WATER QUALITY ASSESSMENT OF SEPANG RIVER BASED ON PHYSICO-CHEMICAL ANALYSIS AND PHYTOPLANKTON COMMUNITY

NUR FARAHIN BINTI MOHD ALI

FACULTY OF SCIENCE
UNIVERSITY OF MALAYA
KUALA LUMPUR

2017

WATER QUALITY ASSESSMENT OF SEPANG RIVER BASED ON PHYSICO-CHEMICAL ANALYSIS AND PHYTOPLANKTON COMMUNITY

NUR FARAHIN BINTI MOHD ALI

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

MASTER OF TECHNOLOGY

INSTITUTE OF BIOLOGICAL SCIENCES
FACULTY OF SCIENCE
UNIVERSITY OF MALAYA
KUALA LUMPUR

2017

UNIVERSITY OF MALAYA

ORIGINAL LITERARY WORK DECLARATION

Name of Candidate: Nur Farahin Binti Mohd Ali

Registration/Matric No: SGH130004

Name of Degree: Master of Technology (Environmental Management)

Title of Project Paper/Research Report/Dissertation/Thesis (“this Work”):

Water Quality Assessment of Sepang River Based on Physico-Chemical Analysis and Phytoplankton Community

Field of Study: Environmental Management

I do solemnly and sincerely declare that:

(1) I am the sole author/writer of this Work;
(2) This Work is original;
(3) Any use of any work in which copyright exists was done by way of fair dealing and for permitted purposes and any excerpt or extract from, or reference to or reproduction of any copyright work has been disclosed expressly and sufficiently and the title of the Work and its authorship have been acknowledged in this Work;
(4) I do not have any actual knowledge nor do I ought reasonably to know that the making of this work constitutes an infringement of any copyright work;
(5) I hereby assign all and every rights in the copyright to this Work to the University of Malaya (“UM”), who henceforth shall be owner of the copyright in this Work and that any reproduction or use in any form or by any means whatsoever is prohibited without the written consent of UM having been first had and obtained;
(6) I am fully aware that if in the course of making this Work I have infringed any copyright whether intentionally or otherwise, I may be subject to legal action or any other action as may be determined by UM.

Candidate’s Signature Date:

Subscribed and solemnly declared before,

Witness’s Signature Date:

Name:

Designation:

ABSTRACT

Water quality assessment of Sepang River based on physico-chemical analysis and phytoplankton community was carried out on monthly basis from May 2014 to February 2015 at 5 sampling stations. Water quality parameters that were analyzed were water temperature, pH, dissolved oxygen, turbidity, total dissolved solid, suspended solid, salinity, conductivity, biochemical oxygen demand, chemical oxygen demand, ammoniacal nitrogen, chlorophyll a, nitrate, nitrite, bromide, chloride, fluoride, sulphate and phosphate. Diversity of phytoplankton at the sampling stations was also examined. Based on the National Water Quality Standard of Malaysia (NWQS) and the results of this study, most of the water quality parameters of Sepang River are classified as moderate. Chloride, sulphate and nitrite present in the river are in high concentrations. A total of 59 species of phytoplankton with 6 main divisions were identified namely Bacillariophyta, Chlorophyta, Chrysophyta, Cyanobacteria, Pyrrophyta and Euglenophyta. The phytoplankton community was dominated by the division of Bacillariophyta and Chlorophyta. From the physical analysis using SPSS (Statistical Package for the Social Sciences) programme, phytoplankton has a negative response or correlation towards turbidity, suspended solid, COD, ammoniacal nitrogen, nitrate, phosphate and sulphate. In addition, from ANOVA analysis, only dissolved oxygen and salinity has shown a significant difference in between both stations and months. The values obtain from Shannon–Wiener formula indicated that high diversity of phytoplankton was found in the upstream of this river. Lastly, the overall water quality index for this river is 84.6 can be classified in class II which is considered as clean.

ABSTRAK

Kajian mengenai penilaian kualiti air di Sungai Sepang, Selangor berdasarkan analisis fizikal dan kimia serta komuniti fitoplankton telah dijalankan di lima lokasi pengumpulan. Analisis kualitatif dan kuantitatif dijalankan setiap bulan selama sepuluh bulan bermula dari Mei 2014 sehingga Februari 2015. Analisis fizikal dan kimia parameter yang telah dijalankan adalah suhu, pH, oksigen terlarut, kekeruhan, total pepejal terlarut, pepejal termendap, kemasinan, konduktiviti, permintaan oksigen biokimia, permintaan oksigen kimia, nitrogen ammoniakal, klorofil a, nitrat, nitrit, bromida, klorida, florida, sulfat, dan fosfat. Keputusan kajian menunjukkan kebanyakan parameter fizikal dan kimia tersenarai di dalam tahap sederhana sebagaimana yang dirujuk kepada NWQS Malaysia. Bagi analisis kimia, klorida, sulfat dan nitrit menunjukkan bacaan kepekatan yang tinggi di dalam air sungai. Keseluruhan 59 spesis fitoplankton beserta 6 divisi telah dikenalpasti iaitu Bacillariophyta, Chlorophyta, Chrysophyta, Cyanobacteria, Pyrrophyta dan Euglenophyta. Komuniti fitoplankton di sungai ini telah didominasi oleh divisi Bacillariophyta dan Chlorophyta. Berdasarkan analisis menggunakan program SPSS pula, fitoplankton menunjukkam tindakbalas negatif kepada kekeruhan, pepejal termendap, permintaan oksigen kimia, nitrogen ammoniakal, nitrat, fosfat dan sulfat. Selain itu, analisis ANOVA menunjukkan hanya oksigen terlarut dan kemasinan yang mempunyai perbezaan signifikasi antara lokasi and bulanan. Bacaan daripada kiraan formula Shannon–Wiener menggambarkan diversiti fitoplankton di bahagian atas sungai ini adalah tinggi. Akhir sekali, indeks kualiti air keseluruhan bagi Sungai Sepang adalah 84 dan ini boleh diklasifikasikan di dalam kelas kedua dan tergolong di dalam tahap yang bersih.

ACKNOWLEDGEMENT

First and foremost, I would like to express my sincere gratitude and appreciation to both of my supervisors, Associate Professor Dr. Rozainah Mohamad Zakaria and Dr. Pozi Milow for their valuable thoughts, dedication and keen interest in helping me to complete my research. I am extremely grateful and thankful for their assistance, suggestions and guidance during my period of studies. They did not only share their knowledge and expertise but also supported me in terms of funding (Research Grant No: RU006G - 2014) and spent their precious time to meet me whenever I am in need of their supervision, encouragement and motivation.

Special thanks to the Department of Environment Malaysia, laboratory mates, university drivers, boatmen and the Assistant Science Officers for providing information about the site and the data needed for the research. I also want to thank the people who have been helping me whole heartedly in completing my Master’s Degree. They are my fellow classmates and my closest friends (Qistina, Farah, Norahizah, Lyiana, Nurain, Adibah, Nadia and Amirah). Without them, I may have not finished writing this dissertation as they are the ones who would always be there for me whenever I’m in need. All of their support and cheering words will be always be in my heart.

Last but not least, I would like to specially thank my parents, Mom (Jarinah Mohd Yusof) and dad (Mohd Ali Mohd Yusof) for all the moral and financial support which they have provided throughout my studies and also my life. Finally, a big thank you to my brothers and sisters for all the love and encouragement that they have given to me in completing my studies.

TABLE OF CONTENTS

ABSTRACT	iii
ABSTRAK	iv
ACKNOWLEDGEMENT	v
TABLE OF CONTENTS	vi-vii
LIST OF TABLES	viii
LIST OF PLATES	ix
LIST OF SYMBOLS AND ABBREVIATIONS	x
LIST OF APPENDICES	xi

CHAPTER 1: INTRODUCTION

1.1	General introduction	1-6
1.2	Objectives	7

CHAPTER 2: LITERATURE REVIEW

2.1	River water quality monitoring	8-9
2.2	River water quality studies	10-12
2.3	Phytoplankton as Bioindicator	13-14
2.4	Relationship between phytoplankton and physico-chemical parameters	15-18
2.5	Background studies of Sepang	19-20

CHAPTER 3: MATERIALS AND METHOD

3.1	Description of the study area	21-25
3.2	Water sampling and preservation	26
3.3	Physico-chemical analysis	26
3.3.1	Temperature and dissolved oxygen	26
3.3.2	pH, conductivity and salinity	27
3.3.3	Turbidity, suspended solid and total dissolved solid	27
3.3.4	Biochemical oxygen demand	28
3.3.5	Chemical oxygen demand	29
3.3.6	Ammoniacal nitrogen	30

3.3.7 Chlorophyll *a* 30
3.3.8 Anion analysis 31
3.4 Phytoplankton Sampling 32
3.4.1 Phytoplankton analysis 33
3.5 Data Analysis 34

CHAPTER 4: RESULTS AND DISCUSSION
4.1 Physico-chemical of Sepang River 35-53
4.2 Anion analysis 54-58
4.3 Phytoplankton analysis 59-72
4.4 Correlation of phytoplankton with parameters 73-79
4.5 Water quality index 80-81

CHAPTER 5: GENERAL DISCUSSION 82-83

CHAPTER 6: CONCLUSION 84

REFERENCES 85-103

APPENDICES 104-109

LIST OF TABLES

Table 4.1:	Mean of physico-chemical parameters of Sepang River in five stations	35-36
Table 4.2:	Mean of physico-chemical parameters of Sepang River measured from May 2014 to February 2015	37-38
Table 4.3:	Anova Analysis for all the physico-chemical parameters	39
Table 4.4:	Anion analysis of Sepang River measured using ion chromatography according to station	54
Table 4.5:	Presence of each species of phytoplankton found according to station	59-61
Table 4.6:	Presence of each species of phytoplankton found according to month	62-65
Table 4.7:	Shannon–Wiener diversity index (H’) values in Sepang River in five stations	70
Table 4.8:	Shannon–Wiener diversity index (H’) values in Sepang River from May 2014 to February 2015	71
Table 4.9:	Correlation analysis of phytoplankton with parameters and chemicals by using IBM SPSS Statistics Version 20 Software	73
Table 4.10:	Water Quality Index (WQI) value for each station of Sepang River	80
Table 4.11:	Water Quality Index (WQI) value for each month of Sepang River from May to October 2014	80

LIST OF PLATES

		Page
Plate 3.1:	Map showing the five stations of the study site at Sepang River	23
Plate 3.2:	Picture of Station 1	24
Plate 3.3:	Picture of Station 2	24
Plate 3.4:	Picture of Station 3	24
Plate 3.5:	Picture of Station 4	25
Plate 3.6:	Picture of Station 5	25
Plate 3.7:	YSI 550A Dissolved Oxygen Meter	26
Plate 3.8:	YSI handheld multimeter	27
Plate 3.9:	BOD bottles	28
Plate 3.10:	Spectrometer (COD Hanna instrument)	29
Plate 3.11:	Spectrophotometer UV-160A	30
Plate 3.12:	Ion chromatography	31
Plate 3.13:	Plankton net	32
Plate 3.14:	500ml specimen bottle and plankton net	32
Plate 3.15:	An inverted microscope	33
Plate 4.1:	*Biddulphia dubia* Cleoe	68
Plate 4.2:	*Chaetoceros curvisetus* Mangin	68
Plate 4.3:	*Chaetoceros didymium* Ehr	68
Plate 4.4:	*Chaetoceros diversum* Cleve	69
Plate 4.5:	*Diatoma elongatum* Agardh	69
Plate 4.6:	*Pediastrum duplex* Meyen	69

LIST OF SYMBOLS AND ABBREVIATIONS

BOD	:	Biochemical oxygen demand
cm	:	Centimetre
COD	:	Chemical oxygen demand
DID	:	Department of Irrigation and Drainage
DO	:	Dissolved oxygen
DOE	:	Department of Environment
NWQS	:	National Water Quality Standard
L or l	:	Litre
m	:	Metre
mg	:	Milligram
ml	:	Millimeter
NH_3	:	Ammoniacal nitrogen
nm	:	Nanometer
NTU	:	Nephelometric turbidity units
SI	:	Sub-index
sp	:	Species
TDS	:	Total dissolved solid
SS	:	Suspended solid
µg	:	Microgram
µS	:	MicroSiemens
WQI	:	Water quality index
°C	:	Degree Celsius

LIST OF APPENDICES

		Page
Appendix A	Tables of National Water Quality Standard for Malaysia Water, Classes and Uses	104-105
Appendix B	DOE water quality classification based on water quality index	106
Appendix C	Records of monthly rainfall amount in KLIA Sepang	107
Appendix D	Records of the numbers of raindays in Sepang	108
Appendix E	Map of Sungai Pelek, Sepang provided by Sepang Municipal Council	109

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Water is the basic unit of life and it is one of the most important and abundant compounds of the ecosystem. All living organisms need water for their survival and growth. Good quality water is essential for all living things. Even modern technologies could not change our dependency on water. Fresh water is a limited resource as important for industry and agriculture as for human existence (Khalil & Ouarda, 2009). There is presently an emphasis on diffuse rather than point sources of water pollution. These adverse effects on water are a result of increasing water demand from many activities such as agriculture, industrial activities, hydroelectric generation and continued pollution. Furthermore, the consequences are further exacerbated by population growth, rapid urbanization and climate change (Birol et al., 2006).

Rivers and streams are very important natural's environment and linked to human lives, animals and vegetations (Wu et al., 2010). As the country progresses towards realizing Vision 2020 through the implementation of its policy agenda for heavy industrialization, infrastructures and urban expansions, water demand has increased steeply and greater pressure is on preserving the current water resources as well as finding alternative courses of action to improve water quality (Muyibi et al., 2008). Rapid industrialization, although relatively well-planned and regulated has been putting increased pressure on urban areas especially in the river basin which is situated in Selangor (Bradley, 2010).

The monitoring of environmental parameters is one of the priorities in the evaluation of environmental status of water resources and in environmental protection policy.

Water quality covers physical, chemical and biological aspects of water quality. All these aspects had profound impacts on aesthetical and usability to consumers, they are linked and inseparable to ensure water quality kept at utmost (Viswanathan et al., 2009; Meybeck et al., 1992). Studies on the rivers in Malaysia have progressed through many organizations which include local universities, government departments, research centers and non-governmental organizations (Ho, 1995). However, few studies have been done on water quality in relation to distribution and species composition of algae (Maznah & Mansor, 2002).

Knowledge on the water quality of a particular river is of upmost important in determining the suitability of the river water to be used for domestic purpose as well as for providing suitable habitat for aquatic organisms. Some of the physico-chemical parameters that are involved in water monitoring are pH, turbidity, Total Dissolved Solid, conductivity, temperature, Dissolved Oxygen (DO), salinity, Ammoniacal Nitrogen (AN), suspended solid, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Chlorophyll *a*. The anions such as Flouride, Chloride, Nitrite, Bromide, Nitrate, Phosphate and Sulphate are also important in determining the status of water.

Biological aspect in water quality often received little consideration in water resources research relative to physical and chemical aspects (James & Evison, 1979; Karr, 1991). This had also being a trend in Malaysia where most water quality related research and studies are focusing more on physical and chemical parameters only (Ghani et al., 2009; Abdullah & Nainggolan, 1991; Latiff et al., 2009) with largely neglecting the biological parameters. Biological studies are able to provide continuous temporal and spatial information in water ecosystem without aforementioned limitations (Swaminathan, 2003).

One of the techniques that cover biological aspects is the bioassessment. Biological assessments of environmental impacts on water quality and aquatic organisms have been used since the early 1900s (Wallace et al., 1996). It is the use of organisms such as bacteria, algae, macrophytes, macroinvertebrates and fishes as the ecosystem indicators and bioaccumulators to assess the water quality. Bioindicators act as a measure of prevailing environmental conditions. They may also be used to observe the functioning and cause-and-effect relationship within an ecosystem. Primary productivity has been used as a biological parameter to monitor the overall response of vegetation to a prevailing environment in terrestrial ecosystems (Khan, 2003). Changes in the rate of primary production as an indication of trophic status of aquatic ecosystems have been one of the major indicators of their health (Herrera-Silveira et al., 2002).

In Malaysia, biological monitoring in water supplies normally involves total coliform count for detection of fecal pollution and the presence of phytoplankton. Microscopic algae called phytoplankton float or swim in lakes, rivers and oceans. Together with the aquatic higher plants, they are the basis of freshwater and marine food chains. Besides that, since phytoplankton need specific conditions to grow, they frequently become the first indicator of change in the environment (Salleh & Tajuddin, 2006). These planktonic algae comprise a wide range of sizes, from the largest forms which are visible to the naked eye to the smallest size ever that are microscopic. Due to their photosynthetic pigment, phytoplankton can be considered as an important primary producer in the food chain (Ismail, 1994). They also provide a rich supply of oxygen for other organisms and acts as an important food source in the culture of freshwater fish and crustaceans. In addition, they often includes a numerous and diverse collection of extremely small, motile plants collectively termed as microflagellates (Tait, 1970).

The advantages of employing phytolankton in biomonitoring of aquatic environment are based on the fact that these organisms reflect the concentration of physico-chemical parameters in the water ecosystem (Zbikowski & Kobak, 2007). Phytoplankton such as diatoms quickly reflected environmental stressors because of their short life cycles as in six days (McCormick & Cairns Jr, 1994). Besides that, they also respond rapidly and predictably to a wide range of pollutants and provide potentially useful early warning signals of deteriorating conditions of the water. However, high phytoplankton density poses problems in drinking water treatment processes and recreational activities. Consumers may have difficulties in using the water because of its taste and odor, and they may also experience a toxic effect (Welch, 1992). The toxic effect of phytoplankton can be found in dinoflagellate Dinophysis species, where they can produce toxin called okadiac acid and dinophysis toxins that will eventually initiate symptoms including diarrhea, nausea and vomiting when the seafood containing toxin are consumed. Another problem which can be caused by phytoplankton is a process known as eutrophication. Eutrophication is when the environment becomes enriched with nutrients. This can be a problem in lakes and rivers as it can cause algal blooms.

Water quality can be judged either by individual parameters for any specific interest or by a few, selected, important parameters to judge the overall water quality. Many countries make use of the water quality index (WQI) method to assess overall river status (Meybeck et al., 1992). These indices differ from country to country but share a similar concept, where a few important parameters are selected and compounded to numerical rating for the evaluation of river water quality (Almamun & Idris, 2008). Malaysia also follows compound WQI to evaluate overall water quality. The existing WQI equations are proposed by the Department of Environment Malaysia (DOE). The equation consists of six parameters, namely dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, suspended solids, ammoniacal nitrogen and pH.

There are many researches that have been carried out about water quality of rivers in Selangor but these water quality researches need to be continuously done in order to maintain the cleanliness and healthiness of the river. Therefore, Sepang River is chosen to be assessing because of its importance and strategic locations of many factors. Sepang is located in the southern part of the state of Selangor, Malaysia. Formerly, it is a small town which now grew to its current size through a series of several developments. It is also one of the famous towns in Selangor where the beautiful Bagan Lalang beach is situated. There is also Sepang Goldcoast; an eco friendly tourist hotspot destination due to its unique resort built in resemblance to a palm tree. Apart from that, there lies an important hub for airline of Malaysia, the Kuala Lumpur International Airport (KLIA) which is currently busy operated. Besides that, The Sepang International Circuit is the home of the Malaysian Grand Prix which is the Malaysian leg of the Formula One race and the Malaysian Motorcycle Grand Prix. These are all the major importance of Sepang district that hold a huge benefits in terms of economic. Sepang River has been listed to be one of the seven river basins in Selangor. The rivermouth of Sepang River is where it is actually connected to the Sepang Goldcoast Resort as well as the Bagan Lalang beach. Hence, this river has to be in a good condition as it will affect all the important hub areas which are located near to the river.

The Sepang River estuary is an economically important area, which supports commercial fish and prawn, and is regarded as being an important breeding ground and nursery for a number of estuarine and marine species of flora and fauna. Pig farm discharges are increasingly affecting the Sepang River estuary. Discharges from pig farms have been the second largest contribution to water pollution, since 1989-1993

(DOE, 1997). Effluent discharged from pig farm usually contains toxic trace metals, which affects environmental and water quality (Arzul & Maguer, 1990).

High percentage of ß-Sitosterol shows that Sepang River rich with many kinds of plants and trees. Along the Sepang River, there are many mangrove trees, oil palm and rubber plantation area which contribute to the source of ß-sitosterol (Piah et al., 2008). Mangrove plants are located on both sides of the Sepang River. Mangrove is one of the most productive ecosystems and is one of the important factors for economic growth. Environmental pollution in the mangrove areas recently becomes unpredictable because of uncontrolled emissions of metals through the river mostly due to agricultural and industrial activities (Kumar et al., 2014). The level of contamination may extend its hazardous effect to aquatic life, system and human health, especially to human consumers of seafood, by bioaccumulation in food chain.

