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STUDY ON CURRENT STATUS OF WATER QUALITY AND HEAVY METALS AROUND TASIK CHINI

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Thesis submitted in fulfillment of the requirements
for the award of the
Bachelor Degree in Civil Engineering

Faculty of Civil Engineering and Earth Resources

UNIVERSITI MALAYSIA PAHANG

JUNE 2018

ACKNOWLEDGEMENTS

First of all, I would like to express my deepest gratitude to my research supervisor, Madam Nadiatul Adilah binti Ahmad Abdul Ghani for her valuable and constructive suggestions during the planning and development of this research work. Her willingness to give her time so generously has been very much appreciated. Besides, her patience and support helped me overcome many crisis situations and also helped me to coordinate my project especially in writing this report. I also sincerely thanks for the time spent for giving opinions, proofreading and correcting the writing in my thesis.

I am particularly grateful for the assistance given by the UMP staff in Environmental Laboratory for the permission to use all required equipment and related materials during completing my research experiments. A special thanks to laboratory assistants, Madam Norazimah binti Abdul Aziz (Environmental Laboratory), Mr. Qari bin Mohd Nor (Environmental Laboratory), Mr. Syed Najmuddin bin Mohammad Nordin (Hydraulic Laboratory), and Madam Kamariah binti Mat Peah (Hydraulic Laboratory) for the guidance on conducting the experiments on site and in laboratory.

Furthermore, I wish to acknowledge the help provided by my friends, Siti Noor Marhidayu binti Mohamad Sukri, Mohd Hafiz Shafiq bin Jilani and also for those involved indirectly to assist me during conducting experiments for this research. I'm sincerely thanks for the time that they spent in helping to complete the task with me.

Finally, I must express my very profound gratitude to my beloved family especially my mother, Siti Khalijah binti Abdullah for their patience, sacrifice and love in my life. I am grateful that my family show their patience and caring to me as I felt stress and confused in completing the research and thesis. They gave me the maximum love and guidance to me which supporting me to complete all the tasks in order to achieve my goals. I really appreciated and thanks them for understanding me and supporting all the time in completing my thesis.

ABSTRAK

Tujuan Kajan ini adalah untuk menganalisis kualiti air di Tasik Chini pada tahun 2017. Sebanyak empat belas parameter kualiti air dan lima logam berat telah diuji dengan berdasarkan Indeks Kualiti Air, Jabatan Alam Sekitar (DOE-WQI) dan dikelaskan mengikut Piawai Interim Kualiti Air Kebangsaan, Malaysia (INWQS). Antara parameter fizikal dan kimia seperti pH, Kekonduksian Elektrik (EC), kekeruhan, suhu, Jumlah Pepejal Terampai (TSS), Pepejal Terampai (SS), Permintaan Oksigen Biokimia (BOD), Permintaan Oksigen Kimia (COD), Oksigen Terlarut (DO), Nitrogen Ammonia (NH3-N), Nitrat (N), Kalium (K), Fosforus (P) dianalisa ketika di tempat asal sampel dan ujian makmal. Lima parameter untuk mengenalpsti kepekatan logam berat untuk dikenalpasti adalah Kadmium (Cd), Kuprum (Cu), Kromium (Cr), Nikel (Ni) dan Plumbum (Pb) telah diuji melalui alat Atomic Absorption Spectroscopy (AAS). Hasil kajian menurut Indeks Kualiti Air (WQI), air di dalam sungai-sungai yang terpilih sebagai lokasi kajian di Tasik Chini diklasifikasikan sebagai kelas III, iaitu air tersebut memerlukan rawatan yang meluas. Berdasarkan hasil kajian yang didapati, aktiviti pembalakan haram, perlombongan besi dan pertanian telah berlaku di sekitar tasik seterusnya memberi kesan kepada pencemaran air di Tasik Chini.

