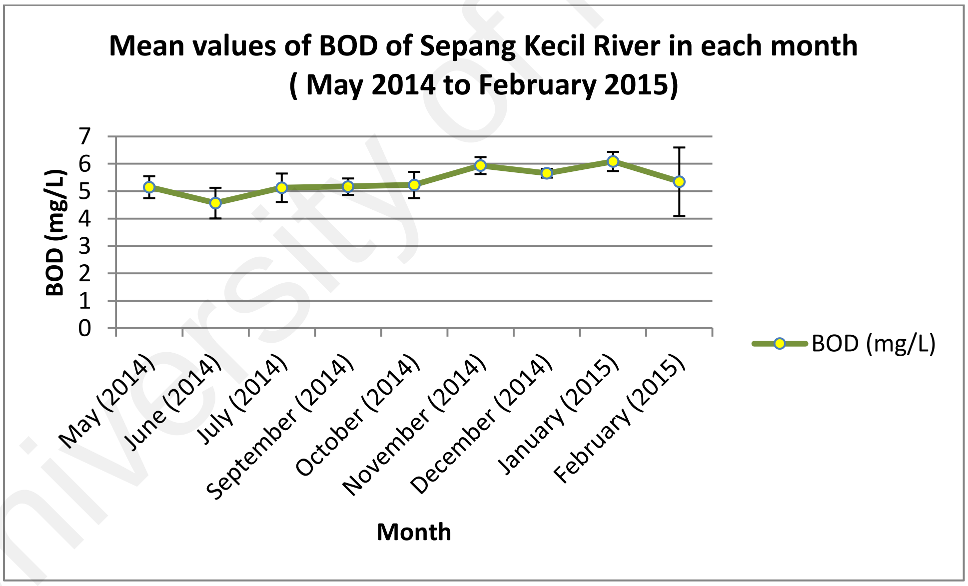

Figure 4.8: Graph of mean values of biochemical oxygen demand (BOD) of Sepang Kecil River in each month from May 2014 to February 2015

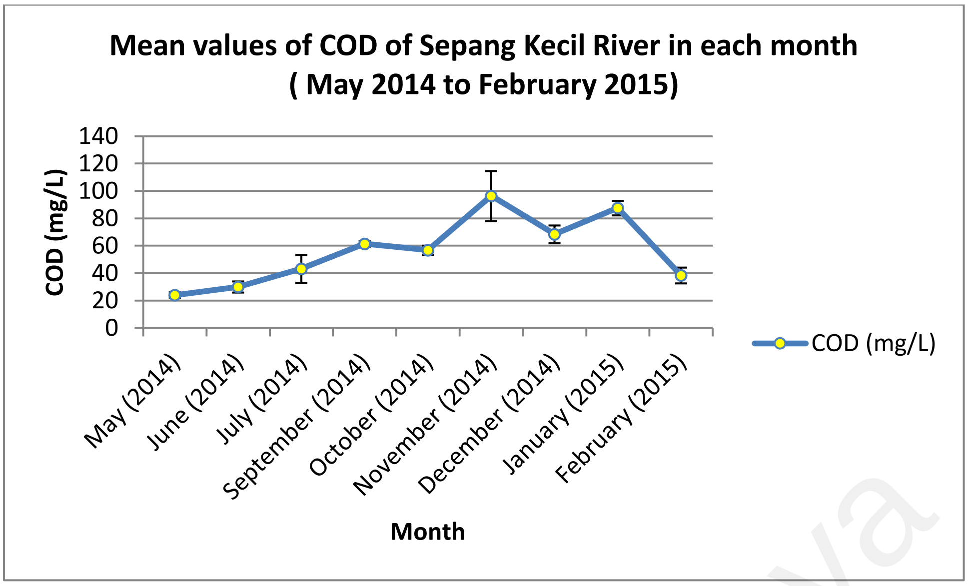

Figure 4.9: Graph of mean values of chemical oxygen demand (COD) of Sepang Kecil River in each month from May 2014 to February 2015

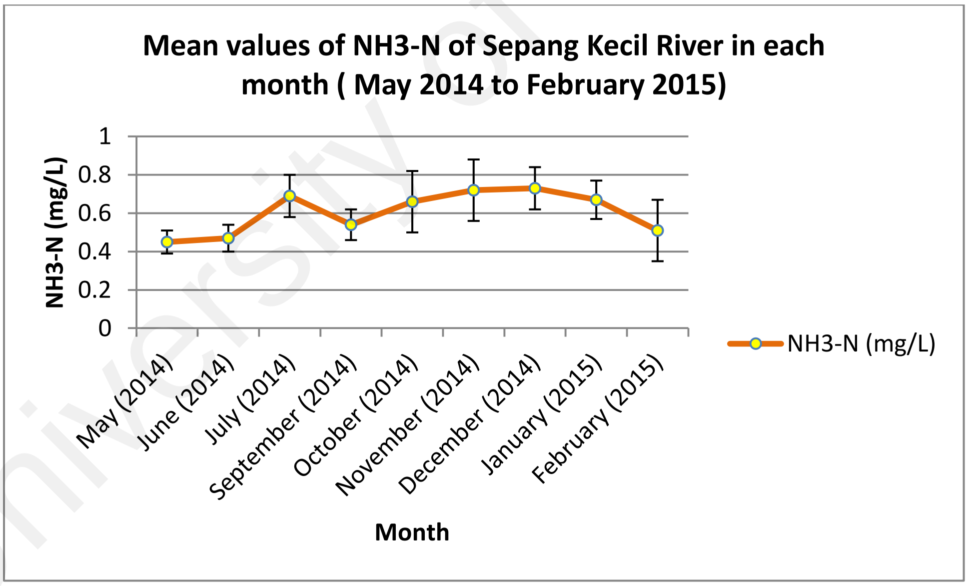

Figure 4.10: Graph of mean values of ammoniacal nitrogen (NH_3-N) of Sepang Kecil River in each month from May 2014 to February 2015

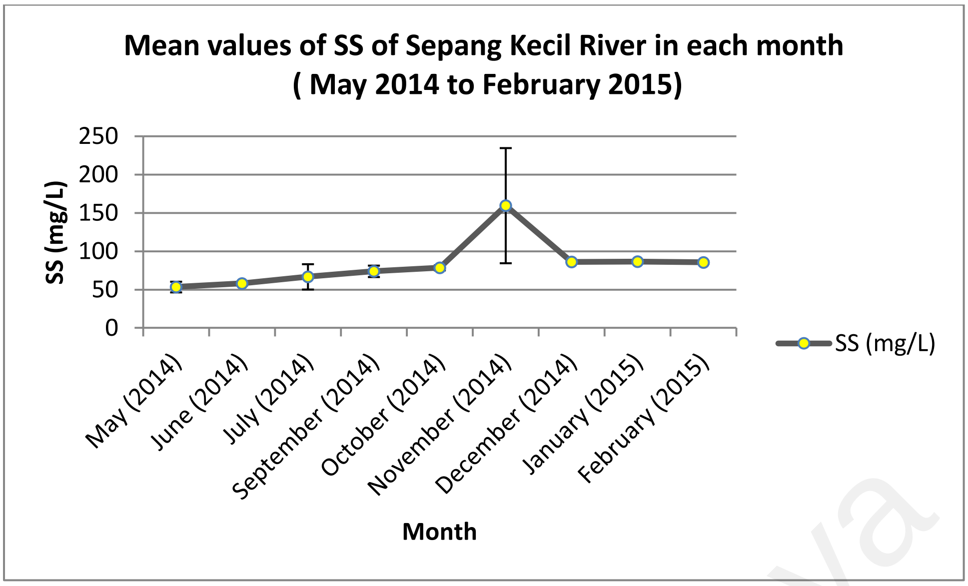

Figure 4.11: Graph of mean values of suspended solid (SS) of Sepang Kecil River in each month from May 2014 to February 2015