Improvement in the sectors of municipal, development, industrial and tourism as well as the addition of the populations at the coastal area have destroyed nature, reducing water quality and increase the pressure on marine resources (Piah et al., 2008). Pollution of water, air and land continued to be one of the major environmental problems in Malaysia. As a result, rivers and oceans are polluted with industrial waste, oil spill and disposal of waste materials. This in turn will cause danger to the health and lives of people living along the river as well as the coastal areas.

1.2 Objectives

The main objectives of this research are:

i. To study the physico-chemical and anion properties of Sepang river.
ii. To study the phytoplankton community of Sepang River.
iii. To describe the water quality of Sepang River using river classification based on DOE-Malaysia water quality index (WQI) and National Water Quality Standard of Malaysia (NWQS).
iv. To relate the water quality of Sepang river according to WQI, NWQS and other physico-chemical properties and Shannon-Wiener Diversity Index.

Therefore, the aim of this study is to provide detailed information on the evaluation of current status of water quality for Sepang River (2016) to be used for the river basin management in the future.

CHAPTER 2

LITERATURE REVIEW

2.1 River Water Quality Monitoring

Freshwater ecosystems have a primary role in the biosphere as conduits of water and nutrients from the continents to the sea. Because of this and the critical role of fresh water as a human resource, ecologist are often asked to assess and monitor the "health", " status" or "condition" of this ecosystems (Bailey et al., 2001). Rivers are an important resource for life which we depend on for water supply, transportation, irrigation, fisheries, hydro-electric power and water use for our industries.

Anthropogenic disturbance of freshwater streams and lakes is one of the major environmental problems faced in Malaysia in the early 90's (Yap, 1997). Apart from that, rapid development has increased many folds in all the major cities and towns. Unfortunately, all these developments including housing, transportation and industry sectors have impacted river systems and created environmental problems such as water pollution, flash flooding and water shortage. There are many factors (point sources and non-point sources pollutants) that contribute to the deteriorating quality of the river water. Besides the point sources pollutants such as sewage, sullage, industrial effluent, agriculture effluent and others, the non-point sources which include urban and rural runoff are also responsible for making the river water unsuitable for our use.

There are 189 river basins in Malaysia and 150 of them are the main river basins (Arsad et al., 2012). About 100 of the main river basins in Malaysia are situated in Peninsular Malaysia, where 50 are situated in Sabah and Sarawak. It is estimated that there are 1800 rivers in Malaysia with total length of more than 38, 000km (Department of Irrigation and Drainage, 2009). Rivers and streams in Malaysia serve as the purpose for agriculture, industry, water supply, transportation, aquatic habitats, water sport and recreational. Monitoring and management of rivers and streams water quality in Malaysia lies under the jurisdictions of two government agencies; one is The Department of Environmental in Malaysia (*Jabatan Alam Sekitar Malaysia*), also known as JAS or DOE, and the other one is The Department of Irrigation and Drainage Malaysia (*Jabatan Pengairan dan Saliran Malaysia*) also known as JPS or DID. Specifically, in Selangor there are other agencies which are responsible for the management of water resources such as *Lembaga Urus Air Selangor* (LUAS) and *Jabatan Bekalan Air* (JBA).

Every year, DOE publishes Environmental Quality Report to report the environmental status of air, water and soil in Malaysia. In assessing and reporting the water quality status of river and streams in Malaysia, DOE uses physicochemical based method through their own developed Water Quality Index Malaysia (WQI Malaysia) (Arsad et al., 2012). The WQI Malaysia was developed in Malaysia by collaboration efforts between DOE and University of Malaya in 1985 (Arsad, 2009). This parameter includes pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH_3-N), Suspended solid (SS) and Dissolved Oxygen (DO). Assessment and valuation of these parameters produced an index value ranging from zero to one hundred. According to the index value, the river water quality can be classified into three main classes. Rating from the index reflects the composite influence of number of water quality parameters overall of water. Calculated index for a given river will determine its quality status, which later will determine the management action needed by respective agencies (Arsad et al., 2012).

2.2 River Water Quality Studies

The history of bioindicator systems for surface water quality assessment started more than a century ago by Kolenati (1848) and Cohn (1853), both quoted by Liebmann, 1962; De Pauw & Vanhooren, 1983; Ilipoulou-Georgudaki et al., 2003 who observed that organisms occurring in polluted water are different than the one presence in the clean water. Discussion on bioindicator had run more than 100 years after Kolenati (1848) literally made first starting point when he concluded that the absence of caddis larvae from a stream can be caused by the presence of a city upstream and it was very old and the very beginning of biological method used in the river monitoring study conducted in Europe (Liebmann, 1960; Sladecek, 1973; Mol, 1980).

Malaysia has started to integrate biological technique for rivers and streams monitoring across the country and this has been started by Department of Irrigation and Drainage in Malaysia (Department of Irrigation and Drainage, 2009). However, the implementation is still new compared to traditional physico-chemical based technique. Until now, the assessment on physico-chemical parameters in water quality is still dominant in many river water quality studied in Malaysia e.g. (Bouza-Deano et al., 2008; Yunus and Nakagoshi, 2004; Latiff et al., 2009). These concentrations on physical and chemical based method are particularly surprising in judging natural waters where the main aim is often the preservation of biological amenities (Arsad et al., 2012). Review on the water quality standards and practices in Malaysia by Idris et al. (2003) reveals, chemical parameter such as Ammoniacal Nitrogen (NH_3-N) was identified as one of the main sources of pollutants to Malaysian rivers. In the review, they suggested direct efforts in searching for other pollutants that frequently found in Malaysian river system.

Studies on the water quality in Malaysia with relation to bioindicator started relatively late as the earliest and well documented one was in 1990 when Khan (1990) conducted a case study in Linggi River Basin to assess water pollution by using diatom community structure and species distribution. He found a marked variation in species association exist between the polluted and unpolluted stations. Later in 1991, Khan furthers the studies on this topic to detect the effect of urban and industrial wastes on species diversity of diatom community in a tropical river, Malaysia (Khan, 1991). Interest on this topic indicate a growth when Yap (1997) made an attempt to classify Malaysian rivers using biological indices such as Shannon-Wiener diversity index and the Saprobic system, concept of Kolkwitz and Marsson. Yap found that the Shannon-Wiener diversity index approach appeared to give interesting and interpretable classification results compared to the Saprobic index.

Diversity is a parameter of community structure which is related to the number of species (species richness) and abundance. This parameter is presented in several ways by different researchers. One of the common diversity indices is Shannon-Wiener diversity index (H') (Krebs, 1999). H' has been used widely in environmental monitoring (Washington, 1984). According to the study of Salusso and Morana (2002), there are three classes of pollution status based on H'. In their scale, water bodies with H' more than 3 has no contaminant, H' values ranged 1-3 contain moderate contaminants and H' less than 1 indicates high pollution level. In addition, Wilhm and Dorris (1968) and Wilhm (1968) also proposed a water quality classification based on H'.

Some of the researchers focused on the relationship between water quality degradation and biological indices and community. Yeng (2006) showed that the increase of water pollution was associated with the appearance of certain phytoplankton (dinoflagellate) in the Ahning Reservoir. Khan (1991) reported that higher diversity values of phytoplankton in the moderately polluted stations compared to polluted stations in the Linggi River Basin Malaysia. Yap (1997) used H' and saprobic index of phytoplankton for water quality assessment of river ecosystem. He concluded that ecological knowledge can be used in the management of water body. Furthermore, Ho and Peng (1997) also worked on H' values of phytoplankton community in three rivers which are Sungai Perlis, Sungai Perai and Sungai Juru in northern Peninsular.

Beginning in the year of 2000, the studies on biological method in the river water quality studies started to increase in Malaysia and examples of these study can be seen in (Al-Shami et al., 2010; Azrina et al., 2006; Maznah & Mansor, 2002). One of the examples of research on biological methods using phytoplankton can be seen in (Maznah & Mansor, 2002) Aquatic pollution assessment based on attached diatom communities in the Pinang River Basin, Malaysia. Their study is on diatom communities in relation with river water quality and they had found certain diatom species that is affected by the degree of water quality in the study area, thus the diatom community could be use as a bioindicator to measure the impacts of pollution.

2.3 Phytoplankton as Bioindicator

Aquatic systems contain a wide variety of microorganisms, which interact with each other in various food webs. According to Hensen (1887), planktons include all drifting organic particles that float freely and involuntarily in an open water. The plant and plant-like organisms form the phytoplankton, (Greek: phyton - a plant), the animal or animal like organisms form the zooplankton, (Greek: zoon-animal) and the bacterial ones the bacterioplankton. Algae or phytoplankton are non-flowering aquatic plants of the planktonic community. They can range from a small single-celled form to more multi-cellular forms. Besides, they are also photosynthetic organisms and exist in a wide variety of habitats. They are most abundant and diverse in oceans, lakes, ponds, streams and other wetlands but they also colonize bark, leaves, rocks, soil, snow and even animals. The photosynthetic activity of phytoplankton in an open water helps to increase the concentration of oxygen in water. Phytoplankton is the main producers in most freshwater environments and thus provides the principal energy base for many aquatic food webs (McCormick & Cairns Jr., 1994). Besides their importance as the primary producers in the food webs and ensuring the ecological balance, species of phytoplankton can be useful indicators of water quality (Kitner & Poulickova, 2003; Rey, 2004). Phytoplankton composition is considered as a natural bioindicator because of its complex and rapid responses to fluctuations of environmental conditions (Livingston, 2000). The main environmental factors recognized as controlling community structure of phytoplankton are physical, (mixing of water masses, light, temperature, turbulence and salinity) and chemical (nutrients).

The most revealing components of the bioindicator-based methods used to identify the ecological state of surface waters are the species richness of algae and their diversity, abundance, and biomass (Barinova et al., 2006; Barinova, 2011). Moreover, phytoplankton species composition is an important part of these characteristics because it plays a central role in the functioning of large rivers. Phytoplankton also shows not only variations in water quality but also changes in physical variables and biotic interactions. Algae are responsive to excessive supplies of inorganic nutrients and may pose problems in long stretches of river experiencing cultural eutrophication, although algae may also enhance water quality for humans in rivers affected by agricultural or industrial waste. The ability to apply phytoplankton-based assessments to evaluate the ecological status of large and lowland rivers lies in developing a better understanding of the ambient conditions in the river relative to undisturbed conditions in such rivers (Wehr & Descy, 1998).

The presence or absence of phytoplankton that is intolerant to pollution reveals much about the health of an ecosystem. Phytoplankton has been used with success in estimation of water pollution (Williams, 1964; Staker, 1974). Algae respond rapidly and predictably to a wide range of pollutants and provide potentially useful early warning signals of deteriorating conditions of the water. From the earliest years of the last century, algae have been identified as a valuable option for the biomonitoring of stream and river ecosystems (Hill et al., 2000). This approach has been applied with success to evaluate a variety of water quality problems (Potapova & Charles, 2003). Phytoplankton communities provide an integrated measurement of water quality as experienced by the aquatic biota and have many biological attributes that make them ideal organisms for biological monitoring. They lie at the base of aquatic food webs and therefore occupy a pivotal position at the interface between biological communities and their physico-chemical environment (Lowe & Pan, 1996). Furthermore, algae have short life cycles and can therefore be expected to respond quickly to changes in the environment (McCormick & Stevenson, 1998).

2.4 Relationship between Phytoplankton and Physico-Chemical Parameters

The growth and density of phytoplankton in a water body is related to many biotic factors such as grazing by zooplankton or other organisms and abiotic factors such as nutrients (principally nitrates and phosphates), temperature, light (Wurtsbaugh & Horne, 1983) and pH (Buzzi, 2002). Other physico-chemical parameters also have a close relationship with the distribution and abundance of phytoplankton.

Temperature exerts a major influence on biological activity and growth that has been widely investigated in phytoplankton ecology. All species have a preferred temperature range. Temperature directly or indirectly affects the vertical distribution of phytoplankton. The direct effect is on plankton mobility which selects certain favorable temperature. The indirect effect is by changing the density and viscosity of water. Indirect effect is on planktons which are carefully adjusted to flotation (Sze, 1998). There is sufficient solar radiation for photosynthetic processes at the surface water. However, intensity of heat damages the phytoplankton cells. Therefore, phytoplankton moves vertically to protect themselves from intensity of heat and light at the surface layer.

A pH indicates the contamination and acidification in a natural water system (Palanaippan et al., 2010). It is an important variable in water quality assessment and is affected by many biological (photosynthesis and respiration) and chemical processes (decomposition) in the water body. Daily variations in pH can also caused by the photosynthesis and respiration cycles of phytoplankton in eutrophic waters. High value of pH is recorded in waters with high organic content and eutrophic condition (Kalff, 2002).

Biochemical Oxygen Demand (BOD) is a measure of the amount of oxygen that bacteria will consume while decomposing organic matter under aerobic conditions (Perry & Vanderklein, 2009). BOD test measures the oxygen demand for carbon component in 5 days. However, this process in tropical areas is complete in 3 days (Hill et al., 2000). The rate of oxygen consumption is affected by temperature, pH, the presence of certain microorganisms and the type of organic and inorganic materials in the water. Chemical oxygen demand (COD) is a measure of oxygen that is required for the oxidation of organic and inorganic matters in water. COD is usually affected by sewage and industrial plants.

Suspended solids (SS) and total dissolved solids (TDS) correspond to non-filterable and filterable residue, respectively. Suspended solid is the suspended or dissolved matter in water or wastewater. Suspended solids are the residue in a well mixed sample of water which will not pass a standard filter. Natural weathering and decomposition of rocks, solid and dead plant materials and the transport or dissolution of weathered product in water contributes a natural background of suspended and dissolved materials to natural waters. TSS has a close association with turbidity and it prevents the penetration of sunlight into the water column which in turn gives a negative effect to the primary production of phytoplankton (Liu, 2005).

Conductivity on the other hand is the ability of substance to conduct electricity and it has more or less linear function of the concentration of dissolved ions in water (APHA, 1992). If the conductivity of the streams suddenly increases, it indicates that there is a source of dissolved ions in the vicinity. Conductivity relates to the total amount of dissolved ions in the water and it has positive correlation with trophic gradient and phytoplankton abundance (Diaz et al., 2007). Sources of pollutants such as wastewater from sewage, agricultural runoff and urban runoff increase ions in water, which increases conductivity (Khan, 1990).

Dissolved oxygen is the amount of oxygen dissolved or carried in the water (Francis-Floyd, 1993). The amount of oxygen in a water body can use as indicator to determine the level of water pollution. Pollution causes a decrease in average DO concentrations. Dissolved oxygen is directly affected on the total phytoplankton density. By decreasing the oxygen levels, some sensitive animals may migrate, weaken or die (MacKinnon & Herbert, 1996).

Salinity refers to the concentration of dissolved salts in water or soil. Guillard (1962) reported that the salinity change can result in osmotic stress on cells, uptake or loss of ions and effects on the cellular ionic ratio in phytoplankton. The salinity tolerance of phytoplankton differs and based on their tolerance extent they are grouped as euryhaline and stenohaline species. Any unnatural change in the salinity is strong enough to affect stenohaline phytoplankton species and could irreversibly change local phytoplankton community structure and establish a new stable climax community (Chakraborty et al., 2011).

Apart from that, ammoniacal nitrogen indicates nutrient status, organic enrichment and health of the water body (Radojevic & Abdullah, 2007). It is a measure for the amount of ammonia, a toxic pollutant often found in landfill leachate and in waste products such as sewage, liquid manure and other liquid organic waste products. High ammonia levels in water also stimulate the growth of aquatic plants and phytoplankton, sometimes leading to ‘blooms’ which may then die and produce anoxic conditions because of the decomposition.

Relative amount of nutrients (C, H, O, N and P) are important for the growth, biomass, physiological state and the community structure of phytoplankton. Nutrients such as phosphorus and nitrogen are essential for the growth of algae and other plants. Excessive concentration of nutrients however, can over stimulate aquatic plant and algae growth and enhance the process of Eutrophication which can lead to an abundant supply of vegetation and causes low dissolved oxygen (Addy & Green, 1997). Anton and Abdullah (1982) studied the effects of nutrient enrichments on phytoplankton composition in Ulu Langat Reservoir, Selangor. Their results showed obvious changes in the phytoplankton composition in response to the addition of both nitrogen and phosphate. In freshwater, reducing the input nutrients, especially phosphorus and nitrogen are able to control Eutrophication (Kalff, 2002).

Inorganic substances such as Chlorophyll *a* may come from wastewater and aquatic organism that live in rivers. Chlorophyll *a* concentrations were used to determine phytoplankton's growth in lake. The concentration of chlorophyll *a* is correlating with the number of phytoplankton individuals. The green pigment (chlorophyll) is present in most photosynthetic organisms and provides an indirect measure of algal biomass and an indication of the trophic status of a water body. It is usually included in assessment programme for lakes, rivers and reservoirs, since excessive algal growth makes water unsuitable or more difficult to treat (Kuo et al., 2007).

2.5 Background Studies of Sepang

In view of the importance and sensitivity of KLIA, the Government of Malaysia has implemented a project as an alternative water supply system to KLIA to mitigate the risk of water supply disruption to KLIA, which will have detrimental effects on the country's image, political aspect and economical aspect (Salleh et al., 2011). This project aimed to optimize storm water as an alternative to conventional raw water source; either direct abstraction from the river or from the dam and reservoir. To produce this scheme, surrounding areas of KLIA such as Kuala Langat and Sepang are being studied. Not all of the past studies concentrating solely on the water quality of Sepang River. For example, one of the studies by Vythilingam et al. (1997) is doing research on the abundance, parity and Japanese Encephalitis (JE) Virus infection of mosquitoes in Sepang district. The two years study shows that based on the elevated abundance and JE infecton rates, *Cx. Tritaenirhynchus* appears to be the most important vector of JE virus in Sepang and the abundance f the mosquito species was affected by the amount of rainfall. Another study in Sepang was carried out by Saed (2001) about ecotoxycology of heavy metals (Cd,Pb,Zn and Cu) in flat tree oysters *Isognomon alatus* from Sepang as shown in his PhD thesis. Previous studies by Ismail & Ramli (1997) also showed that there are elevated levels of heavy metals in some gastropods and sediments of this river near pig farms compared to river mouth.

On the other hand, research by Ya et al. (2014) proved that Sepang River estuary provides a habitat, feeding, and nursery space to 120 individual's fish and fish diversity in the Sepang River can be considered high. To ensure the steady economic value for the local people, they also suggested that it is necessary to have frequent monitoring of fish diversity and further studies should be done in order to conserve the fish in this area by referring to the type of tidal phase which can be affected the diversity of fish that will be caught. It is also recommended that study on the water quality parameters should be done to enhance the accuracy in investigating the factors of fish diversity related to the environment (Ya et al., 2014).

In addition, there was a study conducted by Piah et al. (2008) which focused on the sterol distribution in Sepang River to determine the sources of sterol and the level of sewage contamination. The results obtained showed that cholesterol and terrestrial plants (ß-Sitosterol and stigmasterol) dominated Sepang River while coastal areas were dominated by ergosterol. It is concluded that Sepang River was polluted with sewage based on coprostanol/cholesterol ratios. In addition, there is another study on the rare earth elements present in surface mangrove sediments from several locations throughout west coast of Malaysia done by Kumar et al. (2014). Sepang is chosen as the sampling site because of the mangrove habitat lies on the both sides of the river. Based on the findings, although the concentration level of most of rare earth elements in the surface sediments have not reached extreme or severe of enrichment factor value, however, it is highly recommended for further biological investigation studies should be continuously done on the inputs of anthropogenic activities into mangrove area ecosystems (Kumar et al., 2014). Another seismic engineering study was carried out by Ismail et al. (2016) in order to determine the dynamic properties of the subsurface geo-material structure. The Multichannel Analysis of Surface Wave survey conducted on both sides piers of JKR's Bride crossing the Sepang River shows that the ground soils at this site can be considered as soft soil (Ismail et al., 2016). The seismic study is an important aspect of research to be done at Sepang as it helps future researchers to have a better understanding of the geological side of the area.