ABSTRACT

The purpose of this research is to analyse water quality at Tasik Chini in 2017. A total of fourteen water quality parameters and five heavy metals concentration were measured based on Malaysian Department of Environment Water Quality Index (DOE-WQI) and also classified according to the Interim National Water Quality Standard, Malaysia (INWQS). The physical and chemical variable such as pH, Electrical Conductivity (EC), Turbidity, Temperature, Dissolved Oxygen (DO), Total Suspended Solid (TSS), Suspended Solid (SS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH_3-N), Hardness, Nitrate (NO_3-) Potassium (K), Phosphorus (P) was analyse through in-situ and laboratory experiments. Five parameters of heavy metals concentration to be identified are Cadmium (Cd), Copper (Cu), Chromium (Cr), Nickel (Ni) and Lead (Pb) were tested by using Atomic Absorption Spectroscopy (AAS). Result shown based on Malaysian WQI, the water from most of the selected rivers in Tasik Chini is classified as Class III, where the water required extensive treatment. Based on result collected, illegal logging, iron mining and agriculture activities have taken place in surrounding of the lake consequently affected the pollution of water at Tasik Chini.

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
AN	Ammoniacal Nitrogen
APHA	American Public Health Association
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DOE	Department of Environment
EC	Electrical Conductivity
FE	Iron
HACH DR 5000	Spectrophotometer Procedures Manual
H_2SO_4	Sulphuric Acid
K	Potassium
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
Mg	Magnesium
Mg/L	Milligram per litre
Na	Sodium
NH3-N	Ammoniacal Nitrogen
NO^{-3}	Nitrate
NTU	Nephelometric Turbidity Units
NWQS	National Water Quality Standard
pH	Potential Hydrogen
$PO^{3}{}_{-4}$	Phosphate
SI	Sub-indices
TSS	Total Suspended Solid
$\mu s/cm$	Microsiemens per centimetre
WQI	Water Quality Index

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Water resources are sources of water that are potentially useful. Uses of water include agricultural, industrial, household, recreational and environmental activities. All living things require water to grow and reproduce. Malaysia is endowed with abundant water resources, however the demand for water has increased steadily in recent years. Slightly over two thirds of fresh water is frozen in glaciers and polar ice caps while the remaining is remain unfrozen found mainly as groundwater.

In Malaysia, main water resources is derived from the groundwater and surface water. This fresh water is renewable resources, yet it is limited resources and also world's groundwater is steadily although it is still unclear how much natural renewal balances this usage, and whether ecosystems are threatened. Malaysia is a developing country where the new development and construction is taking place in almost every place in this country. It is a good progress to realize the advancement for Malaysia become a better country however this rapid development has produced great amounts of human wastes, including domestic, industrial, commercial and transportation wastes which inevitably ends up in the water bodies. This effect has raised our concern on quality of our domestic water either it is still safe or was affected by pollutant. The other sources of water in Malaysia is lake. Lake is a large area of water surrounded by land and not connected to the sea except by rivers or streams. The quality of water in lake can be affected by human activities.

The quality of water is identified in terms of it physically, biological and chemical parameters. Water quality in lake is about the degradation of natural process of eutrophication. Social development will accelerate the eutrophication process. In this case, the study is conducted to determine the class of the water body at Jemberau River and Chini Downstream River due to the effect of erosion and sedimentation process around Tasik Chini to know either the water body is still clear or it has been affected by pollutant. Pollution can reduce the water quality as harmful organisms that live in the water, reducing the ecological value of the lake. These changes can alter perceived value of the water body and hence reduce recreational activity and nearby land values.

1.2 Problem Statement

Tasik Chini is facing with the issue of water quality pollution. In 2005, the iron mine that located nearly with Tasik Chini was re-activated because of the high demand for iron. According to M. B. Gazim et al. in 2012, there are logging, iron ore mining, and oil palm activities carry out by local residents at Melai Village upstream of the catchment. Previously, mining was carried out by an appointed mining company, but it was abandoned when the government terminated their contract. The presence of nutrients and heavy metal from mining activities has given negative impact to the environment especially water quality of Tasik Chini.

Mining activity will increase the heavy metal concentration such as iron (Fe), aluminium (Al), barium (Ba), and magnesium (Mg) in water body (Fernandez, 2012). The increasing of heavy metal concentration will be harmful to the aquatic life and affect the quality of water in lake. Unwell-operated mining activity will caused increasing of heavy metal concentrations in water body.

1.3 Research Objectives

i. To analyse the current status of water quality for Tasik Chini.
ii. To identify current heavy metal level in Tasik Chini.
iii. To evaluate the characteristics of each water quality parameters.