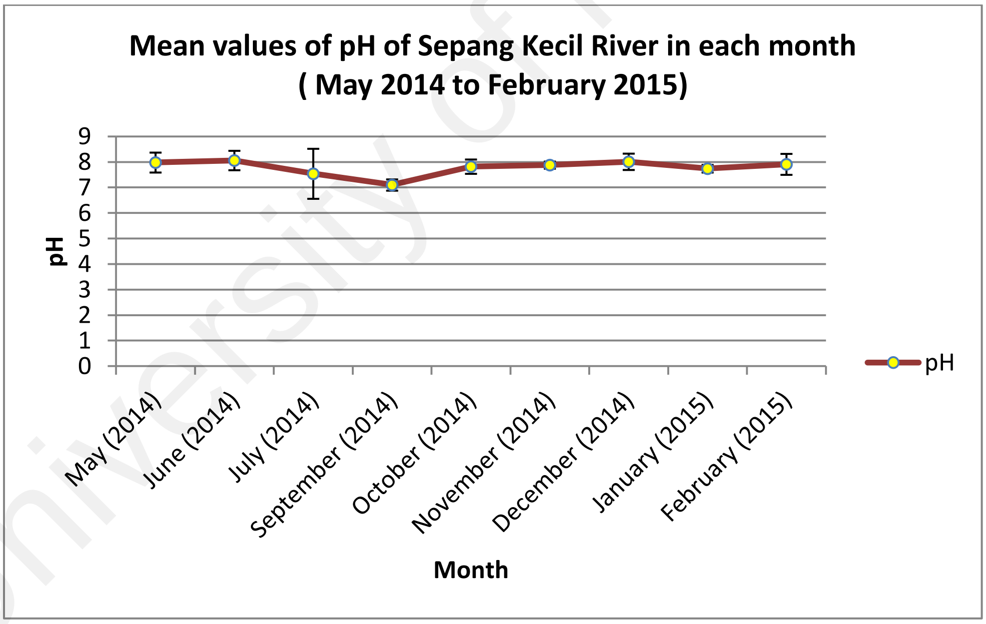

Figure 4.12: Graph of mean values of pH of Sepang Kecil River in each month from May 2014 to February 2015

Based on Table 4.4, DO, BOD and NH_3-N showed that there were significant difference between station with values of .019, .005 and .001 respectively. Other parameter such as COD, TSS and pH showed that there is no significant among the five stations. Based on the month, most of the parameters showed there were significantly differences except for pH.

Table 4.4: Significant differences values of six main parameter of water quality from Analysis of Variance (ANOVA)

Parameter	Significant value for station	Significant value for month
DO	.019*	.001*
BOD	.005*	.006*
COD	.915	.000*
NH_3-N	.001*	.001*
SS	.536	.000*
pH	.437	.035

*. The test result is significant at the 0.05 level

4.2 Water Quality Index Analysis

From this study, Table 4.5 showed that the WQI values of all five stations ranged between 62.21 until 74.96. The lowest WQI value was recorded in station 5 with 62.21 while the highest WQI value was recorded in Station 2 with 74.96. These WQI values of all five stations fall under Class III which was considered as slightly polluted. Based on Table 4.6**,** February (2015) showed the highest WQI value with 79.65 while November (2014) showed the lowest WQI value with 56.58. From the result, the WQI value of May (2014), June (2014), January (2015) and February (2015) fall under Class II while the other five months of sampling fall under the Class III category. Only November (2014) and December (2014) were considered as polluted while the rest of the months were considered as slightly polluted.

Table 4.5: Water Quality Index (WQI) value with their respective classification for each station

STATION	WQI VALUE	WQI CLASS	CLASSIFICATION
1	65.77	III	Slightly Polluted
2	74.96	III	Slightly Polluted
3	74.8	III	Slightly Polluted
4	66.27	III	Slightly Polluted
5	62.21	III	Slightly Polluted

Table 4.6: Water Quality Index (WQI) value with their respective classification for each month

MONTH	WQI VALUE	WQI CLASS	CLASSIFICATION
May (2014)	78.46	II	Slightly Polluted
June (2014)	76.83	II	Slightly Polluted
July (2014)	71.82	III	Slightly Polluted
September (2014)	71.38	III	Slightly Polluted
October (2014)	68.12	III	Slightly Polluted
November (2014)	56.58	III	Polluted
December (2014)	59.25	III	Polluted
January (2015)	62.42	II	Slightly Polluted
February (2015)	79.65	II	Slightly Polluted

4.3 Chemical Analysis

From the Table 4.7, fluoride, bromide, nitrate and sulphate were managed to be detected in all five stations. The values of fluoride were increasing from the downstream to the upstream. For bromide, the values kept on declining starting at station 1 from 12.896 mg/L to 0.625 mg/L at station 4. After that, the value of bromide drastically increased from 0.625 mg/L to 11.535mg/L. Apart from that, the chloride's concentration were managed to be detected only at station 4 with 349.223 mg/L and station 5 with 56.689 mg/L while the nitrites were managed to be detected only at station 2 with 0.842 mg/L and station 3 with 0.315 mg/L. The concentration of nitrates became higher towards the upstream. Also, the phosphates were managed to be detected at station 1, station 2 and station 3. However, the ranges of values for the concentration value of phosphate and sulphate (SO_4^{2-}) were quite high compared to the other anions.

Table 4.7: Mean values of chemical analysis (nutrient/anion) for each station using ion chromatography

Station	Parameter (concentration in mg/L)						
	Fluoride	Chloride	Nitrite$^-$	Bromide	Nitrate	Phosphate	Sulphate
1	0.42	Not detected	Not detected	12.896	2.509	5139.012	2021.365
2	0.581	Not detected	0.842	2.034	22.53	7890.624	1633.828
3	0.751	Not detected	0.315	0.788	34.355	7858.382	1469.81
4	0.935	349.223	Not detected	0.625	38.97	Not detected	1333.63
5	1.038	56.689	Not detected	11.535	34.022	Not detected	1600.685

Table 4.8: Presence of nutrient/anion with its corresponding factor (anthropogenic sources)

Station	**Presence of nutrient/anion**	**Corresponding factor (anthropogenic sources)**
1	Fluoride, bromide, nitrate, phosphate and sulphate	• Fertilizers runoff from plantation areas • Wastewater discharge from the recreational areas and plantation areas • Littering
2	Fluoride, nitrite, bromide, nitrate, phosphate and sulphate	• Fertilizers runoff from plantation areas • Wastewater discharge from the recreational areas and plantation areas
3	Fluoride, nitrite, bromide, nitrate, phosphate and sulphate	• Wastewater discharge from the residential areas
4	Fluoride, chloride, bromide, nitrate and sulphate	• Wastewater discharge from the residential area and plantation areas
5	Fluoride, chloride, bromide, nitrate and sulphate	• Wastewater discharge from the residential area and plantation areas • Littering

4.4 Phytoplankton Analysis

Based on the phytoplankton results, a total of 37 species of phytoplankton with a total of 1020 cells/ml individuals from four main divisions of phytoplankton were identified and recorded at the five sampling stations. The four divisions of phytoplankton were Bacillariophyta (Diatom), Chlorophyta (Green Algae), Cyanobacteria (Blue-green Algae) and Pyrrophyta (Dinoflagellate). From Table 4.9 and Table 4.10, it was found that the division of Chlorophyta dominated with the highest number of species with 18 species found and followed by the division of Bacillariophyta with 17 species. Meanwhile, there were only one species identified and recorded from the division of Cyanobacteria and the division Pyrrophyta. Based on Table 4.9, it was found that the species that were found in all stations were *Archantes* sp., *Biddulphia dubia* (Plate 4.6), *Biddulphia sinensis, Chaetoceros curvisetus, Diatoma elongatum, Diatoma vulgare, Fragilaria capucina, Fragilaria vaucheriae, Lauderia annulata, Lauderia borealis* (Plate 4.5), *Leptoclindrus danicus* (Plate 4.1), *Chlorella* sp., *Closterium juncidum, Closterium parvulum, Closterium turgidum, Coelastrum microsporum, Mougeotia* sp., *Oedogonium* sp., *Pediastrum duplex* (Plate 4.7), *Scenedesmus quadricauda, Ulothrix aequalis* (Plate 4.3) and *Oscillatoria limosa*. From the result, it showed that the highest number of phytoplankton species was mostly found in the downstream which is at station 1 with 36 species and at station 2 with 37 species. Meanwhile, species such as *Biddulphia sinensis, Leptoclindrus danicus, Mougeotia* sp., *Pediastrum duplex, Ulothrix aequalis* and *Oscillatoria limosa* were found in all months based on Table 4.10. The month of January (2015) recorded the highest total number of phytoplankton with 28 species whereas both months of June (2014) and July (2014) recorded the lowest total number of phytoplankton with 21 species respectively based on Table 4.10.