CHAPTER 3

MATERIALS AND METHODS

3.1 Description of the study area

This study was conducted in Sepang River mangroves area in Selangor, on the western coast of Malaysia which lies in between the border of Selangor and Negeri Sembilan. Based on Plate 3.1, Sepang River was situated next to a popular recreational beaches; the Bagan Lalang beach. It lies between latitude 2°35'30" N and 101°43'1" E longitude seawards, facing the Straits of Malacca. All coordinates for the sampling locations were recorded by global positioning system (GPS). Sepang River runs from Sepang town through Sungai Pelek town before reaching the Straits of Malacca (Ya et al., 2015). There are Sepang Goldcoast resort, fisherman villages, palm oil estates, aquaculture sites, charcoal power plants, residential area and development area found within the 5 km radius of the confluence of the river (Ya et al., 2014). Besides that, KLIA and Sepang International Circuit are located within 20 km radius from the river.

It has a diverse ecosystem and also rich with natural resources. There are very few mangrove plant species found in this forest area on both sides of the river of which *Rhizophora mucronata*, *Rhizophora apiculata*, *Avicennia alba*, *Sonneratia alba*, *Bruguiera gymnorrhiz*, *Ceriops tagal* and Xylocarpus granatum are most common. Between all of these species *Rhizophora mucronata* has wide distribution and the highest density with 350 trees per ha (Saberi, 1993). From the visual observation, this sampling site was close to a restaurant, a jetty and a water irrigation facility (Noorhaidah & Yap, 2012).

Apart from that, the study area has a humid tropical climate with two monsoon periods, characterized by the southwest monsoon (June to September) and northeast monsoon (November to March) that brings an annual rainfall of about 2000 mm as well as high air humidity with 80 percent average. October, November and December are the months with maximum rainfall while February, June and July are months of minimum rainfall based on Appendix C and D by Malaysian Meteorological Department. The river is 14 kilometres long with the range of 8 to 9.5 metres deep and the total length of the study area is 8.5 kilometres. The distance between the stations is about 1.7 kilometres measured by using GPS tracking method.

Each station has its own activities which are carried out by the people living near the river. In station 1 at the downstream, there is an aquaculture activity on the left side of the river which is the farming of aquatic organisms such as fish and molluscs. Station 2 on the other hand is near to the main jetty port for fisherman and their boats while station 3 does not have any main activities except for being the route that is used by the fisherman to move up and down along the river stream. There is also a mini fish market for the fisherman to sell their catch at the main jetty. Besides that, station 4 is near to the jetty that is used as an alternative to move across the river. Lastly, station 5 is located at the upstream is where the fishing spot for the tourist is held. There are also residential areas and animal farm located near station 5.

In addition, in Sepang area, the geological of the area was underlain by igneous rock mainly granite with granodiorite, syenite and minor conglomerate. Some of the area is also covered by schist, phyllite, slate and limestone (Geological Map of Peninsular Malaysia, 1985). Based on the area, mostly the soils are clay soil and peat soil.

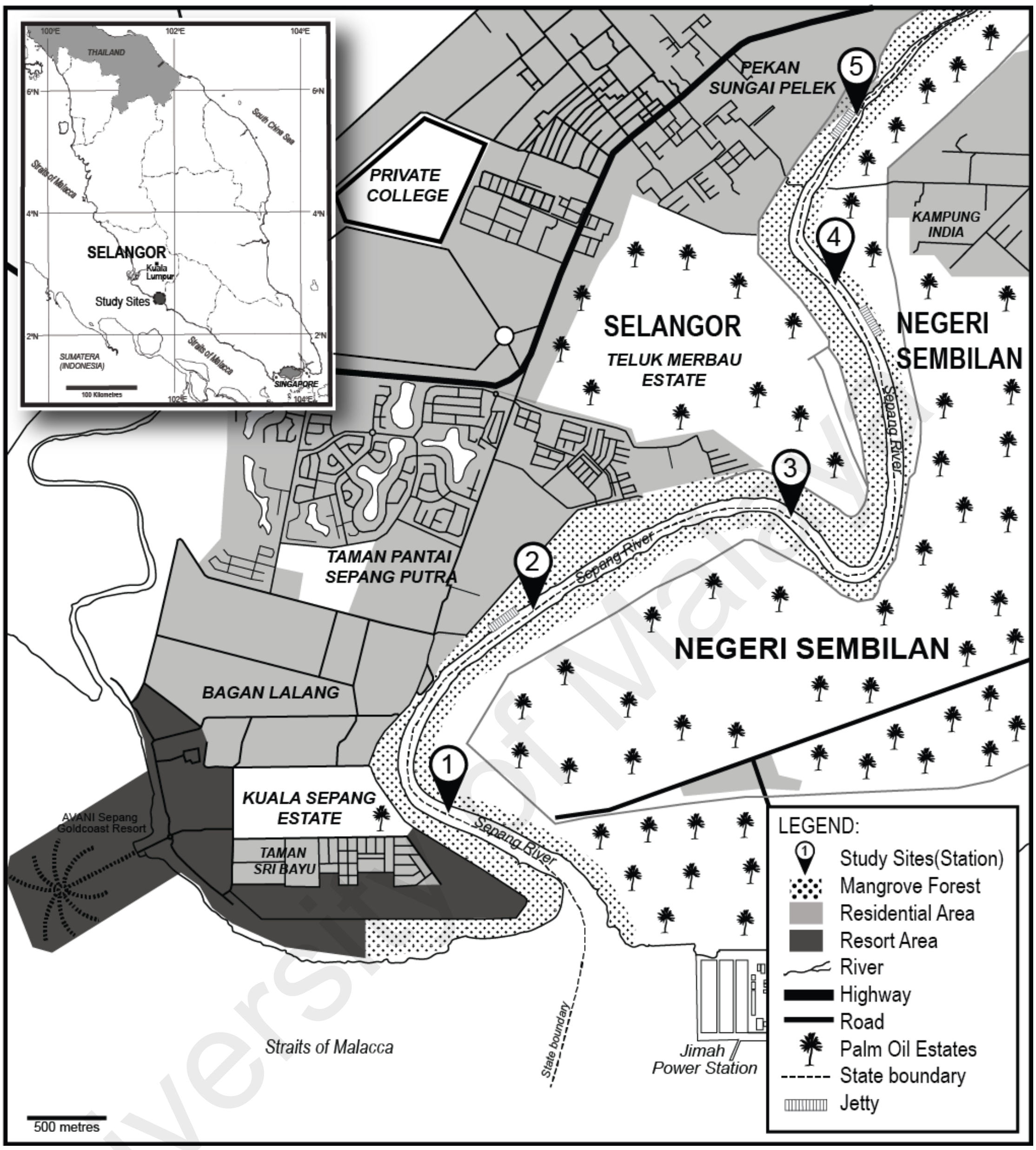

Plate 3.1: Map showing the five stations of the study site at Sepang River

(Source: Based on Appendix E, "*Peta Cadangan Gunatanah Sungai Pelek, Sepang*" provided by Sepang Municipal Council)

Plate 3.2: Picture shows station 1 with aquaculture farm (2°36’9.00”N 101°42’20.49”E)

Plate 3.3: Picture shows station 2 near the jetty area with the fisherman’s boats

(2°36’52.77”N 101°42’36.40”E)

Plate 3.4: Picture shows station 3 with no activities can be seen along the river

(2°37’8.51”N 101°43’30.64”E)

Plate 3.5: Picture shows a clear view of station 4 with no activities carried out on the side of the river (2°37’55.41”N 101°43’40.21”E)

Plate 3.6: Picture shows station 5 with a fishing jetty located at the side of the river (2°38’46.90”N 101°43’52.60”E)

3.2 Water sampling and preservation

Water samples were collected from the five stations located along the river with three replicates, conducted once in every month starting from May 2014 until February 2015. Sample bottles of 500 ml were used to collect the water sample and the bottles were kept in ice and brought to the lab for further analyses. Chemical analysis was conducted immediately within 24 hours of collection, since some variables are subject to change during storage (Bartram and Balance, 1996).

3.3 Physico-chemical analysis

3.3.1 Temperature and Dissolved Oxygen (DO)

Temperature is the degree of hotness and coldness of an environment while dissolved oxygen is defined as the amount of oxygen dissolved in a water body. Both parameters were measured in situ by using YSI 550A Dissolved Oxygen Meter. The average readings of the three recorded values were then calculated.

Plate 3.7: This is YSI 550A Dissolved Oxygen Meter that was used to measure temperature and DO

3.3.2 pH, Conductivity and Salinity

In situ data measurements of pH, conductivity, and salinity were recorded by using YSI handheld multimeter. Three readings were recorded in situ and the average readings were calculated.

Plate 3.8: Picture shows YSI handheld multimeter that was used to record the value of pH, conductivity and salinity

3.3.3 Turbidity, Suspended Solid, Total dissolved solid

Turbidity and suspended solid measurement were taken by using MERCK spectrophotometer in the laboratory. Total dissolved solid were recorded in situ by using YSI handheld multimeter.

3.3.4 Biochemical Oxygen Demand

Standard methods of 5210 B (APHA, 1992) were used to measure BOD of river water sample. The BOD bottles were filled with the water samples and the DO_0 were determined with the DO meter. The BOD bottles were filled to the rim to avoid trapped gas bubbles. The BOD bottles were incubated at 20℃ for 5 days. After 5 day, the DO_5 were determined.

To get the BOD of the water, this equation was used;

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

Plate 3.9: Picture shows BOD bottles which are filled in with water samples

3.3.5 Chemical Oxygen Demand (EPA 410.4 method)

COD measurement was done by using the COD reagent kit. 2 ml of water sample was pipetted into COD HACH vial by using the supplied syringe while keeping the vial at 45 degree angle. The sample was mixed by inverting the vial a couple of times. Next, the blank was made by repeating the steps before with deionized water added into another reagent vial. Then, the vial was inserted into the reactor and was heat for 2 hours at 150°C. The sample is digested in the presence of dichromate at 150°C for 2 hours. Oxidizable organic compounds reduce the dichromate (orange) ion to the chromic (green) ion. After the end of the digestion period, the reactor was turned off and the vials were allowed to cool for twenty minutes to about 120°C. The vial was inverted several times while it is still warm and was leaved in the tube rack to cool. Lastly, HI 83099 COD Multiparameter Photometer (Hanna instrument) was used to take the measurement of COD when vials reached room temperature.

Plate 3.10: Vial was put in the HI 83099 COD Multiparameter Photometer to take COD measurement

3.3.6 Ammoniacal nitrogen

Ammoniacal nitrogen is done by using the test kit and measurement was taken by using MERCK spectrophotometer. The ammonia kit was purchased from MERCK company.

3.3.7 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 measures by using spectrophotometer UV-160A at a wavelength of 665nm 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)

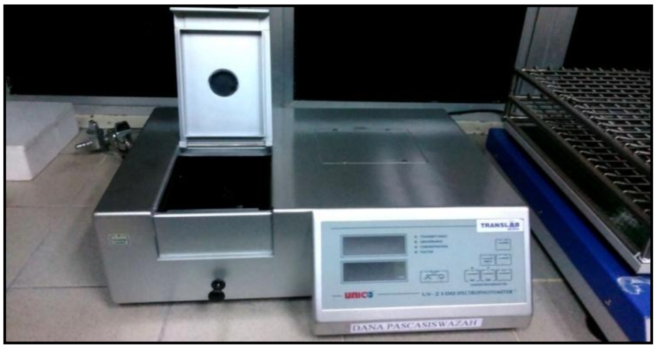

Plate 3.11: Spectrophotometer UV-160A used to detect chlorophyll *a*

3.3.8 Anion Analysis

The collected water samples were immediately brought back to the laboratory. Anion such as Fluoride, Chloride, Nitrite, Bromide, Nitrate, Phosphate and Sulphate were determined by using ion chromatography (Metrohm 882 Compact IC Plus). The process started with the preparation of the anion eluent, suppressor regeneration solution and standard solution for 1ppm, 2ppm and 5ppm. Meanwhile, the ion chromatography must be switched on and let it warmed up. After 1 hour, the standard prepared can be run followed by water samples by injecting the samples through the syringe into the machine. After finished pumped in all the samples one by one, ultra pure water was used to run for cleaning process. All the readings that appeared at the computer screen were recorded. Lastly, the operation was stopped and all the waste water must be thrown out.

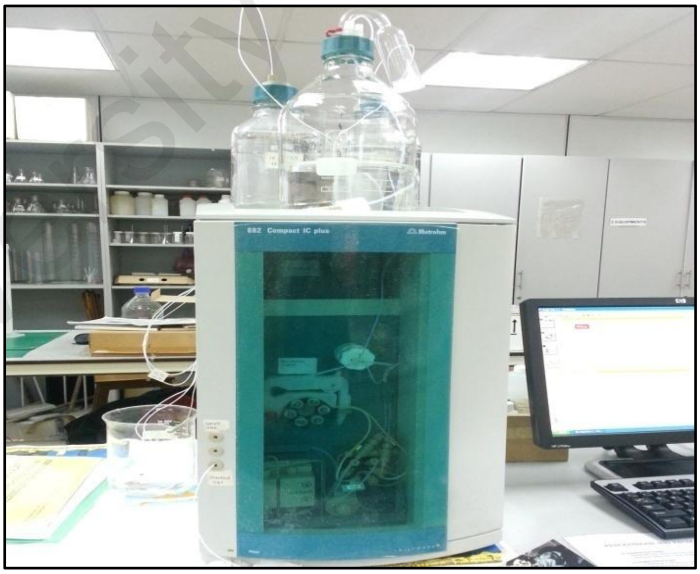

Plate 3.12: Picture shows ion chromatography machine that is used to detect anion

3.4 Phytoplankton sampling

The plankton net with mesh size about 30µm was used to collect the water samples by running the net through the surface water. The water collected at the container at the end of the net was transferred into 500ml specimen bottles and preserved in Lugol's solution. Then, the bottles were brought to the laboratory to be examined and used for the qualitative and quantitative analysis.

Plate 3.13: Picture shows plankton net used in phytoplankton sampling

Plate 3.14: 500ml specimen bottle and plankton net used during sampling

3.4.1 Phytoplankton analysis

A drop of water sample was taken by using pipette and were put on a glass slide and covered with a cover slip. The samples were then observed under the light microscope to identify the phytoplankton to species level whenever possible by using reference books and expertise.

The water sample was put in a container. Then 3 drops of iodine were inserted into the vial by using a pipette. It was put aside for a while, and then the sedimentation chamber were prepared by covering it with a cover slip in between the upper part of the chamber and the base, which is the lower part. The cover slip were spread with vaseline at its sides to make sure that it sticks to the glass slide at the base, to avoid any leakage. When the cover slip is dried and firmly attached in between the sedimentation chamber, 10 mℓ of the water sample was poured into the sedimentation chamber. Then 1 drop of iodine was inserted by using a pipette and was put aside for 40 minutes. After 40 minutes, the upper part of the sedimentation chamber was removed slowly, and the sample that was left in the base was observed under the inverted microscope. The cell counting was done by following the sedimentation chamber method (Lund et al., 1958) and all the Standard of Procedure for phytoplankton analysis were done by following USEPA (1994).

Plate 3.15: An inverted microscope (Olympus BX51) used to identify phytoplankton species

3.5 Data analysis

The comparisons of mean between stations and months were done by using Analysis of Variance (ANOVA) in SPSS software. Shannon-Wiener Diversity Index also was used to measure the phytoplankton species diversity and abundance. Pearson's correlation between phytoplankton and all the parameters were also done by using SPSS software.

Besides that, water quality status and classification were obtained by using the Water Quality Index (WQI) of DOE, Malaysia and were compared to National Water Quality Standard (NWQS). Calculations of WQI were done by entering the six water quality parameters mean values which include DO, BOD, COD, pH, ammoniacal nitrogen (NH_3-N), and suspended solids into a WQI formula. The values were then converted to Sub Indices (SIs) according to the equation below.

The WQI or status of the water was obtained through the calculation of the following formula:

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

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Physico-chemical parameters of Sepang river

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

Station	Temperature (°C)	DO (mg/L)	pH	Conductivity (µS/cm)	Salinity (ppt)	Turbidity (NTU)
1	28.87±1.50	7.67±0.42	7.65±0.30	35.9±19.90	31.99±12.56	17.83±10.12
2	28.79±1.17	7.73±0.83	7.57±0.30	34.52±16.61	29.04±11.82	18.74±10.73
3	28.93±1.48	6.74±1.56	7.62±0.31	34.11±16.78	26.58±9.91	16.51±6.99
4	28.86±1.53	6.32±1.66	7.61±0.25	32.97±14.16	23.2±8.22	20.28±7.94
5	29.39±1.69	5.92±1.38	7.51±0.39	28.81±12.16	18.29±6.87	23.71±9.47

Table 4.1, continued

Station	SS (mg/L)	TDS (mg/L)	BOD (mg/L)	COD (mg/L)	NH3-N (mg/L)	Chlorophyll *a* (µg/L)
1	45.77±13.55	29.97±7.43	2.8±0.92	14.9±0.32	0.42±0.05	0.57±0.16
2	41.76±19.49	29.58±6.94	3.1±0.99	14.8±0.63	0.44±0.07	0.52±0.20
3	40.42±25.27	29.07±6.71	3.2±0.86	14.6±0.52	0.42±0.06	0.51±0.14
4	35.47±8.96	27.08±7.05	3.1±0.59	14.1±1.52	0.42±0.10	0.55±0.28
5	39.81±10.19	26.06±9.43	2.7±0.70	14.8±0.92	0.44±0.07	0.45±0.27

Table 4.2: Mean of physico-chemical parameters of Sepang River measured from May 2014 to February 2015. The symbol "±" refers to standard deviation.

Year	Month	Temperature (°C)	DO (mg/L)	pH	Conductivity (µS/cm)	Salinity (ppt)	Turbidity (NTU)
2014	**May**	29.4±1.14	8.02±0.63	7.38±0.23	48.08±12.33	30.95±9.97	14.76±7.07
	June	28.8±0.84	7.89±0.69	7.52±0.32	47.3±11.29	37.28±12.60	16.90±6.45
	July	32.54±0.50	7.70±0.54	7.6±0.33	63.18±6.21	42.68±4.81	5.98±1.73
	August	30.14±0.30	6.72±0.22	7.46±0.38	16.76±3.35	19.71±2.19	16.06±5.86
	September	28.4±0.38	5.56±1.99	7.47±0.23	16.29±2.87	14.52±2.70	12.36±2.70
	October	26.72±0.47	7.24±1.24	7.82±0.30	27..44±0.66	16.32±2.71	24.40±5.94
	November	27.26±0.40	7.02±0.65	7.8±0.31	25.44±3.44	21.7±6.57	30.12±1.91
	December	27.8±0.84	7.78±0.78	7.64±0.22	37.3±4.10	32.1±9.19	24.08±6.10
2015	**January**	30.34±0.85	5.54±1.39	7.48±0.40	25.32±1.52	21.2±2.12	18.02±2.64
	February	29.68±1.12	5.34±1.52	7.78±0.06	25.54±0.93	21.96±1.66	31.46±8.87

Table 4.2, continued

Year	Month	SS (mg/L)	TDS (mg/L)	BOD (mg/L)	COD (mg/L)	NH3-N (mg/L)	Chlorophyll *a* (µg/L)
2014	**May**	45.77±1.02	23.50±7.19	2.9±0.49	15.2±0.45	0.44±0.01	0.65±0.16
	June	57.14±12.28	22.72±4.84	3.2±0.71	14.0±2.24	0.43±0.01	0.56±0.10
	July	23.52±7.73	31.50±3.06	1.6±0.32	14.6±0.89	0.43±0.01	0.30±0.38
	August	62.80±27.63	21.82±1.70	1.7±0.73	15.2±0.45	0.41±0.04	0.76±0.22
	September	26.40±3.51	18.84±1.88	3.4±0.55	14.0±0.71	0.49±0.06	0.45±0.22
	October	40.40±10.45	39.00±0.68	3.2±0.12	14.6±0.55	0.41±0.09	0.65±0.15
	November	36.60±8.38	37.50±1.03	3.5±0.52	14.6±0.55	0.38±0.08	0.41±0.08
	December	48.78±4.30	32.68±5.44	3.0±0.27	15.0±0.00	0.39±0.05	0.50±0.10
2015	**January**	27.60±5.65	30.70±3.77	3.5±0.44	14.4±0.55	0.52±0.05	0.52±0.05
	February	37.48±10.19	25.26±1.28	3.5±0.40	14.8±0.45	0.35±0.04	0.39±0.08

Table 4.3: ANOVA analysis for all the physico-chemical parameters

Parameter	ANOVA (sd value)	
	Significant(station)	**Significant(month)**
Temperature (°C)	.828	.000*
DO (mg/L)	.006*	.000*
pH	.865	.186
Conductivity (µS/cm)	.890	.000*
Salinity (ppt)	.040*	.000*
Turbidity (NTU)	.465	.000*
SS (mg/L)	.739	.000*
TDS (mg/L)	.735	.000*
BOD (mg/L)	.652	.000*
COD (mg/L)	.281	.331
NH_3-N (mg/L)	.910	.000*
Chlorophyll *a* (µg/L)	.798	.007*

* Correlation is significant at the 0.05 level (2-tailed)

Table 4.1 shows the mean values of physico-chemical parameters of Sepang River for five stations. The highest temperature recorded was at station 5 while the lowest temperature was at station 4 with 29.39°C and 28.86°C respectively. On the other hand, based on Table 4.2, the overall mean temperature ranged from 25°C to 33°C. The highest and the lowest temperature values recorded in July 2014 and October 2014 respectively showed that these values are interrelated with the seasons in Malaysia where July is considered to be in the dry season (DS) and October is in the rainy season (RS) as mentioned by Malaysian Meteorological Department. On dry periods and in a hot climate, the flow of the water is reduced and results in the higher water temperatures while on wet weather period, the flow of water increases resulting in a great mixing of the atmospheric oxygen and results in low temperatures. In addition, the results are within the standard acceptable levels of the National Water Quality Standards, Malaysia (NWQS). Furthermore, the temperature fluctuated and increased from the downstream to the upstream sampling stations and no significant difference was found in between the stations (ANOVA, $P > 0.05$). However, there is a statistically significant difference (ANOVA, $P < 0.05$) are found in between the 10 months. This is primarily due to the weather conditions.