1.4 Scope of Study

This research is conducted on September 2017 until June 2018. Study area is at Tasik Chini. The scope of study on this research is based on mining activity near Tasik Chini. The selected river, Jemberau River and Chini Downstream River are currently facing problem due to the effect of erosion and sedimentation process caused by mining runoff near the river. This activity can contributes to the increment of heavy metal concentration in the river and then will affect the water quality at Tasik Chini. There are two types of test that were conducted which are in-situ test and laboratory test. There are 5 in situ tests have been conducted which are temperature, pH, electrical conductivity, dissolved oxygen (DO) and turbidity. For laboratory test, 10 test are conducted which are Biological Oxygen Demand (BOD5) test, Chemical Oxygen Demand (COD) test, Total Suspended Solid (TSS) test, Suspended Solid (SS) test, Ammoniacal Nitrogen test, Phosphorus test, Nitrate test, Potassium test, Hardness test and Heavy Metal test.

1.5 Significance of Study

From this study, water quality in Tasik Chini will be determined by following the classification from Water Quality Standards for Malaysia (NWQS) and Water Quality Index (WQI). The data and result will be useful for water quality for this research project. It is beneficial result to control the safeness of drinking water in future. Besides, by studying water quality, it increases an awareness among community in Tasik Chini on the cleanliness of their domestic water usage. This research will provide people in Tasik Chini an understanding to protect their health and ecosystems.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Water supply is considered as one of the important element for living things to grow and reproduce. Water and life are closely linked. Moreover, our bodies are made up about 70% of water. Water is essential for life and for most activities of human society. It is required for the maintenance of human health which is completely dependent upon ready access to adequate water supplies. All societies require water both for economic and basic social development. Improving water supply represent important opportunities to increase public health (Hunter, MacDonald, & Carter, 2010).

In this research, Tasik Chini is chosen as a study area to determine the quality of water in this lake. There are many activities near the lake such as logging, mining and agriculture can contribute to pollution of water quality at Tasik Chini. This activities will leave the local community with negative implication and also affecting the ecosystem of Tasik Chini, Long time ago, Tasik Chini is very famous with blossoming lotus but now the lake is overgrown with cattails.

Water is very important in our life therefore the water quality measurement cannot be ignored as it will indicate the safeness of water supply on that certain area for our usage. Water and economy are inextricably linked. A plentiful supply of water is clearly one of the most important factors in the country's overall development of modern societies. Good water resources management and availability of water for cleansing is directly related to the control or elimination of disease. The convenience of water available at home improves the quality of life (Ahiablame, Engel, & Venort, 2012).

2.2 Surface Water

Surface water is water above land surface. Hydrological aspect is the most important factor for maintaining the stability of the lake ecosystem (Gasim, Toriman, Rahman, Islam, & Choon Chek, 2009). Surface water body is potential to receive pollutant from many sources. The quality of surface water is varied by its content of living organisms and by the amounts of mineral and organic matter which it may collect when it flowing (Unless, Act, Rose, If, & Rose, 2013). Characteristics of surface water are change with time and space. Mineral pick up from surface runoff, silt and debris are carried by surface water, will increased the concentration of impurities in water, these, will caused, muddy or turbid streams. Stagnant water, or slow moving areas changing the aesthetic characteristics by plants and algae grow. Most of waste will discharged towards surface water.

2.3 Lake

Lake is a body of water which have a large size and localized in a basin and it is surrounded by land. The sources of water from river, stream, or other moving of water into the lake. Lake water is an essential renewable resource for mankind and the environment. For maintaining recreation and fisheries, good water quality in lakes is essential and it is needed for the drinking water supply.

Lakes and reservoirs differ from river and stream in several ways. Lakes are natural bodies of water which its flow weaker and no longer driven by gravity down the slope. It receives discharged organic matter large enough to cause serious oxygen depletion, lakes have significantly longer retention times than river (Roisin, 2014).