Table 4.9: Presence of phytoplankton species found according to station

No.	Species	Station				
		1	2	3	4	5
Division: Bacillariophyta (Diatom)						
1	*Achnanthes* sp. Bory	+	+	+	+	+
2	*Bellerochea horologicalis* (Brightwellii)	+	+	+		
3	*Biddulphia dubia* Cleoe	+	+	+	+	+
4	*Biddulphia sinensis* Greville	+	+	+	+	+
5	*Chaetoceros curvisetus* Mangin	+	+	+	+	+
6	*Cymbella tumida* Ehr	+	+		+	+
7	*Diatoma elongatum* Agardh	+	+	+	+	+
8	*Diatoma vulgare* Bory	+	+	+	+	+
9	*Fragilaria capucina* (Lyng) Desm.	+	+	+	+	+
10	*Fragilaria vaucheriae* (Lyng) Kutzing	+	+	+	+	+
11	*Gomphonema gracile* Ehr.	+	+		+	+
12	*Gomphonema parvulum* Kutzing	+	+			+
13	*Lauderia annulata* Cleve	+	+	+	+	+
14	*Lauderia borealis* Gran	+	+	+	+	+
15	*Leptoclindrus danicus* Cleve	+	+	+	+	+
16	*Synedra ulna* (Nitz.) Ehr.	+	+	+		+
17	*Triceratium favus* f. *quadarata* Grunow	+	+			+
Division: Chlorophyta (Green algae)						
18	*Chlorella* sp. Ehr	+	+	+	+	+
19	*Closterium juncidum* (Ralf)	+	+	+	+	+
20	*Closterium moniliferum* (Bory) Ehr	+	+	+		
21	*Closterium parvulum* Naeg.	+	+	+	+	+
22	*Closterium turgidum* Ehr	+	+	+	+	+
23	*Coelastrum microsporum* Nageli	+	+	+	+	+
24	*Cosmarium notabile* Breb	+	+			+
25	*Cosmarium subtumidum* Nordstedt		+		+	
26	*Cosmarium undulatum* Cord	+	+			+
27	*Mougeotia* sp. Hassal	+	+	+	+	+
28	*Oedogonium* sp. Agardh	+	+	+	+	+
29	*Pediastrum duplex* Meyen	+	+	+	+	+
30	*Scenedesmus acuminatus* (Lagerheim) Chodat	+	+		+	+
31	*Scenedesmus quadricauda* (Turpin) Breb	+	+	+	+	+
32	*Staurastrum anatinum* Cooke & Wills	+	+			
33	*Staurastrum cuspidatum* Breb	+	+		+	+
34	*Ulothrix aequalis* Kutz	+	+	+	+	+
35	*Zygnema* sp. C. Agard	+	+			+

Table 4.9, continued:

Division: Cyanobacteria (Blue-green algae)						
36	*Oscillatoria limosa* Roth	+	+	+	+	+
Division: Pyrrophyta (Dinoflagellate)						
37	*Peridinium cinctum* Ehrenberg	+	+	+		+

Notes: The symbol + indicates the presence of the species

Table 4.10: Presence of phytoplankton species found according to month

No.	Species	Month								
		May (2014)	June (2014)	July (2014)	September (2014)	October (2014)	November (2014)	December (2014)	January (2015)	February (2015)
Division: Bacillariophyta (Diatom)										
1	*Achnanthes* sp. Bory	+		+		+	+		+	
2	*Bellerochea horologicalis* (Brightwellii)							+	+	+
3	*Biddulphia dubia* Cleoe	+	+	-	-	+	+	+	+	
4	*Biddulphia sinensis* Greville	+	+	+	+	+	+	+	+	+
5	*Chaetoceros curvisetus* Mangin			+	+	+	+	+	+	+
6	*Cymbella tumida* Ehr								+	+
7	*Diatoma elongatum* Agardh		+		+					+
8	*Diatoma vulgare* Bory	+	+	+	+		+	+		+
9	*Fragilaria capucina* (Lyng) Desm.	+	+	+	+	+		+	+	
10	*Fragilaria vaucheriae* (Lyng) Kutzing	+	+			+				
11	*Gomphonema gracile* Ehr.		+	+		+	+	-	+	+
12	*Gomphonema parvulum* Kutzing						+	+	+	+
13	*Lauderia annulata* Cleve	+		+	+		+	+	-	+
14	*Lauderia borealis* Gran	+	+	+	+	+	+	+	+	
15	*Leptoclindrus danicus* Cleve	+	+	+	+	+	+	+	+	+
16	*Synedra ulna* (Nitz.) Ehr.	+			+	+	+			+

Table 4.10, continued:

17	*Triceratium favus* f. *quadarata* Grunow								+	+
Division: Chlorophyta (Green algae)										
18	*Chlorella* sp. Ehr	+	+	+	+	+	+		+	+
19	*Closterium juncidum* (Ralf)	+	+	+	+		+	+	+	
20	*Closterium moniliferum* (Bory) Ehr					+		+	+	+
21	*Closterium parvulum* Naeg.	+	+			+		+	+	
22	*Closterium turgidum* Ehr	+	+	+		+				+
23	*Coelastrum microsporum* Nageli		+	+	+	+	+	+	+	+
24	*Cosmarium notabile* Breb				+			+	+	+
25	*Cosmarium subtumidum* Nordstedt								+	
26	*Cosmarium undulatum* Cord		+		+	+	+		+	
27	*Mougeotia* sp. Hassal	+	+	+	+	+	+	+	+	+
28	*Oedogonium* sp. Agardh			+	+		+	+		+
29	*Pediastrum duplex* Meyen	+	+	+	+	+	+	+	+	+
30	*Scenedesmus acuminatus* (Lagerheim) Chodat	+	+	+	+		+	+	+	
31	*Scenedesmus quadricauda* (Turpin) Breb	+	+	+			+			+
32	*Staurastrum anatinum* Cooke & Wills							+	+	

Table 4.10, continued:

33	*Staurastrum cuspidatum* Breb						+	+	+	+
34	*Ulothrix aequalis* Kutz	+	+	+	+	+	+	+	+	+
35	*Zygnema* sp. C. Agard	+			+	+	+			+
Division: Cyanobacteria (Blue-green algae)										
36	*Oscillatoria limosa* Roth	+	+	+	+	+	+	+	+	+
Division: Pyrrophyta (Dinoflagellate)										
37	*Peridinium cinctum* Ehrenberg	+		+	+	+	+	+	+	+

Notes: The symbol + indicates the presence of the species

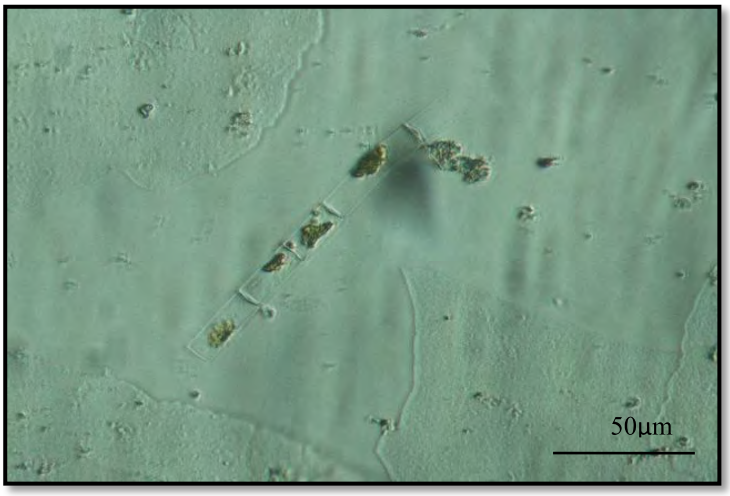

Plate 4.1: *Leptoclindrus danicus* Cleve (Division: Bacillariophyta)

Plate 4.2: *Cosmarium subtumidum* Nordstedt (Division: Chlorophyta)

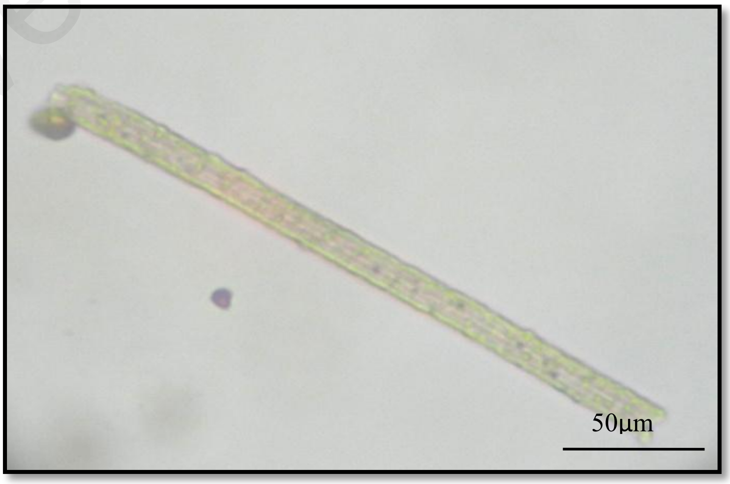

Plate 4.3: *Ulothrix aequalis* Kutz (Division: Chlorophyta)

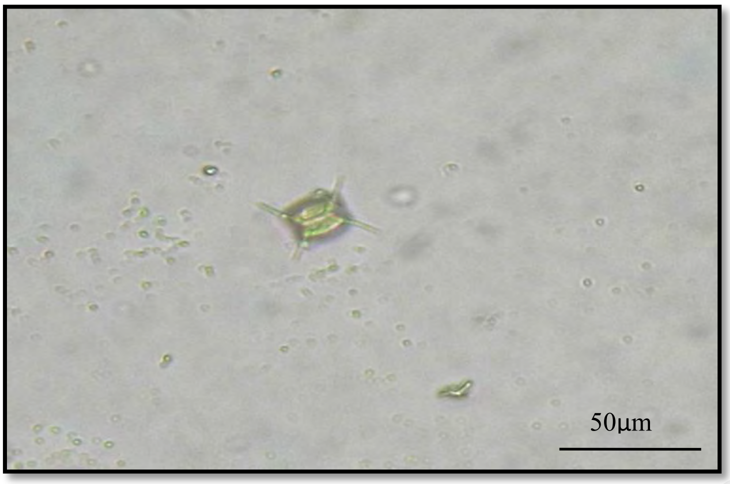

Plate 4.4: *Staurastrum anatinum* Cooke & Wills (Division: Chlorophyta)