Generally, many factors such as the weather condition, sampling time, and the location impacted on the increase or decrease of temperature by which its role affected the percentage of the dissolved oxygen, biological activities and other parameters (Al-Badaii et al., 2013). Besides that, the ranges of the temperature recorded in this study are mostly similar and within the range of those reported for the Semenyih river studied (range 24°C-27.55°C) by Al-Badaii et al., (2013). Moreover, the range of temperature in this study is similar when compared to the other studies such as the Parit river (26°C-32°C) by Gandaseca et al, (2011) and the Juru river (28.4°C-34°C) by Al-Shami et al. (2011).

The range of dissolved oxygen (DO) recorded at the five stations was between 5 mg/L to 8 mg/L. The dissolved oxygen concentration at station 5 has the lowest reading with 5.92 mg/L while station 2 shows the highest reading with 7.67 mg/L. Table 4.1 also shows that DO were decreasing starting from station 2 to station 5 which approaches to the upstream. The concentrations were in a narrow range throughout the 10 months with the lowest concentration recorded was in February 2015. The overall mean of DO from May 2014 to February 2015 was 6.88 mg/L.

Aquatic organisms depend on dissolved oxygen to live and the amount of oxygen taken out of the system by respiring and decaying organisms, stream flow and aeration (Ostrander, 2000). The DO concentration recorded was the highest at station 2 and the lowest at station 5. The main factor contributing to the decreasing of the DO levels as it goes upstream is because of the build-up of the organic wastes in the waste discharge from the point source in the station. This is due to the reason that the concentration of DO is affected by the factors such as the flow of the river, present of sources of organic pollution, temperature of the water and the assimilative capacity of the river.

In station 5, there are fishing activities which can be related to the rubbish thrown by the people involved. The low concentration indicated that the input of the organic pollutants upstream of the sampling station affected the DO concentration at the downstream due to the utilization of DO by the microorganism to breakdown the organic matter.

Furthermore, the ANOVA test showed that the values are significantly different ($p<0.05$) among the sampling stations and months. These results are also within the standard acceptable levels of NWQS for the Malaysian river, which is in between 5-7 mg/L as well as categorized under class II. Additionally, the values of DO are similar when compared to the other studies done by Al-Badaii et al., (2013), Al-Shami et al.

(2011) and Azrina et al. (2006) with 5.58-7.07mg/L, 0.48-7.68 mg/L and 3-10.03mg/L respectively.

The mean of the pH values of the five stations ranged from 7.0 to 8.0, which indicated a small range and in a neutral form. Table 4.1 shows that the values for every station were quite similar and the lowest pH value recorded was in station 5 and the highest was at station 1 with 7.51 and 7.65 respectively. The mean values of pH for all the stations were 7.6. From the upstream to the lower stream, there was just a small fluctuation in between them. Based on table 4.2, May 2014 shows the lowest value with 7.38 while the highest value was recorded in October 2014 with 7.82. The standard deviation of the pH values of all the stations and months were low.

Table 4.1 and Table 4.2 shows that all of the pH values are in the neutral level. In general, this indicates that the pollution or activities surrounding the sampling area did not affect the pH value. Theoretically, unpolluted rivers normally show a near neutral or a slightly alkaline pH. Based on the statistical analysis done on pH, there are no significant difference ($p>0.05$) between the sampling stations and months. Rivers with a pH of 5.5 and below are particularly at risk (Mitsch & Gosselink, 1993). In addition, David et al., 2003 reported that when there is more aquatic life during the warmer months, there is also an increase in DO which in turn can lower the value of pH. This incident can be seen in July 2014 when there is less rainfall occurred. Inflowing water may affect pH as well as the rainfall is naturally slightly acidic because of the carbon dioxide dissolved in it. Changes in pH may also influence the other water quality parameters such as ammonia, phosphate, iron and other trace metals.

On the other hand, these pH values are within the range of the other river quality assessment reported by Al-Badaii et al., (2013) with 6.5-9 and also by Azrina et al. (2006) with 5-7.99. In a slightly polluted river such as in the Juru River, the values are low with the range of 6.53-8.67 as reported by Al-Shami et al. (2011). Therefore, the results obtained are within the standard range and are classified under class I based on NWQS for the Malaysian rivers.

Next, in Table 4.1, the highest and lowest values of conductivity recorded were 35.90µS/cm and 28.81µS/cm. In addition, the conductivity values kept on decreasing as it approached the upstream. Based on Table 4.2, the value of the conductivity was higher in the first three months of sampling and started to decrease from August until February 2015. The highest value was recorded in July 2015 with 63.18µS/cm and the lowest was in September 2015 with 16.29µS/cm. The overall mean of all the months of sampling was 33.27µS/cm.

Conductivity values kept on decreasing from station 1 to station 5 as in the upstream to the downstream. This is because of the salinity values recorded which depended on the distance between the sampling stations and the sea water. Salty water conducts electricity more readily than purer water. Therefore, conductivity is routinely used to measure salinity. Normally, conductivity in the water is affected by the inorganic dissolved solids such as calcium, chloride, nitrate, sulphate, aluminium and sodium. The presence of these cations in the river also affected the conductivity concentration.

Contamination discharges can change the water's conductivity in various ways such as an oil spill would lower the conductivity while the discharge of heavy metals can raise it. The use of boat by the fisherman in all of the sampling stations affected the conductivity as the oil spill can be seen from the boat's engine when they moved about from station 1 to station 5. There is no significant difference ($p>0.05$) among the sampling stations. However, there is a significant difference ($p<0.05$) found in between the sampling months. This can be related to the rainfall occurrence which led to soil runoffs and the presence of the nutrients which is different for every month.

The range of the conductivity levels obtained is from 16.29 μs/cm to 63.18 μs/cm which can be considered as in the same levels as in Semenyih river with 13 μs/cm -124 μs/cm by Al-Badaii et al., (2013) and also in Kenaboi River with the mean of 35.67 μs/cm reported by Othman et al. (2012). The conductivity of Sepang River fell into class I and can be classified as low when referred to the NWQS levels. Most of the freshwater conductivity ranged from 10-1000 μs/cm but the value can exceed for about 1000 μs/cm in the water that receiving pollution.

Table 4.1 clearly shows that the trend of salinity concentration was decreasing starting from station 1 (31.99ppt) to station 5 (18.29ppt) from the downstream to the upstream. The overall mean was 25.82 ppt. Based on table 4.2, the lowest salinity recorded was in September while the highest was in July with 14.52 ppt and 42.68 ppt respectively. Salinity has been identified as a "keystone" parameter because it differentiates freshwater from the brackish and marine systems and so significantly influences plant and animal assemblages and wetland's structure and functions. Based on Table 4.1, it clearly shows that the trend of salinity is decreasing starting from station 1 to station 5. This is due to the distance of the stations with the sea as station 1 is near to the estuarine part. This river salinity was high and similar as the salinity in the sea area of Bagan Lalang due to a result of mixing saltwater and freshwater in the estuary area (Piah et al., 2008).

The statistical analysis proved that there is a significant difference ($p<0.05$) of salinity in between the stations and also months. Various actions, often but not exclusively anthropogenic can cause salts to build up in the water. These include the agricultural drainage from the high salt soils, groundwater discharge from oil and various industrial activities which mostly come from station 1. These activities may increase the salt loading and also alter the natural salt balance. The salinity levels recorded in all stations and months are still within the acceptable levels of NWQS for Malaysian river. In addition, the salinity level of the Sepang River is high when compared to other river such as in the Kenaboi River reported by Salleh et al. (2009) with 11.6ppt. This is not surprising as the Sepang River is located near the sea, hence, the value will be much higher when high tide occurs.

The mean of the turbidity recorded at the five stations was 19.41 NTU. The values kept on fluctuating from the downstream of the river to the upstream. The highest turbidity that can be seen in table 4.1 was at station 5 with 23.71 NTU while the lowest recorded turbidity was 16.51 NTU from station 3. In July, the reading dropped drastically from 16.90 NTU to 5.98 NTU. Table 4.2 also shows that the highest turbidity recorded was in the month of February 2015 with 31.46 NTU and the overall turbidity ranged from 5 NTU to 32 NTU.

According to Table 4.1 and Table 4.2, station 5, November 2014 and February 2015 are among the highest turbidity levels recorded. These depend on the activities done at the surrounding area of the sampling station including the time and seasons of the year. A higher turbidity detected at station 5 was perhaps because of the discharge sources due to the anthropogenic activities done near the station. The discharge from the boats, waste from the bait, rubbish thrown by the tourists during the fishing activities at the jetty provided increased the chances of the water near the station to be polluted. Sewage from the area was dumped directly into the river resulting in high turbidity (Piah et al., 2008). Substances that reduce the water’s clarity can also originate from the natural, developing and develops areas within water shed.

In both November 2014 and February 2015, a higher turbidity detected was maybe because of the soil erosion, river flow, presence sources of organic pollution and run off factors. Both of the sampling months were done during the intermediate and wet seasons where the rainfall amount is high. Therefore, the soil erosions from both sides of the river affected the levels of the water's clarity. In all cases, sand, silt, clay and organic particles may be dislodged from the land surfaces by the rainfall and carried by the overland flow.

On the other hand, based on the statistical analysis, turbidity showed no significant difference ($p>0.05$) in between the stations. However, there is a significant difference ($p<0.05$) in between the sampling months. The turbidity levels of Sepang River are much lower when compared to the Semenyih River as their range has exceeded 200 NTU as reported by Al-Badaii et al., (2013). Therefore, it can be concluded that the levels of turbidity in Sepang River can be classified in class II when referred to NWQS.

Apart from that, the highest recorded SS can be seen at station 1 while the lowest was at station 4. The value kept on decreasing from the downstream to the upstream and stopped at station 4. Then the value increased again in station 5 which was the highest upstream station. Table 4.1 above shows that all the values were quite high especially for station 1, 2 and 3. The mean of all the five stations was 40.65 mg/L. Furthermore, wide range of values was recorded between the ten months of data which is from 27.60 mg/L in January 2015 to 62.80 mg/L in August 2014.

In this study, higher concentration of suspended solid (SS) recorded from the middle to the downstream stations are probably due to the discharges of wastes from the municipal, agricultural and aquaculture activities. Besides that, construction activities by doing the renovations of the jetty near station 1 have probably caused the soils of the river bank to become looser and easily eroded. As a result, the suspended solid concentration is higher at this station. Peng et al. (2002) describes that coprostanol is the major sterols (approximately 60%) in human faeces. The concentration of coprostanol may be used to indicate contamination of the river by human faeces. According to Isobe et al. (2002) the concentration of sterols in the sediment depends on the organic carbon content. The highest concentrations of coprostanol in the uppermost stream area are affected by the untreated sewage (Piah et al., 2008). This is because the area receives fresh water input from the three nearby rivers namely Linau River, Kelembai River and Rambai River. The presence of a high coprostanol in rural areas was derived from domestic animals (Isobe et al., 2002). It is probable that the untreated sewage in the upstream comes from the residential areas of *Kampung Baru Sepang* and *Taman Seri Sepang* (Piah et al., 2008).

Downstream area shows that the area was also severely contaminated with sewage (Piah et al., 2008). The compact settlements at Bagan Lalang village also contributed to the sewage resources. Bagan Lalang beach which is a famous tourist spot is full of rubbish that were thrown into the sea and there are also fishermen’s jetty, seafood restaurants and food stalls that are located close to the coastal area (Piah et al., 2008). Furthermore, tidal effects and mangrove vegetation on both sides of the river made the concentration of this parameter to increase when there is a rainfall. As level of SS increases, a water body begins to lose its ability to support a diversity of aquatic life. Suspended solids absorb heat from the sunlight, which increases water temperature and subsequently decreases the levels of dissolved oxygen. Trebitz et al. (2007) found that turbidity could serve as a possible surrogate for SS.

The suspended solids of all of the stations are classified in class II of NWQS and the range of the suspended solid is small. However, the suspended solid levels for July 2014 is in class I while August 2014 is classified under class III. Based on the NWQS, the maximum threshold limit of suspended solids for Malaysian Rivers which support the aquatic life is 150 mg/L (Rosli et al., 2010). According to the statistical analysis, there is no significant difference ($p>0.05$) in SS between the stations but for the months, the results is vice versa. There are other reports which show a higher range of suspended solid when compared to this study which includes the Semenyih River with 10.3-446 mg/L by Al-Badaii et al., (2013), the Juru River with 51.33-124 mg/L by Al-Shami et al. (2011) and lastly the Langat River with 4.50-534 mg/L reported by Azrina et al. (2006).

According to Table 4.1, the TDS value recorded the highest at station 1 and the lowest can be seen at station 5 with 29.97mg/L and 26.06 mg/L respectively. The values kept on declining from the downstream to the upstream. Besides that, there was a sudden increase of the TDS value from September to October 2015 where the value jumped from 18.84 mg/L to 39.00 mg/L. The values of TDS also ranged between 18 to 39 mg/L.

Total dissolved solid (TDS) is a measure of those solids in water that pass through a 2.0µm filter and include ions such as sodium, chloride and calcium. While effects of elevated TDS on water quality are mostly related to the impacts on the domestic and industrial use, there should be physiological implications for freshwater organism if the levels become sufficiently elevated. The highest recorded TDS was in October 2014 which is due to the heavy rainfall which occurred a day before the sampling day. TDS also is higher in a dry weather rather than in wet periods and this has led to soil erosion of the mangrove forest located on both sides of the river. The high TDS concentration in the rivers is attributed to the presence of the extreme anthropogenic activities along the river course and runoff with high suspended matter (WHO UNESCO, 2001). Dissolved solids from sewage that polluted the river may come from the house squatters, farm animals, industrial factories, private sewage plant or premises using an uncleared septic tank (Piah et al., 2008).

In this study, the concentration of TDS was less than those reported by Al-Badaii et al., (2013) in the Semenyih River that reached 80 mg/L as the highest concentration. Besides that, the range of concentration of 57-120 mg/L was recorded by Gasim et al. (2012) in the Bebar River which is also quite high when compared to the Sepang River. The TDS results obtained are within the standard allowable levels of Malaysian rivers and are classified as class I based on NWQS. Apart from that, ANOVA result showed that there is no significant difference ($p>0.05$) in TDS between the stations but they are significantly different ($p<0.05$) in between the sampling months.

The lowest BOD value of Sepang River was recorded at station 5 while the highest BOD value was detected at station 3. In table 4.2, it shows that November 2014, January and February 2015 showed similar reading of 3.5 mg/L which were among the highest recorded BOD values. On the other hand, July 2014 recorded the lowest BOD value. The mean for the overall reading of 10 months was 2.95 mg/L. The high concentration of BOD implied that the biodegradation process caused by the microorganism occurred in the river especially at station 3 whereas at station 2 and 4 the concentration may be contributed by the nearest anthropogenic activities such as the use of boats to transfer the motorcycle to the other part of the river. Furthermore, the BOD concentration continuously increased because of the natural plant decaying process and other contributors that increased the total nutrient in water bodies such as the fertilizer, construction effluent, animal farm, and septic system (Piah et al., 2008).

BOD concentration is directly associated with DO concentrations. High value of BOD shows a decline in DO. This phenomenon is common as identified in many previous researchers (Rosli et al., 2012). BOD also accounts the oxygen that is required in organic matter decomposition (Amadi et. al., 2010). In addition, BOD value will rise when there is more organic matter such as leaves, wood, wastewater or urban storm water runoff took place at the river water.

The BOD variation in between the stations were not significantly different (p>0.05) based on the statistical analysis but significantly different (p<0.05) in terms of months. Additionally, the BOD values of this river water are within the recommended permissible limit by NWQS and they are categorized in class II and class III. The BOD range of this river is similar to most of the reported BOD data such as in Semenyih River by Al-Badaii et al., (2013), Juru River by Al-Shami et al. (2011), and Langat River by Azrina et al. (2006) with the value of 0.32-4.56 mg/L, 1.51-6.31 mg/L, and 1.29-2.55 mg/L respectively.

The COD concentrations of the water samples in the Sepang River showed a narrow range of values where the highest concentration recorded was at station 1 with 14.9 mg/L and the lowest was at station 4 with 14.1 mg/L. The COD concentration dropped from the downstream until it approached the upstream at station 4. Then the value increased again at station 5. In terms of the monthly data, Table 4.2 shows that June and September 2014 has the same lowest value of 14 mg/L. There were also another two months which recorded the same highest value of 15.2 mg/L which were May and August 2014. The values of COD were mostly in the range of 14 mg/L to 15 mg/L.

Generally, the lower COD level indicates a low level of pollution, while the high level of COD points out the high level of pollution of water in the study area (Waziri & Ogugbuaja, 2010). Higher concentration of COD at station 1 is due to the higher decomposition of organic and inorganic contaminants, dissolved or suspended in water that came from the jetty which is also near to the fish market. The concentration of COD is expected to be higher if the sampling is done at the exact point source.

Besides that, these results were within the standard allowable limit of NWQS which is classified under class II. Based on the statistical analysis, there are no significant difference ($p>0.05$) found in between the stations and months. A low range of COD can be seen when compared to the other reported river. For example, in Semenyih River by Al-Badaii et al., (2013), the range is in between 8.6-63 mg/L. A higher ranged were also found in Juru river by Al-Shami et al. (2011) with 27.67-164 mg/L and also in Langat river with 52.3-233 mg/L reported by Azrina et al. (2006). In addition, a wide usage of chemical and organic fertilizer and discharge of sewage affects the COD level, while the high COD pointing to a deterioration of the water quality attributed to the discharge of municipal effluent (Eisakhani & Malakahmad, 2009).

Based on Table 4.1, the Ammoniacal nitrogen reading shows that most of the values were similar to 0.42 mg/L and 0.44 mg/L which were recorded at station 1, 3, 4 and station 2, 5 respectively. Overall, the values do not show much difference from the downstream to the upstream. In Table 4.2, the highest value can be seen in January 2015 with 0.52 mg/L and the overall mean for the ammoniacal nitrogen in 10 months was 0.425 mg/L. Other form of nitrogen detected in the river water is ammoniacal nitrogen which indicates nutrient status, organic enrichment and health of water body. Ammoniacal nitrogen concentrations started with a higher amount in the downstream and then dropped in a small amount before obtaining back a higher amount of ammonia at the end of the upstream. In terms of month, the values were fluctuating in the dry season and showed an increase in concentration at the end of the wet season. Overall, the range of ammoniacal nitrogen for this river is in between 0.42-0.44mg/L for the stations and 0.35-0.52 mg/L for the monthly data.

Ammonia acts as an indicator of the pollution from the excessive usage of ammonia especially from the fertilizers. Station 2 at the downstream and station 5 at the upstream recorded the highest ammonia concentration due to the distance of these stations with the sullage produced from the fisherman household which goes through a small drain and eventually ends up in the river. A high concentration of nutrients in sullage is a critical issue which can cause algal blooms in the water bodies. Although the concentration of ammonia in the sullage is less than that in the typical sewage, if excessively high, it can degrade the aquatic status of the river. Discharge of untreated sullage adds oxygen demanding substances, nutrients and toxic elements such as ammoniacal nitrogen into the water, which in turn make the streams unsuitable for aquatic flora and fauna (Idris et al., 2003).