2.4 Tasik Chini

Tasik Chini is the study area for this research. Tasik Chini is a second largest natural lake which located at near Pahang River in Central Pahang, Malaysia (Times, News, & Color, 2016). This lake may categorize as the wetlands. Tasik Chini wetland acts as natural sponges to absorb floodwater and help to avoid flood damage. Tasik Chini is located in the east of Peninsular Malaysia in state of Pahang. This lake covers *12,565* acres and consists of various floura and fauna. The lake contains of 12 'seas' which recognized as 'Laut' by the local community there. The 12 'seas' are, Gumum, Pulau Balai, Cenahan, Tanjung Jerangking, Genting Teratai, Mempitih, Kenawar, Serodong, Melai, Batu Busuk, Labuh and Jemberau, Tasik Chini is drained by Chini River. The water from Pahang River will flow into Tasik Chini during the high monsoon season.

2.5 Pollution of Lake

Water pollution means contamination of water or has changed in physical, chemical or biological properties of water bodies. There are point sources pollution and non-point sources for pollutants in water. In addition pollution of lakes including the eutrophication process in lake influence by other factors. Lakes can be classified to 4 classes; oligotrophic lake, mesotrophic lake, eutrophic lake, and hypereutrophic lake. Oligotrophic lake can be described as high clarity, low algal concentrations. Mesotrophic lakes are intermediate between oligotrophic lake and eutrophic lake. Mesotrophic lakes are suitable for recreational activity. Eutrophic lakes have abundant supply of nutrients and have high concentration of algal. Lake at this class, will produce unpleasant tastes and odours because it have large mats of floating algae. Hypereutrophic lakes can be categorized as extremely eutrophic with much accumulated organic sediment besides having intense algal blooms and high algal productivity (Kevern, King, & Ring, 2008).

2.5.1 Point Source Pollution

Point sources pollution means any wastewater discharged directly towards water bodies for example, discharge pipes, where they can be easily measure. Point sources means any discernible, confined and discrete conveyance, well discrete fissure, container rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may discharged. Point sources of pollution are the major causes of degradation of ecosystems, and can have significant effects on human health if they are not properly controlled.

2.5.2 Non-point Source Pollution

Non-point sources pollution, hard to identify, measure and control than point sources pollution. Non-point sources pollution also known as diffuse source pollution, which come from human activities for which pollutants have no obvious point of entry receiving watercourses. Other than that, it is irrespective sources which is transported through the surface runoff by rainwater or melting snow, or through the ground as groundwater, picks up pollutants, and eventually discharges to a body of water. The impact of these pollutants range from simple nuisance substances to severe ecological impacts involve of fish, birds, mammals, and on human health.

2.5.3 Agricultural Run-off

Agricultural run-off is categorized as the non-point source pollution. These pollutants are transported through soil by rainwater and snow. Agricultural run-off consists of nitrogen and phosphorus. Run-off of nutrients especially phosphorus will lead to eutrophication and change taste and odour of the water. Aquatic life will kill in the lake because of deoxygenation of water. In addition run-off of pesticides leads to contamination of lake (V & S, 2013). Other than that, it will cause ecological system dysfunctional by the loss of top predators due to growth inhibition and failure of reproduction. Ploughing tillage will cause turbidity and sediments. These sediments contain of phosphorus and pesticides adsorbed to sediment particles. These factors make siltation at river beds and the aquatic life loss their habitat.

2.5.4 Pollution of Tasik Chini

Recently, Tasik Chini had covered by an aquatic weed call 'cat tail' or Cabomba Furcata. In many years, the lake surface is covered by the famous lotus flower which is Nelumba Nucifera. Tasik Chini condition was worsened by the plantation of the palm oil near the Tasik Chini (HABIBAH, HAMZAH, & MUSHRIFAH, 2010). The development of agricultural near Tasik Chini, caused some pollution to the lake. Agriculture activities, release nitrate and phosphate in the lake due to the used of fertilizers on the palm oil plantation. The replacement of primary forest to oil plantation and rubber plantation caused changes in hydrology, also, phenomenon of eutrophication, sedimentation and pollution.

2.6 Water Quality

There are several parameters on water quality measurement which are physical, chemical and biological parameters. Water quality parameters for lake, are measured according to Malaysia Department of Environment Water Quality Index (DOE-WQI) also, will classified by using National Water Quality Standard, Malaysia (NWQS).