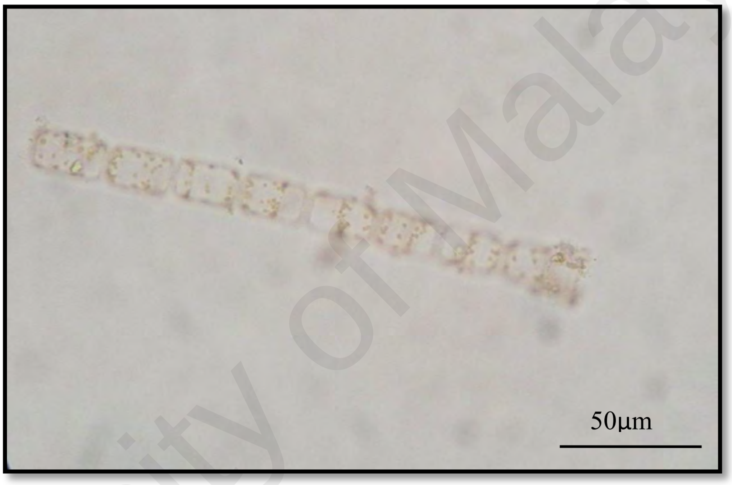

Plate 4.5: *Lauderia borealis* Gran (Division: Bacillariophyta)

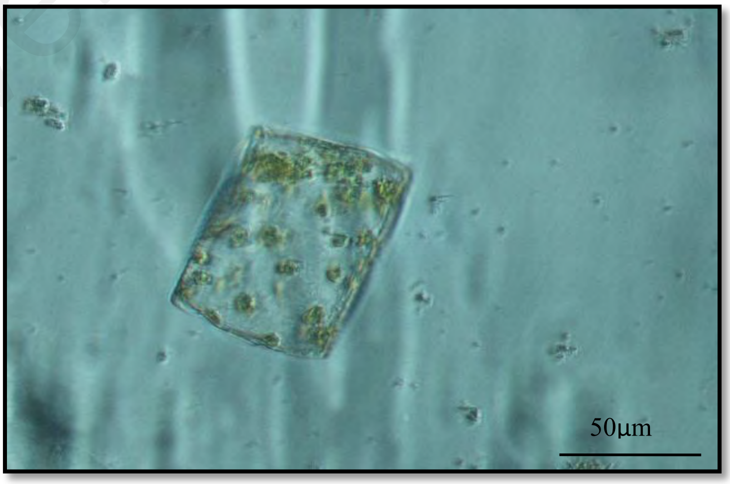

Plate 4.6: *Biddulphia dubia* Cleoe (Division: Bacillariophyta)

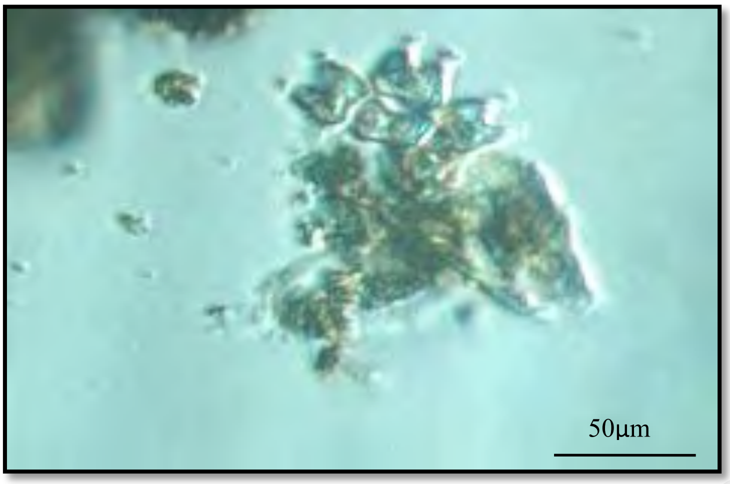

Plate 4.7: *Pediastrum duplex* Meyen (Division: Chlorophyta)

Table 4.11 showed the water quality classes for the station based on the interval (cell width) of H’ values of 1.24 while Table 4.13 showed water quality classes for the month based on the interval (cell width) of H’ values of 1.19. There are five categories of classes according to the range of H’ values in both of this table. Based on the Table 4.12, it was found that the values of H’ were higher at the downstream especially at station 1 and 2. Then, the values become low starting at station 3 and station 4 from the value at station 2. Meanwhile, from the Table 4.14 showed that January (2015) recorded highest value of H’ compared to the other month. All five stations and nine months of sampling in Sepang Kecil River showed as slightly polluted based on the range of H’ values as shown in Table 4.12 and Table 4.14 respectively.

Table 4.11: Water Quality Classes for the station of Sepang Kecil River based on the interval (cell width) of H’ values of 1.24

Shannon - Weiner Index (H’) values	**Class**	**Quality**
>4.96	I	Excellent
3.72-4.96	II	Good
2.48-3.72	III	Slightly polluted
1.24-2.48	IV	Moderately polluted
0.00-1.24	V	Polluted

Table 4.12: Shannon-Weiner Index value for each station of Sepang Kecil River and its water quality classification

Station	Shannon - Weiner Index (H’)	Class	Quality
1	3.26	III	Slightly polluted
2	3.24	III	Slightly polluted
3	2.93	III	Slightly polluted
4	2.93	III	Slightly polluted
5	3.15	III	Slightly polluted

Tables 4.13: Water Quality Classes for the month of Sepang Kecil River based on the interval of H’ values of 1.19

Shannon - Weiner Index (H’) values	Class	Quality
>4.76	I	Excellent
3.57-4.76	II	Good
2.38-3.57	III	Slightly polluted
1.19-2.38	IV	Moderately polluted
0.00-1.19	V	Polluted

Table 4.14: Shannon-Weiner Index value for each month of Sepang Kecil River and its water quality classification

Station	Shannon - Weiner Index (H')	Class	Quality
May (2014)	2.95	III	Slightly polluted
June (2014)	2.85	III	Slightly polluted
July (2014)	2.79	III	Slightly polluted
September (2014)	2.91	III	Slightly polluted
October (2014)	2.88	III	Slightly polluted
November (2014)	3.03	III	Slightly polluted
December (2014)	2.97	III	Slightly polluted
January (2015)	3.15	III	Slightly polluted
February (2015)	3.07	III	Slightly polluted

4.5 Correlation of Phytoplankton with Water Quality Parameter

Based on Table 4.15, analysis showed that BOD, COD, NH_3-N, conductivity, salinity, chlorophyll *a*, nitrite, bromide, phosphate and sulphate have positive correlation with number of phytoplankton species. However, all of the correlations were not significant at $p > 0.05$.

Table 4.15: Pearson Correlation Analysis

Physical and Chemical Parameter	r-value	p-value
DO	-.120	.848
BOD	.176	.777
COD	.381	.527
NH_3-N	.186	.765
SS	-.484	.409
pH	-.462	.433
Temperature	-.304	.619
TDS	-.554	.333
Conductivity	.701	.188
Salinity	.501	.390
Turbidity	-.470	.425
Chlorophyll *a*	.749	.145
Fluoride	-.588	.298
Chloride	-.522	.367
Nitrite	.342	.573
Bromide	.574	.312
Nitrate	-.730	.161
Phosphate	.211	.733
Sulphate	.761	.135

* Correlation is significant at the 0.05 level

CHAPTER 5

DISCUSSION

5.1 Physical and Chemical Parameters of the Sepang Kecil River

Conducting physical and chemical parameter is important in the water quality assessment. Monitoring of physico-chemical parameters is a routine water quality assessment in drinking water supply in Malaysia (Azrina *et al.*, 2006). Temperature is one of the factors that influence the rates of the biological and the chemical processes in the river. Temperature varies due to the light intensity from the sunlight. In this study, July (2014) recorded the highest temperature compared to the other month. This result is related with the season in Malaysia where July (2014) is the dry season as it recorded the lowest amount of rainfall. The range of temperature is recorded between 27.72 ^{0}C to 30.92 ^{0}C. However, this range of temperature is slightly higher than the ranges of temperature reported from the Pinang River (23.6 ^{0}C – 31.2 ^{0}C) (Rosli & Yahya, 2013) and the Semenyih River (24 ^{0}C – 27.55 ^{0}C) (Al-Badaii *et al.*, 2013).