According to the NWQS, the concentration of ammonia in this study is low and can be classified in class III. The value found still below the permissible limit where ammoniacal nitrogen level for aquatic life in river of Malaysia is 0.90 mg/L (DOE, 2006). In addition, there were no significant differences ($p>0.05$) in ammoniacal nitrogen in between the five stations but the results were significantly different ($p<0.05$) according to months. The ammonia concentration of this river was low when compared to the other river basin as the concentration exceeded 1.0 mg/L reported by Al-Badaii et al., (2013) in Semenyih River, 4.0 mg/L in Juru river by Al-Shami et al. (2011) and 5.0 mg/L in Langat river reported by Azrina et al. (2006). Besides, the concentration in all stations of this river is low when compared to the concentration of ammonia in the clean river of Kenaboi reported by Salleh et al. (2009) with 0.48 mg/L.

The value of chlorophyll *a* in Table 4.1 shows a small range which was from 0.45µg/L to 0.57µg/L where the lowest value could be seen at station 5 while the highest value was at station 1. The values fluctuated from the upstream to the downstream in a small range. According to table 4.2, the concentration of chlorophyll *a* increased suddenly from July to August 2014 from 0.3µg/L to 0.76µg/L. The mean of chlorophyll *a* in the ten months of sampling was 0.52µg/L.

They fluctuated unevenly from the May 2014 to February 2015 with the values slightly higher starting from the end of the dry season until the transition to the wet season. Besides that, the amount of chlorophyll in water is the higher after the rainfall, particularly if the rain has flushed away the nutrients into the water. The concentration also comes mostly when there is an increase in the phytoplankton density and biomass in the river itself.

Furthermore, ANOVA results showed that there is no significant difference ($p>0.05$) in chlorophyll *a* in between the stations. However, there is a significant difference ($p<0.05$) of chlorophyll *a* in between the months. Additionally, the concentrations were within the recommended permissible limit but the range of values can be considered as high when compared to the chlorophyll a values reported by Salleh et al. (2009) in Kenaboi River with 0.36µg/L.

4.2 Anion analysis

Table 4.4: Anion analysis of Sepang River measured using ion chromatography according to station.

Station	Nitrate (mg/L)	Nitrite (mg/L)	Fluoride (mg/L)	Chloride (mg/L)	Bromide (mg/L)	Phosphate (mg/L)	Sulphate (mg/L)
1	39.00	Not detected	0.07	Not detected	15.90	0.42	897.5
2	2.14	3.01	2.70	156.00	4.37	17.30	283.9
3	1.55	2.30	0.91	124.9	12.50	Not detected	314.6
4	0.88	0.942	0.68	65.30	1.08	2.54	441.7
5	0.76	Not detected	0.26	52.50	2.26	6.03	117.5

From Table 4.4, the values of nitrate ranged between 0.76 mg/L and 39 mg/L. The values were declining from the downstream to the upstream. For nitrite, the highest concentration was at station 2 with 3.01 mg/L and the lowest was at station 4 with 0.94 mg/L. Nitrite also has the same trend as nitrate. The values kept on dropping as they approached the upstream which was until station 4. The mean concentrations for both nitrate and nitrite were 8.87 mg/L and 2.08 mg/L respectively.

The highest concentration at station 1 is due to the runoff of fertilizer sourcing from the residential area and wastes thrown at the surrounding of the aquaculture port. At station 2, there is also a small farm which was planted by the villagers. Most of the researchers reported that contamination by nitrate is primarily attributed to non-point agricultural sources (Feleke & Sakakibara, 2002). Nitrate originated from agriculture is increasingly growing due to the extreme use of fertilizers. Nitrate salts reach the groundwater as they percolate through the soil. Some other sources of nitrate in ground and surface water are from uncontrolled land discharges of treated or raw wastewater from domestic and industrial wastes, landfills (Islam & Suidan, 1998) and animal wastes particularly from animal farms (Hibiya et al., 2003).

According to the NWQS, the concentration of nitrate in this study is low and can be classified in class 1. Apart from that, the nitrate concentration of this river is high when compared to the other river as reported by Al-Badaii et al., (2013) with 1-8.53 mg/L in Semenyih River, 0.55-2.57 mg/L in Juru river by Al-Shami et al. (2011) and 0.61 mg/L in Kenaboi river reported by Salleh et al. (2009). River water which has a high nitrate level is potentially harmful to humans' and animal's health, in freshwater or estuarine systems close to land; nitrate can reach high levels that can cause death of aquatic life. However, nitrate is much less toxic than ammonia and nitrite (Romano & Zeng, 2007a). On the other hand, nitrite concentrations decreased as they approached the upstream. Nitrite comes through the conversion of ammonia and nitrate. Hence, the sources of contamination from nitrite are the same as nitrate. Nitrite can be classified in class 1 based on NWQS.

Apart from that, the concentration of fluoride ranged from 0.067 mg/L to 2.70 mg/L. The concentration of the fluoride rose as it went upstream until station 2 and then decreased when it reached the upstream. The overall mean of the fluoride's concentration was 0.92 mg/L. The mean values generally occurred in a natural level which falls under class I according to NWQS. The sources of fluoride came from the fertilizers and factories. Similar to nitrate and fluoride, chlorides also kept on decreasing as it approached the upstream. Higher concentration in the lower stream is due the distance between the station and seawater. In the wet season, the rainfall will increase the tides and this will increase the chloride concentration in the middle stream.

The range of the chloride was between 52.50 mg/L to 156 mg/L and the mean was 99.7 mg/L. Table 4.4 also shows that the chloride's concentrations were decreasing from the downstream to the upstream. Chlorine has pungent, noxious odor that some people can smell at concentrations above 3.0mg/L. Because chlorine is an excellent disinfectant, it is commonly added to most drinking water supplies. Free chlorine is toxic to fish and aquatic organisms even in a very small amount. The concentration of chloride for this study is considered high when compared to Juru river basin by Al-Shami et al. (2011) with 2.12-22 mg/L.

The concentration of phosphate ranged from 0.42 mg/L to 17.3 mg/L. The fluctuation of phosphate can be seen as the concentrations firstly increased from the downstream to the upstream and then decreased again as it approached the upstream. The highest value recorded was at station 2. The reason of the high concentration in certain stations is because of the effluents coming from the residential areas. Effluent of detergents and fertilizers are among the examples of things which consist of phosphate ion. These values generally exceeded the normal level of NWQS for Malaysian rivers which is 0.2 mg/L, hence, they fell in class V. In addition, the results are high if compared to the results of the other river basin recorded by Al-Badaii et al., (2013) with 0.08-1.9 mg/L in Semenyih River. Overall, high concentrations of phosphates are generally an indication of pollution associated with eutrophication condition (WHO, 1998). Moreover, domestic effluents particularly which contain detergents, fertilizer runoff and industrial wastewater are the main reasons of high phosphate levels in surface water such as rivers and lakes (Gasim et al., 2012). Rainfall is also significant contributor of phosphorus level in a water body (Cheng et al., 1990).

Sulphate concentration varied from 117.5 mg/L to 897.5 mg/L which indicated a high concentration values. The mean of the sulphate's concentration for the five stations was 411.04 mg/L. The sulphate ion is one of the major anions occurring in natural waters. The values of sulphate are relatively high in the downstream when compared to the upstream. Waste discharge from the residential area is one of the main contributors to the high concentration of sulphate in river water. In the absence of dissolved oxygen and nitrates, sulfates serves as a source of oxygen for biochemical oxidation produced by anaerobic bacteria. The mean value of sulphate which was 411.04 mg/L lies in class V which can be considerd as bad. Besides that, the value of sulphate in this river is considered high when compared to Juru river basin by Al-Shami et al. (2011) with 20-197 mg/L and also in Semenyih River with 1.67-61 mg/L reported by Al-Badaii et al., (2013). According to Hem (1985), the major sources of sulphate in rivers are rock weathering, volcanoes, and human activities such as mining, waste discharge and fossil fuel combustion process.

In addition, the concentrations of bromide were the highest at station 1 and the lowest is at station 4 with 15.90 mg/L and 1.08 mg/L respectively. The overall mean was 7.22 mg/L. The concentration of bromide was the highest in the downstream and it fluctuated and became low in the uppermost stream. This is because bromide is present in typical seawater with the concentration of around 65 mg/L which is around 0.2% of all dissolved salts. Bromide ion is also heavily concentrated by some species of ocean algae which construct methyl bromide and a great number of bromoorganic compounds with it. The throwing of rubbish by the villagers and tourists that consists of bromide such as plastics, soft drinks, pesticide and medication also increase the concentration of bromide in the river. Activities such as loading and unloading fishes from fisherman and cleaning of boats and maintenance maybe also contribute to higher enrichment factor (Kumar et al., 2014).

4.3 Phytoplankton analysis

Table 4.5: The presence of phytoplankton of each species found according to station

Species	Station				
	1	**2**	**3**	**4**	**5**
Cyanobacteria (Blue-green algae)					
1. *Oscillatoria limosa* Roth			+	+	
2. *Oscillatoria tenuis* Roth			+		
3. *Anabaena sphaerica* (Born) Bory			+	+	
Pyrrophyta (Dinoflagellate)					
1. *Peridinium cinctum* Ehrenberg		+	+		
2. *Peridinium willei* Huitfeld-Dass		+			
3. *Protoperidinium divergens* (Ehr) Balech	+		+	+	
4. *Ceratium lineatum* (Ehr) Cleve			+	+	
Euglenophyta (Euglenoids)					
1. *Euglena acus* (Muller) Ehr.			+		
2. *Phacus longicauda* (Ehr) Dujardin			+		
Chrysophyta (Chrysophytes)					
1. *Dinobryon cylindricum* Imhof			+		
Chlorophyta (Green algae)					
1. *Chlorella* sp. Ehrenberg	+	+	+	+	+
2. *Crucigenia quadrata* Morren		+	+	+	+
3. *Closterium juncidum* Ralf	+	+	+	+	
4. *Closterium moniliferum* (Bory) Ehr			+	+	
5. *Closterium parvulum* Naeg		+	+	+	
6. *Closterium tumidum* Johnson		+			
7. *Closterium turgidum* Ehrenberg		+	+		+
8. *Coelastrum microsporum* Nageli			+	+	
9. *Cosmarium undulatum* Cord	+	+	+		

10. *Mougeotia* sp. Hassal			+		
11. *Oedogonium* sp. Agardh		+	+		
12. *Pediastrum duplex* Meyen	+	+	+	+	+
13. *Scenedesmus acuminatus* (Lagerheim) Chodat	+	+	+	+	+
14. *Scenedesmus quadricauda* (Turpin) Breb	+	+	+	+	
15. *Staurastrum anatinum* Cooke & Wills	+	+	+		
16. *Staurastrum cuspidatum* Breb		+	+		
17. *Ulothrix aequalis* Kutzing		+	+		
18. *Zygnema* sp. C. Agardh				+	
Bacillariophyta (Diatom)					
1. *Bacillaria paradoxa* Gmelin	+		+		
2. *Bacteriastrum delicatulum* Cleve				+	
3. *Biddulphia dubia* Cleoe	+	+			
4. *Biddulphia longicruris* Greville	+	+	+		
5. *Biddulphia reticulum* (Ehr) Boyer	+	+	+		
6. *Biddulphia heteroceros* Grunow		+	+		+
7. *Chaetoceros decipiens* Cleve	+	+	+	+	+
8. *Chaetoceros lorenzianum* Grunow	+	+	+	+	+
9. *Chaetoceros diversum* Cleve	+	+	+	+	
10. *Chaetoceros didymum* Ehr	+	+	+	+	+
11. *Chaetoceros curvisetus* Mangin	+	+	+	+	+
12. *Chaetoceros constrictum* Gran	+	+	+	+	+
13. *Cymbella ventricosa* Kutzing			+		
14. *Diatoma elongatum* Agardh	+	+	+	+	+
15. *Diatoma vulgare* Bory	+	+	+	+	+
16. *Fragilaria capucina* (Lyng) Desm			+	+	
17. *Fragilaria vaucheriae* (Lyng) Kutzing			+		
18. *Gomphonema acuminatum* Ehr.		+	+	+	
19. *Gomphonema gracile* Ehr.			+		
20. *Hyalodiscus* sp. Greville			+		
21. *Lauderia borealis* Cleve				+	
22. *Lauderia annulata* Cleve		+	+		

23. *Leptocylindrus danicus* Cleve		+			
24. *Melosira moniliformis* (Muller) Agardh					+
25. *Melosira sulcata* (Ehr.) Kutzing			+		
26. *Nitzschia closterium* W.Sm		+			
27. *Stauroneis anceps* Ehr.		+	+	+	
28. *Synedra ulna* Ehr.		+	+	+	
29. *Tabellaria fenestrate* (Lyng) Kutz		+			
30. *Thalassionema nitzschioides* Grunow		+	+		
31. *Triceratum favus* Ehr.			+	+	

Table 4.6: The presence of phytoplankton of each species found according to month

Species	Month									
	May	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**
Cyanobacteria (Blue-green algae)										
1. *Oscillatoria limosa* Roth	+			+	+	+		+		
2. *Oscillatoria tenuis* Roth							+			
3. *Anabaena sphaerica* (Born) Bory				+		+			+	
Pyrrophyta (Dinoflagellate)										
1. *Peridinium cinctum* Ehrenberg	+				+	+	+			
2. *Peridinium willei* Huitfeld-Dass					+					
3. *Protoperidinium divergens* (Ehr) Balech								+	+	
4. *Ceratium lineatum* (Ehr) Cleve			+					+		
Euglenophyta (Euglenoids)										
1. *Euglena acus* (Muller) Ehr.							+			
2. *Phacus longicauda* (Ehr) Dujardin							+			
Chrysophyta (Chrysophytes)										
1. *Dinobryon cylindricum* Imhof		+				+				
Chlorophyta (Green algae)										
1. *Chlorella* sp. Ehrenberg	+	+			+			+	+	
2. *Crucigenia quadrata* Morren		+	+		+			+	+	

3. *Closterium juncidum* Ralf		+	+	+	+		+	+	+	
4. *Closterium moniliferum* (Bory) Ehr		+			+				+	
5. *Closterium parvulum* Naeg				+	+	+	+		+	
6. *Closterium tumidum* Johnson						+				
7. *Closterium turgidum* Ehrenberg				+						
8. *Coelastrum microsporum* Nageli							+			
9. *Cosmarium undulatum* Cord							+	+	+	
10. *Mougeotia* sp. Hassal						+				+
11. *Oedogonium* sp. Agardh				+						
12. *Pediastrum duplex* Meyen	+	+	+	+		+	+	+	+	
13. *Scenedesmus acuminatus* (Lagerheim) Chodat	+	+	+		+	+	+	+		
14. *Scenedesmus quadricauda* (Turpin) Breb	+					+	+	+		
15. *Staurastrum anatinum* Cooke & Wills		+				+	+	+		
16. *Staurastrum cuspidatum* Breb		+						+		
17. *Ulothrix aequalis* Kutzing	+					+		+		
18. *Zygnema* sp. C. Agardh				+		+				
Bacillariophyta (Diatom)										
1. *Bacillaria paradoxa* Gmelin					+	+		+		
2. *Bacteriastrum delicatulum* Cleve					+					
3. *Biddulphia dubia* Cleoe				+						

4. *Biddulphia longicruris* Greville					+	+				
5. *Biddulphia reticulum* (Ehr) Boyer	+			+						+
6. *Biddulphia heteroceros* Grunow	+									+
7. *Chaetoceros decipiens* Cleve	+			+		+	+	+	+	
8. *Chaetoceros lorenzianum* Grunow							+		+	+
9. *Chaetoceros diversum* Cleve		+				+	+	+	+	+
10. *Chaetoceros didymum* Ehr		+			+	+	+	+	+	+
11. *Chaetoceros curvisetus* Mangin		+			+			+	+	+
12. *Chaetoceros constrictum* Gran			+	+					+	
13. *Cymbella ventricosa* Kutzing					+					+
14. *Diatoma elongatum* Agardh	+	+	+	+	+	+	+	+	+	
15. *Diatoma vulgare* Bory	+	+							+	
16. *Fragilaria capucina* (Lyng) Desm							+		+	
17. *Fragilaria vaucheriae* (Lyng) Kutzing				+						
18. *Gomphonema acuminatum* Ehr.			+			+	+			
19. *Gomphonema gracile* Ehr.						+				
20. *Hyalodiscus* sp. Greville	+			+						
21. *Lauderia borealis* Cleve						+				
22. *Lauderia annulata* Cleve						+				
23. *Leptocylindrus danicus* Cleve	+									+
24. *Melosira moniliformis* (Muller) Agardh			+				+			

25. *Melosira sulcata* (Ehr.) Kutzing				+						
26. *Nitzschia closterium* W.Sm						+				+
27. *Stauroneis anceps* Ehr.										+
28. *Synedra ulna* Ehr.		+	+						+	
29. *Tabellaria fenestrate* (Lyng) Kutz			+	+						
30. *Thalassionema nitzschioides* Grunow	+									+
31. *Triceratum favus* Ehr.								+		

In Sepang River, 6 main division of phytoplankton were found at the five sampling stations which were Bacillariophyta (Diatom), Chlorophyta (Green algae), Chrysophyta (Crysophytes), Euglenophyta (Euglenoids), Pyrrophyta (Dinoflagellate) and Cyanobacteria (Blue-green algae). A total of 59 species in 6 divisions with a total of 3125 cell/ml individuals were recorded from all the sampling stations. Based on table 4.5 and table 4.6, phytoplankton community of the ecosystem were dominated by division Bacillariophyta (diatoms) and then followed by Chlorophyta (green algae). Species such as *Diatoma elongatum, Chaetoceros decipiens, Chaetoceros lorenzianum, Chaetoceros diversum, Chaetoceros didymum, Chaetoceros curvisetus, Chaetoceros constrictum, Pediastrum duplex* and *Scenedesmus acuminatu*s were found in most of the stations. The highest number of phytoplankton species and cell abundance were found in the middle stream and also during the wet season.

Generally, phytoplankton community was dominated by diatoms. Diatoms are represented by a single cell, or short chain forming series of cells that represent a major food source to the various faunal components in these waters. They are unique in having their cells enclosed within a cell wall of silica called frustules which is composed of two interblocking halves. The dominant diatoms are *Diatoma elongatum, Chaetoceros* sp. The pH in itself is probably of little direct importance in determining algal distribution. However, it can be used as a “flag” to reflect chemical conditions which are critical in an aquatic environment. The pH value range in all stations was found to be conducive for the growth of algae particularly in the division of Bacillariophyta. The dominance of diatoms in the middle stream of station 3 indicated that the station is clean.