Table 2.1 Excerpt of the National Water Quality Standards

Parameters	Unit	Classes					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.3	0.9	2.7	> 2.7
BOD_5	mg/l	1	3	3	6	12	> 12
COD	mg/l	10	25	25	50	100	> 100
DO	mg/l	7	5 - 7	5 - 7	3 - 5	< 3	< 1
pH		6.5 - 8.5	6.5 - 9.0	6.5 - 9.0	5 - 9	5 - 9	-
Color	TUC	15	150	150	-	-	
Elec. Conductivity	µS/cm	1000	1000	-	-	6000	-
Floatables		NV	NV	NV	-	-	-
Salinity	%	0.5	1	-	-	2	-
Taste		NOT	NOT	NOT	-	-	-
Total Suspended Solids	mg/l	25	50	50	150	300	300
Temperature	°C	-	Normal + 2°C	-	Normal + 2°C	-	-
Turbidity	NTU	5	50	50	-	-	-
Fecal Coliform	counts/100ml	10	100	400	5000 (20000)[a]	5000 (20000)[a]	-
Total Coliform	counts/ 100 ml	100	5000	5000	50000	50000	>50000

Note :
NV = No visible floatable materials/debris NOT = No objectionable taste

Source: (2006) Department of Environment

Table 2.2 DOE Water Quality Index Classification

Parameters	Unit	Classes				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	<0.1	0.1 – 0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
Biochemical Oxygen Demand (BOD_5)	mg/l	< 1	1 – 3	3 – 6	6 – 12	> 12
Chemical Oxygen Demand (COD)	mg/l	< 10	10 – 25	25 – 50	50 – 100	> 100
Dissolved Oxygen	mg/l	> 7	5 – 7	3 – 5	1 – 3	< 1
pH	mg/l	> 7	6 – 7	5 – 6	< 5	> 5
Total Suspended Solids (TSS)	mg/l	< 25	25 – 50	50 – 150	150 – 300	> 300
Water Quality Index (WQI)	mg/l	> 92.7	76.5 – 92.7	51.9 – 76.5	31.0 – 51.9	< 31.0

Source: (2006) Department of Environment

Table 2.3 NWQS Class Definitions

Class	Definition
I	• Conservation of natural environment. • Water supply I - Practically no treatment necessary (except by disinfection or boiling only). • Fishery I - Very sensitive aquatic species.
IIA	• Water supply II - Conventional treatment required. • Fishery II - Sensitive aquatic species.
IIB	• Recreational use with body contact.
III	• Water supply III - Extensive treatment required. • Fishery III - Common of economic value, and tolerant species; livestock drinking.
IV	Irrigation.
V	None of the above.

Source: (2006) Department of Environment

Table 2.4 Water Quality Formula

Subindex for DO (in % saturation): SIDO

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

Subindex for BOD : SIBOD

$SIBOD = 100.4 - 4.23x$ for $x \leq 5$
$= 108e^{-0.055x} - 0.1$ for $x > 5$

Subindex for COD : SICOD

$SICOD = -1.33x + 99.1$ for $x \leq 20$
$= 103e^{-0.0157x} - 0.04x$ for $x > 20$

Subindex for AN : SIAN

$SIAN = 100.5 - 105x$ for $x \leq 0.3$
$= 94e^{-0.573x} - 5|x - 2|$ for $0.3 < x < 4$

Subindex for SS : SISS

$SISS = 97.5e^{-0.00676x} = 0.05x$ for $x \leq 100$
$= 71e^{-0.0016x} - 0.015x$ for $100 < x < 1000$
$= 0$ for $x \geq 1000$

Subindex for pH : SIPH

$SIPH = 17.2 - 17.2x + 5.02x^2$ for $x < 5.5$
$= -242 + 95.5x - 6.67x^2$ for $5.5 \leq x < 7$
$= -181 + 82.4x - 6.05x^2$ for $7 \leq x < 8.75$
$= 536 - 77.0x + 2.76x^2$ for $x \geq 8.75$

Note :
x = concentration in mg/l for all parameters except pH

Source: (2006) Dr Zaki Zainuddin

$$WQI = 0.22*SIDO + 0.19*SIBOD + 0.16*SICOD + 0.15*SIAN + 0.16*SISS + 0.12*SIPH \quad \text{Equation 2.1}$$

2.6.1 Physical Parameter

Physical parameter may define as characteristics of water which respond to the senses of sight, touch, taste or smell. Physical parameter may affect the quality of aquatic life that related to flow conditions, substrate characteristics and thermal pollution (Lazo, Bekteshi, Xhuvani, Kane, & Qarri, 2015).