The temperature recorded is mostly similar to the range reported by Al-Shami *et al.*, (2011) from the Juru River with 28.4 ^{0}C – 34 ^{0}C. The high temperature is mostly recorded at the downstream where more land based activities occurs. From the result of the temperature that is obtained in this study, there are no significant differences ($p > 0.05$) of temperature between the five stations and vice versa for the month based on the statistical analysis. The temperature's range of this river is within the acceptable levels of the NWQS for Malaysia. Generally, many factors such as the weather condition, sampling time, and location impact on the increase or decrease of temperature by which its role effect on the percentage of dissolved oxygen, biological activities, and other parameters (Al-Badaii *et al.*, 2013).

Total dissolved solid (TDS) represents the total amount of dissolved solid either organic or inorganic in water. However, a very high TDS range (17.66 mg/L – 80.0 mg/L) and conductivity range (13 µs/cm – 124 µs/cm) were reported from the Semenyih River (Al-Badaii *et al.*, 2013) compared to the TDS range (13.64 mg/l – 28.85 mg/l) and the conductivity range (15.94 µs/cm – 27.13 µs/cm) in this study. From this study, station 5 showed high TDS values as there are residential and plantation areas nearby. The run off of fertilizer from the plantation areas into the Sepang Kecil River can cause high of TDS values. Also, people from residential area tend to throw garbage into the river. High concentration of TDS in surface water is the indicator of intense anthropogenic activities along the river area (Yisa and Jimoh, 2010).

TDS has a close relationship with conductivity where a high amount of dissolved solid can increase the conductivity of the water. In addition, there is no significant difference ($p>0.05$) of the TDS and the conductivity among the stations while there is a significant difference ($p<0.05$) between the months which maybe is influenced by the rainfall. The rainfall will cause the soil erosion where more presence of dissolved solid in water will take place. Furthermore, the overall TDS results were within the standard allowable levels of the Malaysian rivers based on the NWQS for Malaysia and are classified in Class I which practically no treatment necessary.

Freshwater usually has a wide conductivity range due to the geology effects. Besides that, the conductivity of the estuaries tends to be the most variable because they are constantly influenced by the freshwater and the saltwater flows. This can be seen as station 1 and 2 are more downstream and are near the sea. The seawater which is salty can conduct electricity more than the freshwater. Meanwhile, conductivity in the water was affected by the inorganic dissolved solids such as aluminum cations, calcium, chloride, iron, nitrate, magnesium sulfate and sodium (Gandaseca *et al.*, 2011). Any changes in the conductivity could be an indicator that some discharged or other source of pollution has entered the river. This can be showed that conductivity at station 1 is higher than other station as jetty port is located at this station. This jetty port is nearby the beach where mostly recreational activities occur. Many of boat are commonly used in recreational activities. The oil spill from the boat engine can occur and thus affecting the conductivity in water. The conductivity of the Sepang Kecil River is categorized under Class I which do not need necessary treatment and is considered to be low based on the NWQS for Malaysia.

Turbidity shows the cloudiness of water. Moreover, if the river water becomes turbid, it can cause a great concern to the aquatic organism. A very high turbidity value is reported in the Perlis River (42.85 NTU – 78.25 NTU) (Amneera *et al.*, 2013) and the Semenyih River (4 NTU – 206.7 NTU) (Al-Badaii *et al.*, 2013) compared to the turbidity level in this Sepang Kecil River (18.02 NTU – 29.22 NTU). Station 5 showed higher value of turbidity compares to the other stations. Turbidity resulted by the presence of suspended particles such as clay, silt, organic matter, plankton and other microscopic or decomposers organisms (Gandaseca *et al.*, 2011). Station 5 which are more upstream, is nearby the densely populated area. The higher turbidity that occurs at this station perhaps due to wastewater discharge sourcing from the residential places and runoff of fertilizer from the plantation areas.

Additionally, soil erosion results in a large amount of sediment and organic pollutants entering rivers, lakes and dams, thus increasing risks of flood disaster and non-point source pollution (Hu *et al.,* 2010). Also, January (2015) recorded a high value of turbidity where this month is in the wet season. High amount of rainfall can cause more soil erosion. Soil erosion during rainfall is strongly affected by runoff and slope steepness. Runoff production is drastically increased when a seal is formed at the soil surface during rainfall (Assouline and Ben-Hur, 2006). In addition, the statistical analysis proved that there is a significant difference ($p<0.05$) of turbidity between the months and in terms of the stations there is no significant difference ($p<0.05$). The water is acceptable for domestic use when its turbidity were below 25 NTU. Overall, the level of turbidity in this study area is classified in Class II which conventional treatment required and the river water is for recreational use based on the NWQS for Malaysia.

Salinity describes the dissolved salt content in water. It was natural for the river especially to contain a certain amount of dissolved salt but excessive amount are toxic to most life forms. From the study, ANOVA results showed that there is a significant difference ($p<0.05$) of salinity between the stations and the months. It was found that mostly, higher salinity values were recorded at station 1 due to its location located at the river mouth and was influenced by the seawater. The tendency of the downstream river water to increase in the salinity value is high when the high tides of the seawater occur.

Areas with lowest salinity concentration can also potentially have the worst water quality (although sediment and pollution loads do not only depend on the amount of discharge water) (Jakobsen *et al.*, 2007). Apart from that, the salinity value recorded was the lowest in December (2014) in which this month was the wet season where the amount of rainfall is high. When the amount of the rainfall is high, more river water from the upstream will flow towards the downstream. Hence, the salinity concentration in the river becomes less. The salinity levels recorded in this river is still within the acceptable levels of the NWQS for the Malaysian rivers.

On the other hand, the concentrations of chlorophyll *a* are high at the downstream and the value kept on declining towards the upstream. The high values of chlorophyll *a* are due to the nutrient input from the anthropogenic activities especially at station 1. There is a beach nearby in this station where most of recreational activities occur. Also, high production of algae and rainfall can increase the chlorophyll *a* values. Urban runoff during the rainfall event will flush away the nutrients load from the land into the river. From the result, chlorophyll *a* value is high from October (2014) to November (2014) which is during the wet season. Meanwhile, the decrease of the chlorophyll *a* may be due to the dilution or high grazing rate of zooplankton on phytoplankton as suggested by La Rosa *et al*., (2002). Furthermore, there was no significant difference ($p>0.05$) of chlorophyll *a* between the stations but the results were significantly different ($p<0.05$) between the months.

Oxygen in river water was measured in form of dissolved oxygen (DO). Oxygen generally becomes dissolved in surface waters as a result of diffusion from the atmosphere and aquatic-plant photosynthesis (Al-Badaii *et al.,* 2013). Amount of DO that can be hold by water depend on the water temperature. The colder the water, the more oxygen in it can hold (Said *et al*., 2004). From the result in this study, result in February (2015) showed the highest DO concentration recorded as the temperature of the water during this month is the lowest. This is because, oxygen dissolved easily in cold water rather than in warm water. The DO concentration is decreasing towards the upstream at station 4 and station 5. Hence, the amount of DO in water is low due to more land based activity occur nearby which give the effect of warmer to the river.

Apart from that, the DO level was lower during the wet season which is in December (2014) possibly due to the high pollutant loads that flow with the rainfall water from the land into the river. Furthermore, ANOVA test shows the values are significantly different ($p < 0.05$) among the stations and the month. Based on the result obtained, the DO concentration of this study is lower compared to the DO level recorded from the Langat River (3.02 mg/L – 10.03 mg/L) (Azrina *et al*., 2006), the Semenyih River (5.58 mg/L – 7.07 mg/L) (Al-Badaii *et al*., 2013) and the Juru River (0.48 mg/L – 7.68mg/L) (Al- Shami *et al*., 2011).

According to the Langat River studies, the upstream stations of the Langat River are used for recreational activities and have generally high vegetation coverage meanwhile the downstream station are milky, smelly and likely to contain a lot of suspended matter that could due to the sewage pollution . Overall, the DO level was found to be low in this study which falls under Class III based on the NWQS for Malaysian river. The reason for low DO level is caused by the high discharge of organic pollution and nutrient along the river which will normally increase respiration during organic matter degradation (Yisa and Jimoh, 2010). In Class III, the water requires extensive treatment and it can be used for livestock drinking.

Besides that, the biochemical oxygen demand (BOD) usually measures the amount of oxygen consumed by the microorganisms in decomposing organic matter in the water. Organic matter can serve as food for bacteria. In this study, the value of the BOD recorded at station 5 and in the month of January (2015) showed the highest record compared to the other stations and months. January (2015) is in the wet season where there is a run off of high loads of organic matter and wastewater from the anthropogenic activities into the river during the rainfall. The BOD value started increasing from July (2014) to January (2014) in which this period of month is the wet season. High BOD can be attributed to inadequate treatment of sewage or effluent from agro-based and manufacturing industries (Department Of Environment, 2013). If the amount of BOD was higher, the water was considered polluted. Furthermore, the BOD concentration continuously increases because of natural plant decaying process and other contributors that increase the total nutrient in water bodies such as fertilizer, construction effluent, animal farm, and septic system (Al-Sabahi, 2009).