The next abundance division is the chlorophytes with the most common species including *Pediastrum duplex, Scenedesmus acuminatus, Crucigenia quadrata,* and *Closterium juncidum.* Chlorohytes are common freshwater species commonly known as green algae. Next is Pyrrophyta (dinoflagellate) where most of them were found in the upperstream. Some of the species found were *Protoperidinium divergen*, *Peridinium cinctum*, *Peridinium wille*, and *Ceratium lineatum.* Dinoflagellate are mainly unicellular species possessing flagella that allows movement in the water column. Many of these are autotrophic containing necessary pigments to allow the occurrence of photosynthesis; others lacking these pigments are heterotrophic and capable of engulfing prey. Some of the species found are *Protoperidinium divergen*, *Peridinium cinctum*, *Peridinium wille*, and *Ceratium lineatum.*

The next division is Cyanobacteria or blue green algae which most of them can be found in station 3 and 4 in the middle stream. The most common and abundant species of cyanobacteria found were *Oscillatoria limosa* and *Anabaena sphaerica*. The least common species found were euglenoids and chrysophytes which the species found were *Euglena acus, Phacus longicauda* and *Dinobryon cylindricum.* Among the observed Cyanobacteria, some species are known for their potential toxic proliferation such as the *Oscillatoria limosa,* though no blooms were recorded during the study period. The most common and abundant species of cyanobacteria found are *Oscillatoria limosa* and *Anabaena sphaerica*. The least common species found are the euglenoids and chrysophytes with the species found are *Euglena acus, Phacus longicauda* and *Dinobryon cylindricum.*

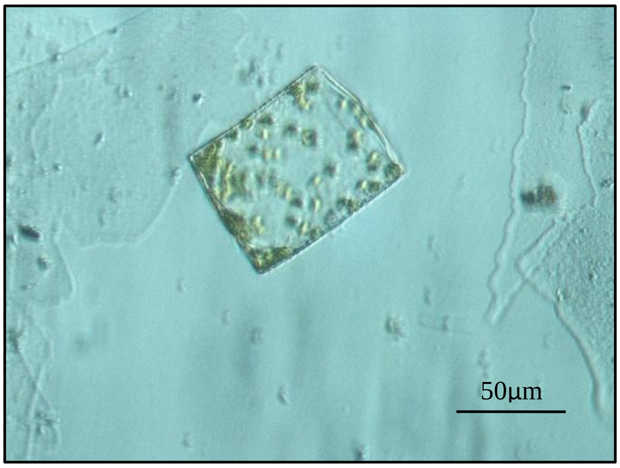

Plate 4.1: *Biddulphia dubia* Cleoe

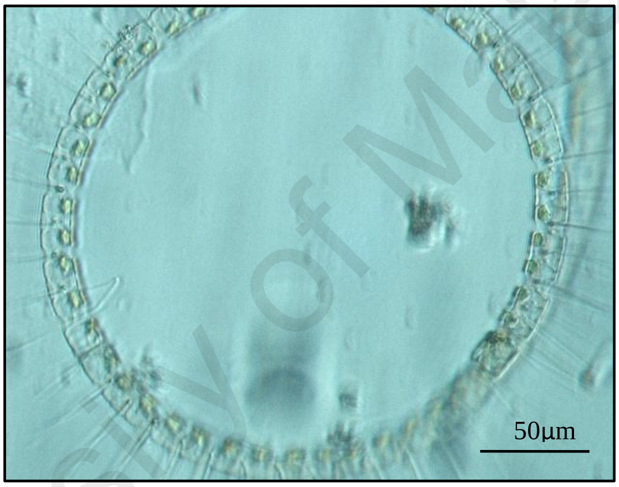

Plate 4.2: *Chaetoceros curvisetus* Mangin

Plate 4.3: *Chaetoceros didymium* Ehr

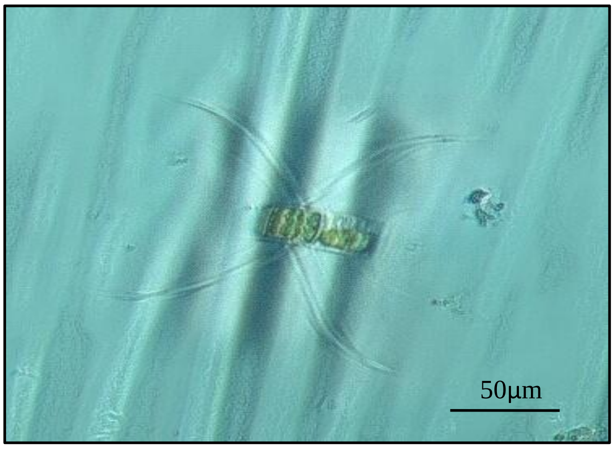

Plate 4.4: *Chaetoceros diversum* Cleve

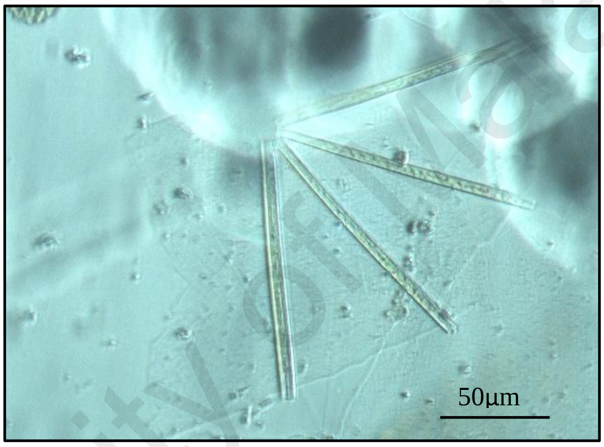

Plate 4.5: *Diatoma elongatum* Agardh

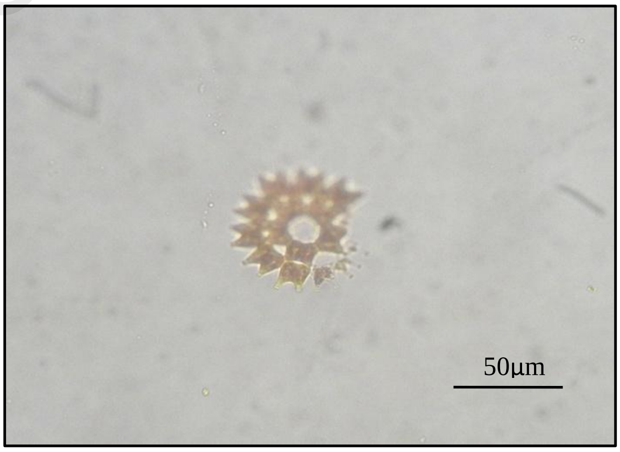

Plate 4.6: *Pediastrum duplex* Meyen

Table 4.7: Shannon–Wiener diversity index (H’) values in Sepang River in five stations

Station	**Shannon–Wiener Diversity Index**
1	2.519
2	2.906
3	2.956
4	2.684
5	2.241

Table 4.8: Shannon–Wiener diversity index (H') values in Sepang River from May 2014 to February 2015

Year	Month	Shannon–Weiner diversity index
2014	May	2.332
	June	2.379
	July	1.927
	August	2.174
	September	2.276
	October	2.514
	November	2.492
	December	2.595
2015	January	2.483
	February	2.231

Based on Table 4.7, there was an increased in Shannon–Wiener index values starting from station 1 at the downstream until station 3 and the index then drops when reaching the upstream. On the other hand, in table 4.8, the index fluctuates in a small range from May 2014 to February 2015. Starting from July 2014, the index values increased gradually with the highest value was recorded in December 2014 but then they were slowly decreasing by the time it approaches February 2015. High species richness is assumed to indicate high biotic integrity because many species are adapted to the conditions present in the habitat. Species richness is predicted to decrease with increasing pollution because many species are stressed. However, many habitats may be naturally stressed by low nutrients, low light and other factors. A slight increase in nutrient enrichment can increase species richness in headwater and naturally unproductive, nutrient-poor streams (Bahls et al., 1992).

The mean of all the station is 2.661 and based on the study of Salusso and Morana (2002), these means that this river contains moderate contaminants. Bahls et al. (1992) also used Shannon diversity because of its sensitivity to water quality changes. The composition of algal species is diverse in the middle stream as the water is much cleaner than the downstream and the upstream.

4.4 Correlation between phytoplankton with parameters and anion

Table 4.9: Correlation analysis of phytoplankton with physico-chemical parameters and anion

Parameter	Pearson Correlation	
	r-value	p-value
Temperature (°C)	.644	.241
DO (mg/L)	.148	.812
pH	.431	.469
Conductivity (µS/cm)	.420	.481
Salinity (ppt)	.299	.625
Turbidity (NTU)	-.765	.131
SS (mg/L)	-.035	.956
TDS (mg/L)	.442	.456
BOD (mg/L)	.791	.111
COD (mg/L)	-.148	.813
NH_3-N (mg/L)	-.430	.470
Chlorophyll *a* (µg/L)	.102	.871
Nitrate (mg/L)	-.242	.695
Nitrite (mg/L)	.666	.220
Fluoride (mg/L)	.260	.673
Chloride (mg/L)	.581	.304
Bromide (mg/L)	.426	.475
Phosphate (mg/L)	-.226	.715
Sulphate (mg/L)	-.098	.875

* Correlation is significant at the 0.05 level (2-tailed).

Based on the statistical analysis of Pearson's correlation between phytoplankton density and water quality parameters, there was a positive relationship shown by parameters such as temperature, DO, pH, conductivity, salinity, TDS, BOD, Chlorophyll *a*, Nitrite, Fluoride, Chloride and Bromide. On the other hand, there was a negative correlation between the number of phytoplankton with turbidity, suspended solids, COD, Ammoniacal nitrogen, Nitrate, Phosphate and Sulphate.

Temperature has a major influence on the chemical and biological processes including reaction rates, saturation constants of dissolved gases, water density and metabolic rates of the animals. Warm waters are more susceptible to eutrophication which is a build-up of nutrients and possible algal blooms because photosynthesis and bacterial decomposition both work faster in higher temperatures. There are both direct and indirect effects of temperature in the growth and distribution of phytoplankton. In general, changes in temperature may produce marked alterations in the balance of the major anabolic processes in phytoplankton. For each species, there is an optimum temperature range at which metabolism occurs. The high water temperature of the river seems to provide a favourable environment for growth and survival of some species of phytoplankton. Palleyi et al. (2008) reported that in the Brahmany estuary of Orissa, India, the phytoplankton abundance increase with the increase of salinity level.

Oxygen is less soluble in warmer water and this can affect the aquatic life. By contrast, salts are more soluble in warmer water, so temperature can affect the water's salinity. Temperature directly affects the metabolic rates of plants and animals. Aquatic species have evolved to live in water of specific temperatures. If the water becomes colder or warmer, the organisms do not function effectively and become more susceptible to toxic wastes, parasites and diseases. If temperature suddenly changes extremely, many organisms will die. Algal photosynthetic rates are influenced by temperature because the cellular processes are temperature dependent (Khan & Ansari, 2005). Temperature and photon flux density are important factors for quantifying growth as well as photosynthesis (Coles & Jones, 2000), with rates accelerating with increasing temperature between 25°C and 45°C. Most algae probably reach their optimal growth rate in the range of 20°C to 25°C and a few common freshwater algae grow at temperatures above 25°C to 30°C. The highest number of phytoplankton species recorded was in October which is mainly diatoms and green algae while the lowest was in July. Each phytoplankton species has a definite temperature tolerance range and blue green and green algae prefer high temperatures (Campbell & Edward, 2011). Shen (2002) reported that the most favourable temperature for phytoplankton growth is 30°C. Two species of phytoplankton which are *Pediastrum duplex* and *Oscillatoria limosa* have a very similar response to high temperature.

In some circumstances, water can contain too much oxygen and is said to be supersaturated with oxygen. This can be very dangerous to the aquatic life. Supersaturated conditions occur in highly turbulent waters because of aeration and also in waters experiencing algal blooms or with many aquatic plants because of photosynthesis. Aquatic organisms depend on dissolved oxygen to live and the amount of oxygen taken out of the system by respiring and decaying organisms, stream flow and aeration (Ostrander, 2000). Phytoplankton produces 90% of total oxygen produced by plants (Kamat, 1982). This is one of the important roles of phytoplankton in maintaining the proportion of the oxygen in the air.

A fluctuation pattern of DO gives an idea about the variations of distribution of algae throughout the 10 months. The phytoplankton can use up the dissolved carbon dioxide in the water and releases oxygen which is essential for all living organisms

(Ismail, 1994). Temperature will affect things through the production of oxygen by phytoplankton and other plants over the course of a day. Chambers and Mill (1996) indicated that DO levels are closely related to water temperature, DO levels increases as water temperature decreases. Oxygen is produced during photosynthesis and consumed during respiration and decomposition. Increased temperature or excess nutrients may result in higher algal and plant growth, causing DO levels to decrease.

The pH of a water body varies during the course of the day as the balance between photosynthesis and respiration changes with the light intensity and temperature. Inflowing water may affect pH as well as rainfall is naturally slightly acidic because of carbon dioxide dissolved in it. Changes in pH may also influence other water quality parameters such as ammonia, phosphate, iron and other trace metals.

There was a positive correlation between the number of phytoplankton and pH based on Pearson's correlation analysis. The value of the correlation coefficient is $r=.431$, $p>0.05$ with an average strength. This is maybe due to the presence of diatom species as the dominant species that is tolerant to the high value of pH. If the value is too acidic, then these diatoms might not be able to survive. Most aquatic organism prefers a pH ranges between 6.5 to 8.0. Rivers with a pH of 5.5 and below are particularly at risk (Mitsch & Gosselink, 1993). A pH value outside this range reduces the diversity in the water body because it stresses the physiological systems of most organisms and can reduce reproduction. In addition, David et al. (2003) reported that when there is more aquatic life during the warmer months, there is also an increase in DO which in turn can lower the value of pH.

The risk of contributing turbidity to aquatic systems is highest when the land surfaces are bare and rainfall events occur. Turbidity may also result from the formation of algal blooms. In many aquatic systems, water clarity is determined by the abundance of suspended algae. Eutrophic systems support large algal populations which reduce the clarity of water and increase its colour. Suspended particles absorb heat, so water temperature rises faster in turbid water than it does in clear water. Then, since warm water holds less DO than cold water, the concentration of DO decreases. If penetration of light into the water is restricted, photosynthesis of green plants in water is also restricted. This means less food and oxygen is available for aquatic animals. Plants that can either photosynthesize in low light or control their position in the water, such as the blue green algae, have an advantage in highly turbid waters.

SS can also be an indicator for eutrophication. Elevated levels of suspended material in the water column can reduce light availability and lead to elevated water temperatures due to increased absorbance of thermal radiation. Light availability and temperature affect bacterial, algal and zooplankton physiology as well as the feeding and movements of macroinvertebrates and fish. In addition to impacting submersed plant communities and productivity, suspended solids may clog the filtering apparatus and digestive tracts of planktonic organisms (Schueler et al., 1997).

As level of SS increases, a water body begins to lose its ability to support a diversity of an aquatic life. Suspended solids absorb heat from sunlight, which increases water temperature and subsequently decreases levels of dissolved oxygen. Besides that, photosynthesis will also decrease since less light penetrates the water and less oxygen is produced by plants and phytoplankton which will eventually cause a drop in the amount of dissolved oxygen.

High conductivity is associated with the presence of high concentration of the anions and cations which are essential for the growth and distribution of phytoplankton. These elements are needed in biological activities involving the photosynthesis, respiration and nitrification (Reynolds, 1984). Increase conductivity levels in a water body can affect a high growth of phytoplankton. In fact, Egborge (1974) found out that phytoplankton production is strongly correlated with conductivity.

Chlorophyll *a* is the green pigment found in plants and algae. Plants and algae use this pigment to trap the energy from the sun so that they can grow. Chlorophyll *a* is the most common out of the six types present in every plant that perform photosynthesis. During photosynthesis, the green pigment chlorophyll absorbs light and produces organic carbon (carbohydrates) from carbon dioxide and water. The amount of organic carbon produced by plants is called primary productivity. In addition, the growth of planktonic algae in a water body is related to the presence of nutrients, principally nitrogen and phosphorus as well as temperature and light. Besides, the green pigment is present in most photosynthetic organisms and provides an indirect measure of algal biomass and an indication of the trophic status of a water body. It is usually included in assessment programme for lakes and reservoirs, since excessive algal growth makes water unsuitable or more difficult to treat (Kuo et al., 2007).

Apart from that, the results from the correlation test between the number of phytoplankton and chlorophyll *a* value showed a positive correlation with value $r = .102$, $p>0.05$ which indicated that the number of phytoplankton increased when chlorophyll *a* increased. This also has to be related with the relationship of nutrient and chlorophyll *a*. When nutrient is high, the concentration of chlorophyll *a* is low. Thus the number of algae is low. The high concentration does not affect the growth of phytoplankton that can cause bloom. The other factors which can cause this are the wind speed and water temperature. wind induce internal waves and colder water temperatures induce mixing of the epilimnion and when these two processes are combined, nutrient rich water is supplied to the surface, providing the phytoplankton with nutrients. This is supported by Hecky et al., (1981) said high winds and cold temperature cause less stratified water which allows epilimnion to mix, bringing nutrients to the surface and raising chlorophyll *a* values.

Furthermore, higher levels of phytoplankton were associated with lower levels of nutrients. Nitrate is often a limiting factor affecting the growth of algae and other aquatic organisms. The number of individual species of phytoplankton is high in high oxygen concentration water and vice versa. At all events, higher ammoniacal nitrogen values can be toxic to fish, but in small amount of concentrations, it could serve as nutrients for excessive growth of algae (Corwin et. al., 1999).

Among the phytoplankton species, cyanobacteria are known to be the better competitor for nitrogen (Tilman et al., 1986, Michard et al., 1996, Giani and Delgado, 1998). Limiting nutrients such as phosphorus and nitrogen are often the factors that limit the activity of cyanobacteria in freshwater ecosystem. Phosphorus is an essential nutrient for living organisms and exists in water bodies as both dissolved and particulate species. It is generally the limiting nutrient for phytoplankton growth and therefore controls the primary productivity of a water body. Phytoplankton species such as *Cymbella lanceolata,* and *Tabellaria fenestrate* were less tolerant towards the phosphorus as the species require just a small amount of phosphorus. Overall, high concentrations of phosphates are generally an indication of pollution associated with eutrophication condition (WHO, 1998).

4.5 Water quality index analysis

Table 4.10: Water Quality Index (WQI) value for each station of Sepang River

Station	WQI
1	84.5
2	83.9
3	84.9
4	85.4
5	84.8

Table 4.11: Water Quality Index (WQI) value for each month of Sepang River from May to October 2014

Year	Month	WQI
2014	**May**	84.4
	June	83.8
	July	87.2
	August	84.5
	September	85.6
	October	84.6
	November	81.0
	December	84.4
2015	**January**	85.0
	February	84.5

Water quality index (WQI) of Sepang River was determined by Malaysia Department of Environment formula based on six parameters including DO, BOD, COD, Ammoniacal nitrogen, SS and pH. Based on the above Table 4.10, the WQI values are slightly higher and can be considered cleaner in the middle and the upstream. Water and sewage from the premises concerned are distributed directly to the sea and polluting the coastal areas of Bagan Lalang (Piah et al., 2008). This can be seen in station 1 and 2. The middle stream (station 3) is not contaminated with sewage and rich in marine life. Besides, it is confirmed that the area was indeed rich in terrestrial plants (Piah et al., 2008).

Besides that, Table 4.11, in terms of month, a high WQI are recorded in the earlier month of sampling starting in July 2014 until the end of sampling but slightly lower value is obtain during the wet season. The overall mean of stations and monthly WQI of Sepang River was 84.6 and it falls under class II where conventional treatment is required for water supply and only sensitive aquatic species can tolerate the fishery industries. The water also can be used for recreational activities with full body contact without worries.

This water quality rating clearly shows that the water body is classified under a clean range and suitable for human use. It is also found that the pollution load is relatively low and has less effect to the quality of the river.

CHAPTER 5

GENERAL DISCUSSION

Rivers play a significant role in providing water resources for human and ecosystem survival and health. Hence, river water quality is an important parameter that must be preserved and monitored. Good quality of water is more essential for the aquatic flora and fauna. The water quality criteria should be more stringent for their survival and ecological balance. For holistic and sustainable use of water and other appropriate indices such as SCI diversity index, index of biotic integrity (IBI), index of saprobic condition (S) and others could be considered (DOE, 1994). This is normal because the normal monitoring program cannot evaluate the river's ecological status. At least biannual or quarterly sampling of planktons, macrophytes, invertebrates, fish and other aquatic flora and fauna should be done to determine the biological integrity of the rivers in various seasons (Al-Mamun & Zainudin, 2013).

Water quality index provides a single number that expresses the overall water quality based on several water quality parameters. The calculated WQI can be used as an indicator for the river whether it is in a good condition or not .There are many other water quality parameters that are not included in the index. However, a water quality index based on some very important parameters can provide a simple indicator of the water quality. Most of the rivers in the state of Selangor are undergoing tremendous development and they are subjected to pollution from both point and non point sources. For the Sepang River, the results of mean WQI from all the stations are 84 which has been classified as clean and received a minimum anthropogenic pollution in relation to the WQI. This index results showed that the river water of Sepang River is clean and it is suitable for human use. Besides that, it is also found that pollution load is relatively low and has no significant effect to the quality of this river. Results of this study also showed that the present policy on managing the river water quality has produced encouraging results. Nevertheless, water quality is highly variable over time due to both natural and human factors (Ahmad et al., 2009).

Physico-chemical and anions analyses are one of the important parts of the water quality monitoring process. However, these parameters showed that there is no fixed pattern values obtained and no major changes were detected in every station and month, thus contributing to a quite similar reading for WQI and NWQS. This is maybe due to the same land use pattern of station chosen as well as limited sampling time of the study. The density and composition of phytoplankton obtained are low and the results can be strengthen if the phytoplankton count is more. The species detected are mostly common and can be found both in clean and polluted water. Hence, the phytoplankton community could not be used solely as a guide in assessing the water quality of this river based on species found. Therefore, the findings in this study are inconclusive but some data can still be useful for the river basin management. Thorough analysis needs to be done in the future to classify the water quality status of Sepang River.