BOD is also related to DO and they are inversely proportional to each other (Akkoyunlu and Akiner, 2012). From the result, station 5 showed that the BOD value is the highest while the DO value is the lowest. However, the BOD range recorded in this study is lower than the level recorded from the Perlis River (5.68 mg/L – 9.08 mg/L) (Amneera *et al.*, 2013). The high BOD level in the Perlis River is because of certain sampling station generates high sullage production and is contributed by the nearest activities such as the residential areas. Meanwhile, the Sepang Kecil River is only affected because of the nearest residential area, recreational activities and plantation areas. However, the value of BOD in this study is higher than the range reported by Azrina *et al.*, (2006) for Langat River with range of 1.29 mg/L – 2.55 mg/L. Based on the statistical analysis, the BOD are significantly different ($p < 0.05$) between the stations and months. According to the parameter limits of the NWQS for Malaysian river, based on the overall mean of BOD values obtained is classified under Class III in which the river water need extensive treatment and can only be used for livestock drinking.

Meanwhile, a wide usage of chemical substances such as fertilizers from the activity of agriculture that are discharged into river can affect the level of chemical oxygen demand (COD). Increased fertilizer application have contributed large amounts of nutrients to downstream water bodies (Liu and Qiu, 2007), resulting in very poor water quality in the main rivers. Measurement of COD in the river to show how much the river was being polluted. From the result of COD that is obtained in this study, station 1 showed a higher value of COD compared to the other stations where there is a plantation area nearby this station. The runoff of fertilizer is commonly occurring in plantation area and this can lead to an increasing of COD value. In terms of months, November (2014) recorded the highest COD value which is the wet season where the amount of rainfall is high. The higher level of COD indicated the higher pollution of water of while lower level of COD indicated low level of pollution of water at the study area (Waziri and Ogugbuaja, 2010). An increasing and decreasing COD concentration values for every sampling may contribute by weather condition, distance from discharge sources, accessibility, run off factors and safety factor during sampling time (Amneera *et al.*, 2013).

However, the range of COD level in this study is quite low as very high COD levels are reported from the Langat River (Amneera *et al.*, 2013), the Juru River (Al – Shami *et al*, 2011), and the Langat River (Azrina *et al*, 2006) in the range of 52.3 mg/L – 233.0 mg/L, 27.67 mg/L – 164 mg/L and 52.3 mg/L – 233 mg/L respectively. According to the statistical analysis, there is no significant difference ($p > 0.05$) of COD between the stations but there is a significant difference ($p < 0.05$) in terms of the months. Overall, the value of COD is classified under Class IV based on the NWQS for Malaysian rivers. The wide usage of chemical and organic fertilizer and discharge of sewage affect COD level, while the high COD pointing to a deterioration of the water quality is attributed to the discharge of municipal effluent (Eisakhani and Malakahmad, 2009).

The values of the ammoniacal nitrogen (NH_3-N) is showing an increasing value from September (2014) to December (2014) which is in the wet season. This could be an indication of heavily loaded nitrogenous inputs from the livestock farming, domestic sewage, industrial waste, and fertilizer runoff from the plantation nearby the river. Also, the NH_3-N values at station 4 and station 5 showed the highest as high loads of nutrient due to fertilizer run off from the plantation area nearby. Besides that, the range of NH_3-N in this study is lower than the ranges of NH_3-N recorded from the Perlis River (1 mg/L – 2.8 mg/L) (Amneera *et al.*, 2013) and the Semenyih River (0.02 mg/L – 1.91 mg/L) (Al-Badaii *et al*., 2013). At all events, higher NH_3-N values can be toxic to fish, but in small concentrations, it could serve as nutrients for excessive growth of algae (Corwin *et al*., 1999). In addition, the NH_3-N in this study has a significant difference

($p<0.05$) between stations and months. Based on the NWQS of Malaysian Rivers, the overall mean values of NH_3-N were classified under Class III which extensive treatment required and river water can use for livestock drinking.

Suspended solid (SS) is generally regarded as an important environmental parameter because it can reflect the biogeochemical process of aquatic ecosystem (Weyhenmeyer *et al.,* 1997). The SS ranges recorded from the Perlis River (30 mg/l – 68.78 mg/l) is lower compared to the SS ranges in this study. In addition, there are other river studies which exceeded the SS range in this study such as from the Langat River reported by Azrina *et al.*, (2006) and the Semenyih River with by Al-Badaii *et al.*, (2013) with 4.50 mg/L -534 mg/L and 10.3 mg/L -446 mg/L respectively. However, the recommended NWQS maximum threshold limit of SS level for Malaysian river was from 25 mg/l to 50 mg/L. According to the statistical analysis, SS showed no significant difference ($p > 0.05$) between the stations but there is a significant difference ($p < 0.05$) between the months.

Meanwhile, from the result of the SS value showed that there is a sudden increase in November (2014) where this month recorded the highest amount of rainfall. TSS was recorded maximum during monsoon due to the higher concentration of dissolved organic matter, suspended sediments and turbulent freshwater discharge could be the important factors and minimum in summer could be due to the clean water condition and low runoff (Kannan and Kannan, 1996). The TSS increase was likely due to the high rainfall and flooding, since particles eroded from the soil surface by the rainfall would be carried in the runoff and deposited as bottom sediments in the river, later to be churned up and re-suspended by further rainfall events (Ching *et al.*, 2015). High value of SS recorded at station 4 and station 5 due to water discharge that containing suspended substances from the residential areas and plantation nearby. For overall, average of SS value is classified under Class III which extensive treatment required based on the NWQS. Moreover, suspended solid can affect the clarity of water. Suspended solids or particles are one of the natural pollutants in surface water that will cause turbidity in waters especially the river water (Mahvi and Razazi, 2005). One of the reasons that can cause high turbidity in water due to the presence of suspended solid that deposited in the water. The murkier the water indicated the higher amount of TSS (Gandaseca *et al.*, 2011).

Overall, the ranges pH values of all station of Sepang Kecil River were within the acceptable pH limit. According to DOE of Malaysia, the pH range from 6.5-8.5 was acceptable for domestic water supply. Based on the pH result recorded, the range is within the acceptable and under Class I based on the NWQS for Malaysia where practically no treatment is necessary. From the pH results that were obtained in this study, the pH value started to increase during the wet season in October (2014) until December (2014). Heavy rainfall and acid precipitation have caused the leaching of acid and metals concurrently into the water, which can have an immediate or a long-term effect by influencing the chemical composition and pH fluctuations of the water (Ching *et al.*, 2015). The pH range for station in this study (7.1 – 8.06) is slightly high compared to the pH range recorded from the Perlis River (6.46 – 7.38) (Amneera *et al.*, 2013) and the Langat River (5 – 7.99) (Azrina *et al.*, 2006). The pH value increase due to the photosynthetic algae activities that consumes CO2 dissolved in water (Driche *et al.*, 2008). In addition, pH shows no significant difference ($p>0.05$) in between the stations and months based on the statistical analysis.

Nitrogen mostly used in agriculture practices as nutrient for plant growth in the form of nitrate and nitrite. This nutrient can get into water directly as the result of fertilizer run off. Nitrate levels in water fluctuate by season, and higher nitrate levels also occur following heavy rainfall (Sulaiman *et al.,* 2014). From the study, high value of nitrate was present as it approaches the upstream. The upstream stations have plantation areas nearby where high loads of fertilizer discharged into the river. River water which is high in nitrate levels is potentially harmful to human and animal health; in fresh water or estuarine systems close to land, nitrate can reach high levels that can cause the death of aquatic life (Al-Badaii *et al.*, 2013). The nitrate value in this study are quite high compared to the studies reported by Al-Shami *et al.*, (2011) in the Juru River and Al-Badaii *et al.*, (2013) in the Semenyih River with 0.55 mg/L - 2.57 mg/L and 1 mg/L - 8.53 mg/L respectively. Overall, nitrate and nitrite can be classified under Class V based on the NWQS for Malaysian rivers.

Phosphorus is one of the key elements necessary for animal and plant growth and phosphates are formed chemically through the oxidation of this element (Sulaiman *et al.,* 2014). The range phosphate value in this study found to have exceeded the normal level of the NWQS for Malaysian rivers which is 0.2 mg/L and thus they fall under Class V as compared to the study by Al-Badaii *et al.*, (2013) in the Semenyih River with 0.08 mg/L -1.9 mg/L. High phosphate levels at downstream station such as at station 1 to station 3 particularly comes from the sources of fertilizer runoff and also wastewater discharged from the residential area around the stations. Wastewater of fertilizer and detergent are among of water discharged that containing phosphate ion. Nutrients such as nitrite, nitrate, inorganic phosphate and silicate were abundant during monsoon due to monsoonal flow of fresh water and land runoff (Arumugam *et al.*, 2016).