CHAPTER 6

CONCLUSION

This water quality of Sepang River shows a similar pattern in between the sampling station and month. According to the INWQS for Malaysian rivers most of the water quality parameters (temperature, DO, turbidity, suspended solid, BOD, COD and ammoniacal nitrogen) were within the range of moderate condition. Only pH was within good condition range when compared to NWQS class. Based on the NWQS, chloride, sulphate and nitrite concentrations were high whilst nitrate, bromide, and fluoride concentrations were low. The total number of species and the total number of individual phytoplanktons for all the stations and months were 59 and 3125 cell/ml respectively. They were found most in the middle stream. The divisions Bacillariophyta and Chlorophyta were highest in terms of number of species and individuals. Species such as *Diatoma elongatum, Chaetoceros decipiens, Chaetoceros didymum , Chaetoceros curvisetus, Pediastrum duplex* and *Scenedesmus acuminatu*s were found in most of the stations and months. Some of the parameters such as temperature, DO, pH, conductivity, salinity, TDS, BOD and chlorophyll *a* shows a positive correlation with phytoplankton. Shannon–Wiener values obtain from the results also indicate that this river has a high diversity of phytoplankton. The WQI of Sepang River can be classified as clean and falls within Class II. This water quality rating clearly shows that the water body was clean and suitable for human use. The chemical, physical and biological aspects of water quality are interrelated and must be considered together. Continuous monitoring of water quality of the river water at the area also should be done to monitor the water quality status. All agencies involved include the local communities' plays an important role and should be more effective to prevent the deterioration of the river water quality.

REFERENCES

Abdullah, K. (2002). Integrated river basin management. *Rivers: Towards Sustainable Development", Penerbit Universiti Sains Malaysia, Penang*, 3-14.

Abdullah, P., & Nainggolan, H. (1991). Phenolic water pollutants in a Malaysian river basin. *Environmental Monitoring and Assessment, 19*(1-3), 423-431.

Aburto, M. O., de los Angeles Carvajal, M., Barr, B., Barbier, E. B., Boesch, D. F., Boyd, J., Ezcurra, E. (2012). *Ecosystem-based management for the oceans*: Island Press.

Addy, K., & Green, L. (1997). Dissolved oxygen and temperature. *Natural Resources Fact Sheet,* (96-3).

Ahmad, A., Mushrifah, I., & Othman, M. S. (2009). Water quality and heavy metal concentrations in sediment of Sunagi Kelantan, Kelantan, Malaysia: A baseline study. *Sains Malaysiana, 38*(4), 435-442.

Ahmad, M. K., Islam, S., Rahman, S., Haque, M. R., Islam, M. M. (2010). Heavy metals in water, sediment and some fishes of Buriganga River, Bangladesh. *International Journal of Environmental Response, 4* (2), 321-332.

Al-Badaii, F. (2011). *Water quality assessment of the Semenyih River.* MSc Thesis, Universiti Kebangsaan Malaysia, Selangor, Malaysia.

Al-badaii, F., Gasim, M., Mokhtar, M., Toriman, M., & Rahim, S. A. (2012). Water-pollution study based on the physico-chemical and microbiological parameters of the Semenyih River, Selangor, Malaysia. *The Arab World Geographer, 15*(4), 318-334.

Al-Badaii, F., Shuhaimi-Othman, M., & Gasim, M. B. (2013). Water Quality Assessment of the Semenyih River, Selangor, Malaysia. *Journal of Chemistry, 20*(1), 1-10.

Almamun, A. and Idris, A. (2008). Twelfth International Water Technology Conference, IWTC12, Alexandria, Egypt.

Al-Mamun, A., & Zainuddin, Z. (2013). Sustainable river water quality management in Malaysia. *IIUM Engineering Journal, 14*(1), 29-42.

Al-Shami, S., Rawi, C. S. M., Nor, S. A. M., Ahmad, A. H., & Ali, A. (2010). Morphological deformities in Chironomus spp.(Diptera: Chironomidae) larvae as a tool for impact assessment of anthropogenic and environmental stresses on three rivers in the Juru River System, Penang, Malaysia. *Environmental entomology, 39*(1), 210-222.

Al-Shami, S. A., Rawi, C. S. M., Ahmad, A. H., Hamid, S. A., & Nor, S. A. M. (2011). Influence of agricultural, industrial, and anthropogenic stresses on the distribution and diversity of macroinvertebrates in Juru River Basin, Penang, Malaysia. *Ecotoxicology and environmental safety, 74*(5), 1195-1202.

Amadi, A., Olasehinde, P., Okosun, E., & Yisa, J. (2010). Assessment of the water quality index of otamiri and oramiriukwa rivers. *Physics International, 1*(2), 116-123.

Anton, A., & Abdullah, F. (1982). *Effect of phosphate and nitrate enrichments on reservoir phytoplankton.* Paper presented at the Proceeding of Regional Workshop on Limnology and Water Resources Management in the Developing Countries of Asia and the Pacific. University of Malaya, Kuala Lumpur.

APHA (1992). *Standard methods for the examination of water and wastewater.* 18th ed. Washington, DC: American Public Health Association.

APHA (2007). WEF (2005) Standard methods for the examination of water and wastewater. *American Public Health Association, American Water Works Association, and Water Environment Federation*.

Arsad, A. (2009). *Development of river restoration plan for upstream tributary of Sungai Pulai based on water quality and land used activities.* Universiti Teknologi Malaysia, Faculty of Civil Engineering.

Arsad, A., Abustan, I., Rawi, C. S. M., & Syafalni, S. (2012). Integrating Biological Aspects into River Water Quality Research in Malaysia: An Opinion. *OIDA International Journal of Sustainable Development, 4*(02), 107-122.

Arzul, G., & Maguer, J.-F. (1990). Influence of pig farming on the copper content of estuarine sediments in Brittany, France. *Marine Pollution Bulletin, 21*(9), 431-434.

Azni Idris, Wan Nor Wan Azmin, Mohd Amin Mohd Som and Abdullah Al-Mamun.(2004). The Importance of Sullage (Grey-Water) Treatment for the Restoration and Conservation of Urban Streams, 1st International Conference on

Managing Rivers in The 21st Century: Issues & Challenges – Rivers 2004, 21-23 Sept 2004.

Azrina, M., Yap, C., Ismail, A. R., Ismail, A., & Tan, S. (2006). Anthropogenic impacts on the distribution and biodiversity of benthic macroinvertebrates and water quality of the Langat River, Peninsular Malaysia. *Ecotoxicology and environmental safety, 64*(3), 337-347.

Bahls, L. L., Bukantis, R., & Tralles, S. (1992). *Benchmark biology of Montana reference streams*: Water Quality Bureau, Department of Health and Environmental Sciences.

Bailey, R. C., Norris, R. H., & Reynoldson, T. B. (2001). Taxonomic resolution of benthic macroinvertebrate communities in bioassessments. *Journal of the North American Benthological Society, 20*(2), 280-286.

Bailey, R. C., Norris, R. H., & Reynoldson, T. B. (2004). *Bioassessment of freshwater ecosystems*: Springer.

Barinova, S. (2011). *Algal diversity dynamics, ecological assessment, and monitoring in the river ecosystems of the eastern Mediterranean*: Nova Science Publishers.

Barinova, S., Medvedeva, L., & Anissimova, O. (2006). Diversity of algal indicators in environmental assessment. *Pilies Studio, Tel Aviv, 498*.

Bartram, J., & Ballance, R. (1996a). *Water quality monitoring: a practical guide to the design and implementation of freshwater quality studies and monitoring programmes*: CRC Press.

Bartram, J., & Ballance, R. (1996b). Water quality monitoring: a practical guide to the design and implementation of freshwater quality studies and monitoring programs.

Bhuiyan, M. A. H., Ismail, S. M., Siwar, C., & Elfithri, R. (2014). The Role of Natural Capital for Ecosystem: Focusing on Water Resource in Pahang, Malaysia. *Life Science Journal, 11*(5).

Birol, E., Karousakis, K., & Koundouri, P. (2006). Using economic methods and tools to inform water management policies: a survey and critical appraisal of available methods and an application. *Science of the Total Environment, 365*(1-3), 105-122.

Bishop, J. (2012). *Limnology of a small Malayan river Sungai Gombak* (Vol. 22): Springer Science & Business Media.

Bishop, J. E. (1973). Observations on the vertical distribution of the benthos in a Malaysian stream. *Freshwater Biology, 3*(2), 147-156.

Bispo, P., Oliveira, L., Bini, L., & Sousa, K. (2006). Ephemeroptera, Plecoptera and Trichoptera assemblages from riffles in mountain streams of Central Brazil: environmental factors influencing the distribution and abundance of immatures. *Brazilian Journal of Biology*, *66*(2B), 611-622.

Bode, R. W., & Novak, M. A. (1995). Development and application of biological impairment criteria for rivers and streams in New York State. *Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL,* 97-107.

Bouza-Deaño, R., Ternero-Rodriguez, M., & Fernández-Espinosa, A. (2008). Trend study and assessment of surface water quality in the Ebro River (Spain). *Journal of Hydrology, 361*(3), 227-239.

Boyd, C. E., & Tucker, C. S. (2012). *Pond aquaculture water quality management*: Springer Science & Business Media.

Boyde, C.E., (2000). Water quality: An introduction. Alabama agricultural experiment station, Department of fisheries and allied aquacultures Auburn University, USA., ISBN: 0-7923-7853-9, pp: 120-121.

Bradley, R. M. (2010). Direct and indirect benefits of improving river quality: quantifying benefits and a case study of the River Klang, Malaysia. *The Environmentalist, 30*(3), 228-241.

Buzzi, F. (2002). Phytoplankton assemblages in two sub-basins of Lake Como. *Journal of Limnology, 61*(1), 117-128.

Campbell, K. L. and Edwards, D. R. (2001). Phosphorus and water quality impacts. P. 91-109. In W.F Ritter and A. Shirmohammadi, (eds.) Agricultural Nonpoint Source Pollution: Watershed Management & Hydrology. Lewis Publishers, Boca Raton, FL.

Cech, T. V. (2010). *Principles of water resources: history, development, management, and policy*: John Wiley & Sons.

Chakraborty, N., Banerjee, A., & Pal, R. (2011). Accumulation of lead by free and immobilized cyanobacteria with special reference to accumulation factor and recovery. *Bioresource technology, 102*(5), 4191-4195.

Chakraborty, P., Acharyya, T., Babu, P. R., & Bandyopadhyay, D. (2011). Impact of salinity and pH on phytoplankton communities in a tropical freshwater system: An investigation with pigment analysis by HPLC. *Journal of Environmental Monitoring, 13*(3), 614-620.

Chambers, P. A., & Mill, T. (1996). *Dissolved oxygen conditions and fish requirements in the Athabasca, Peace and Slave rivers: assessment of present conditions and future trends*: Northern River Basins Study.

Chan, N. W., Anisah L. A., Ibrahim, L., and Ghazali, S. (2003). River Pollution and Restoration towards Sustainable Water Resources Management in Malaysia. In: National Seminar on Society, Space and Environment in a Globalised World: Prospects & Challenge, 29-30 May 2003, The City Bayview Hotel, Penang.

Chapman, D. V., & Organization, W. H. (1996). Water quality assessments: a guide to the use of biota, sediments and water in environmental monitoring.

Cheng, D., Jones, P., & Powell, J. (1990). Manly Dam Catchment Water Quality Study. *University of Technology, Sydney*.

Chua, Y. P. (2013). *Mastering research statistics*. Shah Alam: Mcgraw-Hill Education.

Cohn, F. (1853). *Living organism in drinking water*: Springer.

Coles, J. F., & Jones, R. C. (2000). Effect of temperature on photosynthesis-light response and growth of four phytoplankton species isolated from a tidal freshwater river. *Journal of Phycology*, *36*(1), 7-16.

Corwin, D., Carrillo, M., Vaughan, P., Rhoades, J., & Cone, D. (1999). Evaluation of a GIS-linked model of salt loading to groundwater. *Journal of Environmental Quality, 28*(2), 471-480.

Cowardin, L. M., Carter, V., Golet, F. C., & LaRoe, E. T. (1979). Classification of wetlands and deepwater habitats of the United States: US Department of the Interior, US Fish and Wildlife Service.

Cunningham, W., Cunningham, M., & Saigo, B. (2007). *Environmental science: A global concern*: Glossary EL.

Cuvin-Aralar, M. L., Focken, U., Becker, K., & Aralar, E. V. (2004). Effects of low nitrogen-phosphorus ratios in the phytoplankton community in Laguna de Bay, a shallow eutrophic lake in the Philippines. *Aquatic ecology, 38*(3), 387-401.

David, M., Metzger, P. and Casadewall, E. (2003). Two cyclobotryococcenes from the B race of the green alga *Botryococcus braunii*. *Phytochemistry,* 27(9): 2863-2867.

De Pauw, N., & Vanhooren, G. (1983). Method for biological quality assessment of watercourses in Belgium. *Hydrobiologia, 100*(1), 153-168.

Department of Environment (1991). Progress in Malaysia towards Environmentally Sound and Sustainable Development 1976–1990, Department of Environment, Ministry of Science, Technology and the Environment, Malaysia.

Department of Environment (1994). *Classification of Malaysian Rivers*. Final report on development of water quality criteria and standards for Malaysia (Phase IV-river classification). Government of Malaysia, Ministry of Science, technology and the environment.

Department of Environment (1997). *Malaysia environmental quality report*. Kuala Lumpur: DOE.

Department of Environment (2001). *Malaysia environmental quality report*. Kuala Lumpur: DOE.

Department of Environment (2006). *Malaysia environmental quality report*. Kuala Lumpur: DOE.

Department of Environment (2011). *Malaysia environmental quality report*. Kuala Lumpur: DOE.

Diaz, M., Pedrozo, F., Reynolds, C., & Temporetti, P. (2007). Chemical composition and the nitrogen-regulated trophic state of Patagonian lakes. *Limnologica-Ecology and Management of Inland Waters, 37*(1), 17-27.

Department of Irrigation and Drainage Malaysia (2009), Panduan Penggunaan Makroinvertebrata untuk Penganggaran Kualiti Air Sungai, ed. Department of Irrigation and Drainage Malaysia (Kuala Lumpur, Malaysia: Jabatan Pengairan dan Saliran Malaysia) 116.

Driche, M., Abdessemed, D., & Nezzal, G. (2008). Treatment of wastewater by natural lagoon for its reuse in irrigation. *American J. of Engineering and Applied Sciences, 1*(4), 408-413.

Egborge, A. (1974). The seasonal variation and distribution of phytoplankton in the River Oshun, Nigeria. *Freshwater Biology, 4*(2), 177-191.

Eisakhani, M., & Malakahmad, A. (2009). Water quality assessment of Bertam River and its tributaries in Cameron Highlands, Malaysia. *World Applied Sciences Journal, 7*(6), 769-776.

Federation, W. E., & Association, A. P. H. (2005). *Standard methods for the examination of water and wastewater.* Washington, DC, USA: American Public Health Association (APHA).

Feleke, Z., & Sakakibara, Y. (2002). A bio-electrochemical reactor coupled with adsorber for the removal of nitrate and inhibitory pesticide. *Water research, 36*(12), 3092-3102.

Francis-Floyd, R. (1993). *Dissolved oxygen for fish production.* University of Florida, United States: Fisheries and Aquatic Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences.

Gandaseca, S., Rosli, N., Ngayop, J., & Arianto, C. I. (2011). Status of water quality based on the physico-chemical assessment on river water at wildlife sanctuary Sibuti mangrove forest, Miri Sarawak. *American Journal of Environmental Sciences, 7*(3), 269-275.

Gasim, M. B., Mokhtar, M., Surif, S., Toriman, M. E., Rahim, S. A., & Lun, P. I. (2012). Analysis of thirty years recurrent floods of the Pahang River, Malaysia. *Asian Journal of Earth Sciences, 5*(1), 25.

Geological Map of Peninsular Malaysia, (1985), Minerals and Geosciences Department, Malaysia

Ghani, P. H. A., Yusoff, M. K., Manaf, L. A., & Daud, M. B. (2009). Ammonium ion trend in selected Malaysian river. *World Applied Sciences Journal, 6*(3), 442-448.

Giani, A., & Delgado, P. (1998). Growth dynamics and competitive ability of a green (Oocystis lacustris) and a blue-green alga (Synechocystis sp.) under different N: P ratios. *Verhandlungen-Internationale Vereinigung für theoretische und angewandte Limnologie, 26*, 1693-1697.

Greenburg, A. E., Clesceri, L. S., & Eaton, A. D. (1992). *Standard methods for the examination of water and wastewater.* Washington, DC: Public Health Assoc.

Guillard, R. (1962). Salt and osmotic balance. *Physiology and biochemistry of algae, 929*, 529-540.

Guillard, R. R., & Ryther, J. H. (1962). Studies of marine planktonic diatoms: i. *Cyclotella nana* hustedt, and *Detonula confervacea* (cleve) gran. *Canadian journal of microbiology, 8*(2), 229-239.

Hecky, R., & Kling, H. (1981). The phytoplankton and protozooplankton of the euphotic zone of Lake Tanganyika: Species composition, biomass, chlorophyll content, and spatio-temporal distribution. *Limnol. Oceanogr, 26*(3), 548-564.

Hem, J. D. (1985). *Study and interpretation of the chemical characteristics of natural water* (Vol. 2254): Department of the Interior, US Geological Survey.

Heng, L. Y., Chukong, L. N., Stuebing, R. B., & Omar, M. (2006). The water quality of several oxbow lakes in Sabah, Malaysia and its relation to fish fauna distribution.

Hensen, V. (1887). *Über die Bestimmung des Planktons oder des im Meere treibenden Materials an Pflanzen und Tieren*: Schmidt & Klaunig.

Herrera-Silveira, J. A., Medina-Gomez, I., & Colli, R. (2002). Trophic status based on nutrient concentration scales and primary producers community of tropical coastal lagoons influenced by groundwater discharges. *Hydrobiologia, 475*(1), 91-98.

Hibiya, K., Terada, A., Tsuneda, S., & Hirata, A. (2003). Simultaneous nitrification and denitrification by controlling vertical and horizontal microenvironment in a membrane-aerated biofilm reactor. *Journal of biotechnology, 100*(1), 23-32.

Hill, B., Herlihy, A., Kaufmann, P., Stevenson, R., McCormick, F., & Johnson, C. B. (2000). Use of periphyton assemblage data as an index of biotic integrity. *Journal of the North American Benthological Society, 19*(1), 50-67.

Ho, S.-C. (1995). Status of limnological research and training in Malaysia. *Limnology in Developing Countries (eds B. Gopal and RG Wetzel). International Association for Limnology. International Scientific Publications*, 163-189.

Ho, S.C. (1995). Status of limnological research and training in Malaysia. In Gopal, B. & R. G. Wetzel (eds). Limnology in Developing Cuntries:163-189.

Ho, S., & Peng, T. (1997). The use of river plankton and fish in water quality classification of Sg. Perai, Sg. Juru and Sg. Perlis. *Journal Ensearch, 10*(2), 115-124.

Horne, A. J., & Goldman, C. R. (1994). *Limnology*: New York: McGraw-Hill.

Hosmani, S. P. (2010). Phytoplankton diversity in lakes of Mysore district, Karnataka state, India. *The Ecoscan, 4*(1), 53-57.

Idris, A. B., Mamun, A., Amin, M., Soom, M., Noor, W., & Azmin, W. (2003). Review of water quality standards and practices in Malaysia. *Pollution Research, 22*(2), 145-155.

Iliopoulou-Georgudaki, J., Kantzaris, V., Katharios, P., Kaspiris, P., Georgiadis, T., & Montesantou, B. (2003). An application of different bioindicators for assessing water quality: a case study in the rivers Alfeios and Pineios (Peloponnisos, Greece). *Ecological indicators, 2*(4), 345-360.

Islam, S., & Suidan, M. T. (1998). Electrolytic denitrification: long term performance and effect of current intensity. *Water research, 32*(2), 528-536.

Ismail, A. (1994). Heavy metals in freshwater snails of Kuala Klawang's rice field, Negeri Sembilan, Malaysia. *Environmental monitoring and assessment, 32*(3), 187-191.

Ismail, A., & Ramli, R. (1997). Trace metals in sediments and molluscs from an estuary receiving pig farms effluent. *Environmental Technology, 18*(5), 509-515.

Ismail, R., Ibrahim, A., Ab Hamid, H., Majid, T. A., & Adnan, A. (2016). Seismic Site Classification of JKR Bridge at Sungai Sepang Using Multichannel Analysis of Surface Wave (MASW) *InCIEC 2015* (pp. 159-167): Springer.

Isobe, K.O., Tarao, M., Zakaria, M.P., Chiem, N.H., Minh, L.Y. & Takada, H. (2002). Quantitative Application of fecal sterols using gas chromatography-mass spectrometry to investigate fecal pollution in tropical waters: Western Malaysia and Mekong delta, Vietnam. *Environmental Science and Technology, 36*(21), 4497-4507.

James, A., & Evison, L. (1979). *Biological indicators of water quality*: John Wiley.

Juahir, H., Zain, S. M., Yusoff, M. K., Hanidza, T. T., Armi, A. M., Toriman, M. E., & Mokhtar, M. (2011). Spatial water quality assessment of Langat River Basin (Malaysia) using environmetric techniques. *Environmental monitoring and assessment, 173*(1-4), 625-641.

Kalff, J. (2002). *Limnology: inland water ecosystems* (Vol. 592): Prentice Hall New Jersey.

Kamat, N. (1982). Topics in algae: Retrieved from http://www.agris.fao.org

Karr, J. R. (1991). Biological integrity: a long-neglected aspect of water resource management. *Ecological applications, 1*(1), 66-84.

Kathiresan, K. (2004). Ecology and environment of mangrove ecosystem. *UNU–INWEH–UNESCO International Training course on coastal biodiversity in mangrove ecosystem course manual. CAS in Marine Biology, Annamalai University, Parangipettai*, 76-89.

Khalil, B., & Ouarda, T. (2009). Statistical approaches used to assess and redesign surface water-quality-monitoring networks. *Journal of Environmental Monitoring, 11*(11), 1915-1929.

Khan, A., Al-Oufi, H., McLean, E., Goddard, S., Srikandakumar, A., & Al-Sabahi, J. (2003). Analysis of fatty acid profiles of kingfish (Scomberomorus commerson) from different coastal regions of Sultanate of Oman. *International Journal of Food Properties, 6*(1), 49-60.

Khan, F. A., & Ansari, A. A. (2005). Eutrophication: an ecological vision. *The botanical review, 71*(4), 449-482.

Khan, I. (1990). Assessment of water pollution using diatom community structure and species distribution—A case study in a tropical river basin. *Internationale Revue der gesamten Hydrobiologie und Hydrographie, 75*(3), 317-338.

Khan, I. N. (1991). Effect of urban and industrial wastes on species diversity of the diatom community in a tropical river, Malaysia. *Hydrobiologia, 224*(3), 175-184.

Kitner, M., & Poulícková, A. (2003). Littoral diatoms as indicators for the eutrophication of shallow lakes. *Hydrobiologia, 506*(1-3), 519-524.

Kitsiou, D., & Karydis, M. (2000). Categorical mapping of marine eutrophication based on ecological indices. *Science of the Total Environment, 255*(1), 113-127.

Klemm, D. J., Blocksom, K. A., Thoeny, W. T., Fulk, F. A., Herlihy, A. T., Kaufmann, P. R., & Cormier, S. M. (2002). Methods development and use of macroinvertebrates as indicators of ecological conditions for streams in the Mid-Atlantic Highlands region. *Environmental monitoring and assessment, 78*(2), 169-212.

Kolenati, F. A. (1848). *Genera et species Trichopterorum*. Munich, Germany: Amad. Haase.

Kolkwitz, R., & Marsson, M. (1908). *Ökologie der pflanzlichen Saprobien*: Borntraeger.

Kramer, D. L. (1987). Dissolved oxygen and fish behavior. *Environmental Biology of Fishes, 18*(2), 81-92.

Krebs, C. J. (1999). *Ecological methodology* (Vol. 620): Benjamin/Cummings Menlo Park, California.

Kumar, K., Saion, E., Halimah, M., Yap, C. K., & Hamzah, M. S. (2014). Rare earth element (REE) in surface mangrove sediment by instrumental neutron activation analysis. *Journal of Radioanalytical and Nuclear Chemistry, 301*(3), 667-676.

Kuo, J.-T., Hsieh, M.-H., Lung, W.-S., & She, N. (2007). Using artificial neural network for reservoir eutrophication prediction. *Ecological modelling, 200*(1), 171-177.

Latiff, A. A. A., Karim, A. T. A., Muhamad, A., Hashim, N. H., & Hung, Y.-T. (2009). Study of metal pollution in Sembrong River, Johor, Malaysia. *International Journal of Environmental Engineering, 1*(4), 383-404.

Liebmann, H. (1960). *Handbook of Freshwater Biology*: Oldenbourg, Germany.

Liebmann, H. (1962). *Handbook of Freshwater Biology:* Oldenbourg, Germany.

Lim, R.P. (1987). Water Quality and Final Composition in the Streams and Rivers of the Ulu Endau Area, Johore, Malaysia. *Malayan Nature Journal*, *41*: 337-347

Liu, G. (2005). *An investigation of UV disinfection performance under the influence of turbidity & particulates for drinking water applications.* University of Waterloo.

Livingston, R. J. (2000). *Eutrophication processes in coastal systems: origin and succession of plankton blooms and effects on secondary production in Gulf Coast estuaries*: CRC press.

Lowe, R. L., & Pan, Y. (1996). Benthic algal communities as biological monitors. *Algal ecology: freshwater benthic ecosystems*, 705-739.

LU, H., LI, X., & JIANG, N. (2005). Estimation of suspended solids concentration in Lake Taihu using spectral reflectance and Simulated MERIS. *Journal of Lake Science*, *2*, 003.

Lund, J., Kipling, C., & Le Cren, E. (1958). The inverted microscope method of estimating algal numbers and the statistical basis of estimations by counting. *Hydrobiologia, 11*(2), 143-170.

MacKinnon, M., & Herbert, B. (1996). Temperature, dissolved oxygen and stratification in a tropical reservoir, Lake Tinaroo, northern Queensland, Australia. *Marine and freshwater research*, *47*(7), 937-949.

Makhlough, A. (2008). *Water Quality Characteristics Of Mengkuang Reservoir Based On Phytoplankton Community Structure And Physico-Chemical Analysis [TD370. M235 2008 f rb]*. Universiti Sains Malaysia.

Mallya, J. (2007). The effects of dissolved oxygen on fish growth in aquaculture, United Nations University. *Fisheries Training Programme, UNU-FTP*, *30*.

Maznah, W. W., & Mansor, M. (2002). Aquatic pollution assessment based on attached diatom communities in the Pinang River Basin, Malaysia. *Hydrobiologia, 487*(1), 229-241.

McCormick, P. V., & Stevenson, R. J. (1998). Periphyton as a tool for ecological assessment and management in the Florida Everglades. *Journal of Phycology, 34*(5), 726-733.

McCormick, P. V., & Cairns Jr, J. (1994). Algae as indicators of environmental change. *Journal of Applied Phycology, 6*(5-6), 509-526.

Meybeck, M., Kuusisto, E., Makela, A., & Malkki, E. (1992). Water Quality in J. Bartman and R. Ballance (Ed.) Water Quality Monitoring-A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes: E&FN Spon Press, London.

Meybeck, M., Friedrich, G., Thomas, R., & Chapman, D. (1992). Rivers. *Water Quality Assessments*, 238-316.

Michard, P., Guibal, E., Vincent, T., & Le Cloirec, P. (1996). Sorption and desorption of uranyl ions by silica gel: pH, particle size and porosity effects. *Microporous materials, 5*(5), 309-324.

Mitsch, W., & Gosselink, J. (1993). WetlandsVan Nostrand Reinhold. *New York*, 722.

Mol, A. (1980). The role of the invertebrate fauna in the biological assessment of water quality. *Hydrobiological Bulletin, 14*(3), 222-223.

Muyibi, S. A., Ambali, A. R., & Eissa, G. S. (2008). The impact of economic development on water pollution: trends and policy actions in Malaysia. *Water Resources Management, 22*(4), 485-508.

Nather Khan, I. (1985). Studies on the water quality and periphyton community in the Linggi River Basin, Malaysia. *PhD Diss., University of Malaya (unpublished).*

Noorhaidah, A., & Yap, C. (2012). Distribution of heavy metal concentrations in the different soft and hard tissues of tropical mud-flat snail Telescopium telescopium (family: Potamididae) collected from Sepang Besar River. *Pertanika Journal of Tropical Agricultural Science (Malaysia)*, 35(3), 427-438.

Ostrander, G. K. (2000). *The laboratory fish.* New York: Elsevier.

Othman, F., ME, A. E., & Mohamed, I. (2012). Trend analysis of a tropical urban river water quality in Malaysia. *Journal of Environmental Monitoring, 14*(12), 3164-3173.

Palanaippan, M., Gleick, P. H., Allen, L., Cohen, M. J., Christian-Smith, J., & Smith, C. (2010). *Clearing the waters: a focus on water quality solutions*: United Nations Environment Programme.

Palleyi, S., Kar, R., & Panda, C. (2008). Seasonal variability of phytoplankton population in the Brahmani estuary of Orissa, India. *Journal of Applied Sciences and Environmental Management, 12*(3).

Parsons, T. R., Maita, Y., & Lalli, C. M. (1984). *A manual of biological and chemical methods for seawater analysis*. Oxford,United Kingdom: Publ. Pergamon Press.

Peng, Z., Zhang, G., Mai, B., Min, Y. & Wang, Z. (2002). Spatial and temporal trend of sewage pollution indicated by coprostanol in Macao Estuary, southern China. *Marine Pollution Bulletin, 45*(1), 295-299.

Perry, J. and Vanderklien, E. (1997)**.** *Water Quality*. Oxford: Blackwell Science.

Perry, J., & Vanderklein, E. L. (2009). *Water quality: management of a natural resource*: John Wiley & Sons.

Perry, J.; Vanderklein, E. (1996). *Water Quality Management of a Natural Resource*. Oxford, United Kingdom: Blackwell Science.

Piah, A. M., Ali, M. M., Zakaria, M. P., & Mohamed, C. A. R. (2008). Taburan sterol dalam sedimen di Sungai Sepang Besar, Selangor. *Sains Malaysiana, 37*(4), 307-312.

Plafkin, J. L., Barbour, M. T., Porter, K. D., Gross, S. K., & Hughes, R. M. (1989). Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish *Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish*: EPA.

Potapova, M., & Charles, D. F. (2003). Distribution of benthic diatoms in US rivers in relation to conductivity and ionic composition. *Freshwater Biology, 48*(8), 1311-1328.

Praveena, S., Ahmed, A., Radojevic, M., Abdullah, M. H., & Aris, A. (2007). Factor-cluster analysis and enrichment study of mangrove sediments-an example from Mengkabong, Sabah.

Praveena, S. M., Radojevic, M., & Abdullah, M. H. (2007). The Assessment of Mangrove Sediment Quality in Mengkabong Lagoon: An Index Analysis Approach. *International Journal of Environmental and Science Education, 2*(3), 60-68.

Radojevic, M., M.H. Abdullah & A.Z. Aris (2007). *Analisis air*. Puchong Selangor: Scholar Press.

Rambok, E., Gandaseca, S., Ahmed, O. H., Majid, N. A., & Muhamad, N. (2010). Comparison of selected soil chemical properties of two different mangrove forests in Sarawak. *American Journal of Environmental Sciences, 6*(5), 438-441.

Ratnayaka, D. D., Brandt, M. J., & Johnson, M. (2009). *Water Supply*. Butterworth: Heinemann.

Reaugh, M. L., Roman, M. R., & Stoecker, D. K. (2007). Changes in plankton community structure and function in response to variable freshwater flow in two tributaries of the Chesapeake Bay. *Estuaries and Coasts, 30*(3), 403-417.

Rey, F. (2004). Effectiveness of vegetation barriers for marly sediment trapping. *Earth Surface Processes and Landforms, 29*(9), 1161-1169.

Reynolds, C. S. (1984). *The ecology of freshwater phytoplankton*. United Kingdom: Cambridge University Press.

Romano, N., & Zeng, C. (2007a). Acute toxicity of ammonia and its effects on the haemolymph osmolality, ammonia-N, pH and ionic composition of early juvenile mud crabs, Scylla serrata (Forskål). *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology, 148*(2), 278-285.

Romano, N., & Zeng, C. (2007b). Ontogenetic changes in tolerance to acute ammonia exposure and associated gill histological alterations during early juvenile development of the blue swimmer crab, Portunus pelagicus. *Aquaculture, 266*(1), 246-254.

Rosas, I., Mazari, M., Saavedra, J., & Baez, A. (1985). Benthic organisms as indicators of water quality in Lake Patzcuaro, Mexico. *Water, Air, and Soil Pollution, 25*(4), 401-414.

Rosli, N. A., Zawawi, M. H. & Bustami, R. A. (2012). Salak River water quality identification and classification according to physico-chemical characteristics. *Procedia Engineering*, *50*: 69–77.

Saberi,0. (1993). Forest profile and tree morphology of a mangrove forest in Sepang, Selangor, Malaysia. *Biotrop Special, 51*(1), 43-51.

Saed, K. (2001). *Ecotoxicology of heavy metal (Cd, Pb, Zn and Cu) in flat tree oyster Isognomon alatus from Sepang River Malaysia.* PhD thesis, University Putra Malaysia.

Salleh, A. & Tajuddin, Z. M. (2006). *Phytoplankton of Carey Island*. Kuala Lumpur: Golden Hope Plantations.

Salleh, A., Sarini, A.W., Nadia, M.K., and Saifulnazri, N. (2009). Diversity of Algae at Kenaboi Forest Reserve, Jelebu, Negeri Sembilan, Malaysia. *Malaysian Journal of Science 28*(4): 359-368.

Salleh, H., Hau, T., & Hamid, Z. (2011). Alternative Water Supply Scheme for Kuala Lumpur International Airport (KLIA), Sepang, Selangor: Technical paper, Water Supply Department, Ministry of Energy, Green Technology and Water, Malaysia.

Salusso, M., & Morana, L. (2002). Comparison of biotic index used in monitoring of 2 lotic systems in north-western Argentina. *Revista de biologia tropical, 50*(1), 327-336.

S. Harun, M.H. Abdullah, M. Mohamed et al. (2010). Water quality study of four streams within Maliau Basin Conservation Area, Sabah, Malaysia, *Journal of Tropical Biology and Conservation 6*: 109-113.

Shannon, C. E. (2001). A mathematical theory of communication. *ACM SIGMOBILE Mobile Computing and Communications Review, 5*(1), 3-55.

Shen, D. (2002). Study on limiting factors of water eutrophication of the network of rivers in plain. *Journal of Zhejiang University(Agriculture and Life Sciences), 28*(1), 94-97.

Schueler, Thomas, Brown, Whitney (1997). National pollutant Removal Performance Database for Stormwater Best Management Practices, Center for Watershed Protection

Sládecek, V. (1973). *System of water quality from the biological point of view*: Schweizerbart'sche Verlagsbuchhandlung.

Staker, R. D., Hoshaw, R. W., & Everett, L. G. (1974). Phytoplankton distribution and water quality indices for lake mead (colorado river) 1. *Journal of Phycology, 10*(3), 323-331.

Stevenson, R. J. (1984). Epilithic and epipelic diatoms in the Sandusky River, with emphasis on species diversity and water pollution. *Hydrobiologia, 114*(3), 161-175.

Strickland, J., & Parsons, T. (1968). Bull. Fish. Res. Board Can. *A practical handbook of seawater analysis, 167*, 1-310.

Swaminathan, M. (2003). Bio-diversity: an effective safety net against environmental pollution. *Environmental pollution, 126*(3), 287-291.

Sze, P. (1998). *A biology of the algae*. Georgetown University, USA.

Tait, G. (1970). Coproporphyrinogenase activities in extracts of Rhodopseudomonas spheroides. *Biochemical Journal, 118*(2), 28P.

Tilman, D.; Kiesling, R.; Sterner, R.; Kilhan, S. S.; Johnson, F. A. (1986).Green, blue-green and diatom algae: taxonomic differences in competitive ability for phosphorus, silicon and nitrogen. *Archiv filr Hydrobiologie*, *106*: 473-485.

Trebitz, A.S., Brazner, J.C., Cotter, A.M., Knuth, M.L., Morrice, J.A., Peterson, G.S., Sierszen, M.E., Thompson, J.A., Kelly, J.R. (2007). Water quality in Great Lakes coastal wetlands: basin-wide patterns and responses to an anthropogenic disturbance gradient. *J. Great Lakes Res*. *33* (3): 67–85.

USEPA, A. (1994). plain English guide to the EPA Part 503 biosolids rule US EPA/832/r-93/003. *Environmental Protection Agency Office of Wastewater Management, Washington DC*.

USEPA, U. Environmental Protection Agency. 2003. *Final NPDES general permit for new existing sources and new discharges in the offshore subcategory of the oil and gas extraction category for the western portion of the outer continental shelf of the Gulf of Mexico*, 1-117.

Viswanathan, S., Voss, K. A., Pohlman, A., Gibson, D., & Purohit, J. (2009). Evaluation of the biocriteria of streams in the San Diego Hydrologic Region. *Journal of Environmental Engineering, 136*(6), 627-637.

Vythilingam, I., Oda, K., Mahadevan, S., Abdullah, G., Thim, C. S., Hong, C. C., . . . Igarashi, A. (1997). Abundance, parity, and Japanese encephalitis virus infection of mosquitoes (Diptera: Culicidae) in Sepang District, Malaysia. *Journal of medical entomology, 34*(3), 257-262.

Wallace, J. B., Grubaugh, J. W., & Whiles, M. R. (1996). Biotic indices and stream ecosystem processes: results from an experimental study. *Ecological applications*, 140-151.

Washington, H. (1984). Diversity, biotic and similarity indices: a review with special relevance to aquatic ecosystems. *Water research, 18*(6), 653-694.

Waziri, M., & Ogugbuaja, V. (2010). Interrelationships between physicochemical water pollution indicators: A case study of River Yobe-Nigeria. *Am. J. Sci. Ind. Res, 1*(1), 76-80.

Wehr, J. D., & Descy, J. P. (1998). Use of phytoplankton in large river management. *Journal of Phycology, 34*(5), 741-749.

Welch, I. (1992). Sequential sales, learning, and cascades. *Journal of Finance*, 695-732.

Wilhm, J. L. (1968). Use of biomass units in Shannon's formula. *Ecology*, 153-156.

Wilhm, J. L., & Dorris, T. C. (1968). Biological parameters for water quality criteria. *Bioscience*, 477-481.

Williams, L. G. (1964). Possible relationships between plankton-diatom species numbers and water-quality estimates. *Ecology*, 809-823.

Wu, H., Chen, P., & Tsay, T. (2010). Assessment of nematode community structure as a bioindicator in river monitoring. *Environmental pollution, 158*(5), 1741-1747.

Wurtsbaugh, W. A., & Horne, A. (1983). Iron in eutrophic Clear Lake, California: its importance for algal nitrogen fixation and growth. *Canadian Journal of Fisheries and Aquatic Sciences, 40*(9), 1419-1429.

Ya, N., Singh, H., Samat, A., Rashid, H. M., Ramli, N., Makhtar, N., & Dzakaria, N. (2014). Fish diversity in sepang besar estuary- a preliminary analysis. *International Journal of Advances in Agricultural & Environmental Engineering, 1*(2), 229-233.

Ya, N., Singh, H., Samat, A., Rashid, H. M., Ramli, N., Makhtar, N., & Dzakaria, N. (2015). Length-Weight relationship of six fish species from Sepang Besar River estuary, Malaysia. *Journal of Advanced Research in Applied Sciences and Engineering Technology, 1*(1), 27-35.

Yap, C. K., Noorhaidah, A., Azlan, A., Azwady, A. N., Ismail, A., Ismail, A., . . . Tan, S. (2009). Telescopium telescopium as potential biomonitors of Cu, Zn, and Pb for the tropical intertidal area. *Ecotoxicology and environmental safety, 72*(2), 496-506.

Yap, S.-Y. (1997). Classification of a Malaysian river using biological indices: a preliminary attempt. *Environmentalist, 17*(2), 79-86.

Yeng, C. (2006). *A study on limnology and phytoplankton biodiversity of Ahning Reservoir.* Dissertation, University Sains Malaysia, Penang.

Yunus, A. J. M., & Nakagoshi, N. (2004). Effects of seasonality on streamflow and water quality of the Pinang River in Penang Island, Malaysia. *Chinese Geographical Science, 14*(2), 153-161.

Yusop, Z., Nazahiyah, R., & Abustan, I. (2007). Stormwater quality and pollution loading from an urban residential catchment in Johor, Malaysia. *Water science and technology, 56*(7), 1-9.

Żbikowski, J., & Kobak, J. (2007). Factors influencing taxonomic composition and abundance of macrozoobenthos in extralittoral zone of shallow eutrophic lakes. *Hydrobiologia, 584*(1), 145-155.