Besides that, other nutrients such as fluoride, bromide, chloride and sulphate also can get into the water from several sources such as the wastewater from the industries and agriculture run off. Excessiveness of these nutrients poses a risk to the water especially for drinking purpose. Fluoride increases towards the upstream as more land based activities nearby are found along the river. The fluorides value in this study falls under Class I according to the NWQS for Malaysian rivers which no practically treatment necessary. Meanwhile, bromides are high in value at downstream and upstream compared to the middle stream as more land use activity nearby occur.

Chloride was mostly found in high concentration at the upstream. Fish and other aquatic life forms cannot survive in high levels of chlorides (Sulaiman *et al.,* 2014). In this study, the range of chloride value obtained is much higher when compared to the studies reported by Al-Shami *et al.*, (2011) in the Juru River with 2.12 mg/L - 22 mg/L. Besides that, the chloride level in this river is categorized under Class II where conventional treatment required and for recreational use based on the NWQS for Malaysian rivers. Wastewater discharge from the residential area, recreational area and plantation area are one of the main contributors to the high concentration of sulphate in the river water especially at station 1. Moreover, the sulfate values are categorized under Class V based on the NWQS for Malaysian rivers. In this study, the sulfate values are considered very high compared to the studies reported by Al-Badaii *et al.*, (2013) in the Semenyih River and Al-Shami *et al.*, (2011) in the Juru River with 1.67 mg/L - 61 mg/L and 20 mg/L - 197 mg/L respectively.

5.2 Water Quality of Sepang Kecil River

In this study, all five stations are classified as slightly polluted based on the water quality index. This means that the human activities nearby does affect the quality of this river. Furthermore, from the finding of the study, station 1 and station 5 showed that the results of physical and chemical parameter obtained are mostly high in concentration compared to others station. Station 1 is located at the downstream and nearby the river mouth of Sepang Kecil River. Arienzo *et al.*, (2001) studied the impact of the land based activities and urban runoff on the contamination of the Sarno river basin in southern Italy and their results indicated degradation in the river water quality, especially near the river mouth. There is a place of recreational and tourism activities that took place nearby station 1 and also the jetty port for the fisherman to place their boats. Frequent used of boat can cause oil spill into the river. Also, throwing of waste by the villagers and tourist also one of the main contributor to river pollution. Thus, all these land based activities have affected the water quality at this station.

Meanwhile, the residential place and plantation area are mostly nearby the area of station 4 and station 5 where this station is located at the upstream part. The river water in this station became milky and smelly due to the wastewater discharge from this densely populated area and also the plantation nearby. The main causes of river pollution are rapid urbanization, arising from the development of residential, commercial, and industrial sites, infrastructural facilities and others (Amneera *et al.*, 2013). According to the fishermen in this study area, nowadays, there was a decrease in the fisheries activities compared to the previous years back. Stobutzki *et al.,* (2006) reported that the water quality deterioration and the habitat modification in Malaysia have reduced the fish production to 4–20 % of the original yields.

Generally, all of land use and anthropogenic activities pose a grievous threat not only to aquatic ecosystem in the river but also the provinces in which river water is used as domestic supply (Al-Badaii, 2011; Gasim *et al.*, 2005). Meanwhile, based on the water quality index for each month, only November (2014) and December (2014) were considered as polluted while the rest of the month were considered as slightly polluted. November (2014) and December (2014) are in the wet season where the amount of rainfall is high. Rainfall events represent disturbances to water bodies because they initiate changes in the environment and hydrological conditions (Li *et al.,* 2015). Urban runoff during rainfall events had increased the pollutant loads which disturb the physical and the chemical characteristic of the river water. Overall, the Water Quality Index (WQI) for the Sepang Kecil River is recorded as slightly polluted which is categorized into Class III with the value of 69.0.

5.3 Phytoplankton

From the analysis of the phytoplankton species result, a total of 37 species with a total of 1020 cells/ml individuals from four groups of divisions are recorded namely Bacillariophyta, Chlorophyta, Cyanobacteria and Pyrrophyta. There are 17 species of Bacillariophyta, 18 species of Chlorophyta, one species from Cyanobacteria and one species from Pyrrophyta are recorded. The most abundant species belong to the division of Chlorophyta and Bacillariophyta which is known as the green algae and diatom respectively. Most of the species in the division of Chlorophyta live in the freshwater habitat and largely of it in the marine habitats. The most common species found includes *Pediastrum duplex*, *Mougeotia* sp., and *Chlorella* sp. Meanwhile, the next abundant species belong to Bacillariophyta with the most common species found are *Leptoclindrus danic*us and *Biddulphia sinensis*. Diatoms are extremely abundant in the marine and the freshwater ecosystem. They are photosynthetic which means they are an important food sources for the aquatic organisms. Most of diatoms are planktonic but some of them are the bottom dweller or they can grow on other algae or plants.

The least number of species are from Cyanobacteria and Pyrrophyta. Cyanobacteria are often called as blue-green algae and are a photosynthetic nitrogen fixing group. The most common species found in this division is *Oscillatoria limosa* which are mostly found in the downstream and the upstream of this river. *Oscillatoria* was found in large number in almost every station, thus they are good indicators of contaminated water bodies (Das *et al,*. 2007). Cyanobacteria release toxins that can cause blooms where this will float on the water surfaces forming the scums. However, during the period of this sampling, no bloom is found and recorded in this river. Meanwhile, the common species found from division of Pyrrophyta or dinoflagellates is namely *Peridinium cinctum*. Palmer (1969) showed that the genera such as *Oscillatoria*, *Euglena*, *Scenedesmus*, *Chlamydomonas*, *Navicula*, *Chlorella*, *Nitzschia* and

Ankistrodesmus have been recorded in waters with organic pollution. The occurrence of *Oscillatoria*, *Euglena*, *Scenedesmus*, *Chlorella* and *Nitzschia* were recorded repeatedly and are considered as indicators of polluted water bodies, in relation to the results of the Palmer Pollution Index. In this study, similar genera such as *Oscillatoria*, *Scenedesmus*, *and Chlorella* were also can found. Overall, the Sepang Kecil River hold a low number of phytoplankton species found compared to the studies reported by Salleh *et al.*, (2009) in the Kenaboi River with total of 102 species from five divisions and Saifullah *et al.*, (2014) in the Kuala Sibuti River estuary with a total of 46 species under three divisions.

In this study, the Shannon-Weiner Index (H') was used to determine the diversity of the phytoplankton. One of the common diversity indices is Shannon-Wiener index (H') (Krebs, 1999). It was found that station 1, and in the month of January (2015) showed the highest value of species diversity. High diversity of phytoplankton will initiate algal bloom. This will lead to a problem in the drinking water treatment and disrupts the recreational as well as the tourism activities nearby the Sepang Kecil River. Diversity indices of microalgae have been used as an indicator of the water quality and trophic status of aquatic environments (Shanthala *et al.*, 2009). In this study, all five stations and nine months of sampling in Sepang Kecil River showed slightly polluted. Overall, the H' values in this study showed that the Sepang Kecil River is classified as slightly polluted level which similar with the overall classification of water quality index value obtained.

Apart from that, phytoplankton is used as the indicator to know the deterioration of the water quality. The advantages of employing algae in biomonitoring of aquatic environment are based on the fact that these organisms reflect the concentration of physico-chemical parameters in the water ecosystems (Zbikowski *et al.,* 2007). Algae can serve as an indicator of the degree of deterioration of water quality and are valuable indicators of short-term impacts (Hill *et al.* 2000; Li *et al.* 2012; Schletterer *et al.* 2011). Phytoplankton plays a vital role which they act as the producer to the primary food supply in the aquatic ecosystem. Variations in some of the physical and chemical parameters have been reported to influence phytoplankton abundance (Adesalu and Nwankwo, 2009). In this study, phytoplankton has a positive correlation with the physical and chemical parameter such as biochemical oxygen demand, chemical oxygen demand, ammoniacal nitrogen, conductivity, salinity and chlorophyll *a*, nitrite, bromide, phosphate and sulphate. A minor change in physico-chemical parameters can influence the primary production (Sharma *et al.*, 2007).

There was a relationship between the temperature and the distribution of phytoplankton. When the temperature of water is high, it provides a suitable condition for growth and the survival of algae. This is due for the photosynthesis process. High temperatures reduced dissolved oxygen in the water because of high temperature encourages the use of oxygen by the organism for respiration process (Ismail and Mohamad, 1992). However, if the temperature is too low, it will slow down the growth and if it is too high, it will be lethal for some species. Shen (2002) reported that the most favorable temperature for phytoplankton growth was 30º C. Furthermore, the water temperatures of this Sepang Kecil River were in the ranges of this optimum temperature. Algal photosynthetic rates are influenced by temperature because the cellular processes are temperature dependent (Reynolds, 1984; Khan 2005).

Dissolved oxygen is necessary to many forms of life. Dissolved oxygen is also produced as a waste product of photosynthesis from phytoplankton. The increase in DO may be attributed to the higher photosynthetic rate accompanied by a higher light intensity on the surface waters (Wheeler *et al.*, 2003). Phytoplankton also requires dissolved oxygen for respiration when there is no light for photosynthesis. A dissolved oxygen level that is too high or too low can harm the aquatic life and affect the water quality. However, when the phytoplankton is abundant, it can cause oxygen depletion. Changes in the algal community can reflect the occurrence of pollutants or other environmental stressors (Johnstone *et al.,* 2006), especially nutrients, which cause dramatic increase in algae. This event led to low oxygen concentration that affects other organisms in aquatic food chain (Camargo and Alonso, 2006).

The majority of the aquatic life prefers a pH range of 6.5-9.0. If the pH level in the water is too high or too low, the aquatic life will die. Meanwhile, the excessiveness of phytoplankton may cause the pH level to rise and this can be lethal to the aquatic life. Apart from that, based on the correlation analysis, the phytoplankton species and the pH showed a negative correlation. It was observed that at station 4, the value of pH was the highest with 7.99; hence the total number of phytoplankton species was one of the lowest values. Apart from that, when the wastewater with the high BOD level is discharged into the river, it will accelerate the bacterial growth in the river and consumed the oxygen levels in the river. Hence, the oxygen will reduce to levels that are lethal to most of the aquatic life. Moreover, there is more phytoplankton presence to add oxygen to the water through the process of photosynthesis. Meanwhile, if the COD level is high, the water results in having more nutrients within it and stimulates the growth of the phytoplankton.

Turbid water appears cloudy and murky while suspended solid reduces the water clarity by creating muddy appearance. As such, turbidity and suspended solid are closely related to total suspended solid. Turbidity and suspended solid are also resulted by the algal bloom. An algal bloom occurs when an algae grows quickly across the surface of water excessively. Turbidity and suspended solid can inhibit the photosynthesis process by blocking the sunlight. The higher the turbidity and the suspended level, lesser light can penetrate the lower level of the water. This can cause the dissolved oxygen level in water to drop and the aquatic life may die. Turbidity thus directly affects the phytoplankton growth by modifying the light conditions (Colijn, 1982).

Most aquatic organism can only tolerate to a specific salinity ranges. Algae differ in their adaptability to salinity and based on their tolerance extent they are grouped as halophilic (salt requiring for optimum growth) and halotolerant (having response mechanism that permits their existence in saline medium) (Rao *et al.,* 2007). Dissolved solid are important to the aquatic life by balancing their cell density. High content of total dissolved solid in the water will cause the cells to shrink and this can affect the phytoplankton ability to move in water either by floating or sinking from their normal range. In this study, a high value of TDS was shown from the station 5 where the number of phytoplankton species is the third lowest. Meanwhile, an increase in the conductivity is due to the additional nutrient from the agricultural run-off. Based on the result, the conductivity value is higher at station 1 and the number of phytoplankton species is also high. Nutrients are essential for the growth of phytoplankton in which too much input of nutrients will lead to an algal bloom.

Chlorophyll *a* is the pigment that makes the plant and algae green by which the energy of the sunlight is captured for the photosynthesis process. Presence of chlorophyll and other pigments help in carrying out photosynthesis (Singh & Singh, 2014). Algal biomass in water can be estimated by quantifying chlorophyll a. Besides that, phytoplankton species and chlorophyll *a* showed that a positive correlation with the value $r = .749$, $p > 0.05$. Based on the result, station 1 showed that when the number of phytoplankton species is high, the chlorophyll a is also high.

Apart from that, excessive nutrients, mainly nitrogen and phosphorus in the water can stimulate the growth of algae where this nutrient acts as the fertilizer. As a result, it indicates pollution to the river. Nitrates stimulate the growth of algae and plankton, and can cause overproduction if there is too much of nitrogen. When the algae and plankton die, they decompose and consume oxygen (Sulaiman *et al.,* 2014). Phosphates stimulate the growth of algae and the aquatic plants that provide food for fish. Hence, this may cause an increase in the fish population. In this study, the amount of phosphate is higher at station 2 while the number of phytoplankton species is the highest compared to other station. Excess phosphates, however, may cause an excessive growth in algae and aquatic plants, choking waterways and using up large amounts of oxygen, referred to as eutrophication (Sulaiman *et al.,* 2014). Eutrophication has resulted in a change in species composition, food chain structure and element cycling in the marine ecosystem (Gao & Song, 2005).

CHAPTER 6

CONCLUSION

The result showed that the analyses of the physical and the chemical parameters of the Sepang Kecil River recorded at all five stations were varying for each month. The DO, BOD, NH_3-N and SS were categorized under Class III while pH, conductivity and TDS were categorized under Class I based on NWQS for Malaysian rivers. Also, the turbidity and the COD were classified under Class II and Class IV respectively. Only fluoride and chloride were classified under Class I and Class II respectively while the rest of the anions fall under Class V. Overall, the WQI for the Sepang Kecil River was recorded as slightly polluted which is categorized into Class III with the value of 69.0. A total of 37 phytoplankton species with a total of 1020 cells/ml individuals from four divisions were identified and recorded. Division of Chlorophyta showed the highest in terms of the number of phytoplankton species and the number of individual followed by the Division of Bacillariophyta. Species such as *Biddulphia dubia*, *Leptoclindrus danicus*, *Mougeotia* sp., *Pediastrum duplex*, *Ulothrix aequalis*, and *Oscillatoria limosa* were mostly found in all stations and months. Overall, the downstream river has a high diversity of phytoplankton and the classification of water quality based on overall H' values showed that this river was slightly polluted. This result has showed similar with the overall classification of WQI value obtained. Phytoplankton diversity does show the pollution level of the river. Most of the parameters in this study have showed a positive correlation with the phytoplankton. Furthermore, it is recommended that more public education programs implemented to raise the community awareness and understand of the value of our rivers by providing and handling out some brochure to the local resident. The brochure will give some information on how to protect and enhance the quality of river. Also, it is recommended to improve the beds and bank of river by building artificial structures such as rock chutes and planting more mangrove trees to halt erosion. Other recommendation is that to restrict the area of river that are known to be frequently used for resident and living organism from any recreational activities. On the other side, long term monitoring of the algae is required to determine the eutrophication level for the mitigation purposes. In addition, it is suggested that to have frequent monitoring of the fish diversity in this Sepang Kecil River as for the future study and further studies should be done to determine the levels of heavy metals in fish to know the pollution level in this river. It is also recommended to conduct a survey at recreational place nearby this river to know on how this recreational activity can affect and relate to the water quality of river as for the future study.

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APPENDICES

APPENDIX A: BEST FIT EQUATIONS FOR THE ESTIMATION OF THE VARIOUS SUBINDEX VALUES

Subindex for DO (in % saturation)

SIDO = 0	for $x \leq 8$
SIDO = 100	for $x \geq 92$
SIDO = $-0.395 + 0.030x^2 - 0.00020x^3$	for $8 < x < 92$

Subindex for BOD

SIBOD = 100.4 - 4.23x	for $x \leq 5$
SIBOD = 108 * exp (-0.055x) - 0.1x	for $x > 5$

Subindex for COD

SICOD = -1.33x + 99.1	for $x \leq 20$
SICOD = 103 * exp (-0.0157x) - 0.04x	for $x > 20$

Subindex for NH3-N

SIAN = 100.5- 105x	for $x \leq 0.3$
SIAN = 94 * exp (-0.537x) - 5 * | x-2|	for $0.3 < x < 4$
SIAN = 0	for $x \geq 4$

Subindex for SS

$SISS = 97.5 * \exp(-0.00676x) + 0.05x$ for $x \leq 100$

$SISS = 71 * \exp(-0.0061x) - 0.015x$ for $100 < x < 1000$

$SISS = 0$ for $x \geq 1000$

Subindex for pH

$SIpH = 17.2 - 17.2x + 5.02x^2$ for $x < 5.5$

$SIpH = -242 + 95.5x - 6.67x^2$ for $5.5 \leq x < 7$

$SIpH = -181 + 82.4x - 6.05x^2$ for $7 \leq x < 8.75$

$SIpH = 536 - 77.0x + 2.76x^2$ for $x \geq 8.75$

Notes: * means multiply with

Sources: (Department of Environment, 2013)

APPENDIX B: MONTHLY RAINFALL DATA IN KLIA SEPANG FROM MALAYSIAN METEROLOGICAL DEPARTMENT

Year	Month (mm)												ANNUAL (mm)
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
2014	–	–	–	–	282.8	88.2	59.8	143.6	178.6	257.8	486.4	385.0	2212.2
2015	201.4	48.4	–	–	–	–	–	–	–	–	–	–	–