2.6.1.1 Temperature

Temperature is physical water quality parameter. Temperature is one of the most important parameters in natural surface water system. It becomes an important indicator for identifying healthy or poor water conditions. Most of the chemical reactions that occur in natural system is effect by temperature. The temperature at Tasik Chini during wet and dry season was normal according to the climates. Other than that, temperature did not show a big difference for both seasons.

2.6.1.2 Turbidity

Turbidity is a test for water clarity where it is usually disturbed by the suspended solid and plankton that are suspended in water column. Low levels of turbidity may indicate a healthy, well-functioning ecosystem, with balance of food chain in an ecosystem. However, high levels of turbidity, gives problem towards the ecosystem. The turbidity may block the light needed by submerged aquatic plant. In addition, turbidity may raise the temperature of water bodies above normal condition because of the suspended particles have absorbs the heat from sunlight. As a result, turbidity may affect the dissolved oxygen in water.

According to the study by Bazani Gasim et al., 2007, the mean turbidity at Tasik Chini was 16.41 NTU. Turbidity in wet season is higher than in dry season. Water is acceptable for domestic use when the turbidity is within *5-25* NTU. This is according to National Water Quality Standard (NWQS) for Malaysia. However, Ministry of Health has set the threshold level of turbidity for raw water is 1000 NTU.

2.6.1.3 Total Suspended Solid (TSS)

Total suspended solid or TSS is to test the suitability of water for public, industrial and agricultural uses, and TSS is physical characteristics of water. Suspended solid is important indicator of water quality. Increase of total suspended solid directly reduced dissolved oxygen content in water, hence reducing the ability of a water body to support life. Study shows that, TSS values were higher during wet and dry season in Tasik Chini. The maximum threshold levels for Malaysian rivers according to National Water Quality Standard (NWQS) between 25 to 50 mg.

2.6.2 Chemical Parameter

Chemical parameter may refer as the capability of solvent in water. Chemical parameters include, total dissolved solid, alkalinity, hardness, fluorides, metals, organics, and nutrients. Chemical parameter is related to chemical compounds or combinations of compounds which considered toxicity to human and aquatic life, or have potential to occur in water environment at harmful levels.

2.6.2.1 pH

The pH of water is defined as the negative log of the hydrogen-ion activity. pH is one of the most important chemical factor for aquatic life. If the surface water is too acidic or too alkaline will disrupts the aquatic life cycle. pH scale is from 1 to 14. A solution with pH less than 7 has more H+ activity it is considered as acidic. Meanwhile, pH more than 7 has more OH- and considered as alkaline. pH values were higher during wet season than dry season. For Malaysia Rivers, the threshold level by National Water Quality Standard (NWQS) is 5.00-9.00.

2.6.2.2 Electrical Conductivity (EC)

Electrical conductivity is the ability of the solution to conduct electrical current (Moore, Richards, & Story, 2008). The ion in water is transport the electrical current. Increasing of the conductivity is caused by increasing of the ions concentration. Other than that, EC is an alternative way to measure the presence of inorganic dissolved solid such as, chloride, nitrate, sulphate, phosphate, sodium, calcium, magnesium and iron. These substances will increase the conductivity of a water body. Inorganic dissolved solid are important to aquatic life, however, the excessive of these content will harm the aquatic life also decrease the DO level in water body.

2.6.2.3 Dissolved Oxygen (DO)

Dissolved oxygen (DO) is the amount of molecular oxygen dissolved in water and one of the most parameter which affects the health of aquatic ecosystem. According to the study by Mir Sujaul Islam et al., 2012, the DO values were low during rainy season which is from September to December 2006. The main factors that influent the value of DO were photosynthetic activities, seasonal variables and the decomposition of organic matter.

2.6.2.4 Biochemical Oxygen Demand (BOD)

BOD is the amounts of oxygen require to biochemically oxidize by organic matter in presence of water. The BOD readings, tells about how much the oxygen being consumed. BOD levels during dry season were higher compared to wet season. This is due to the large volume of fresh water which diluted the organic matter in surface water which caused the BOD values decreased during the dry season. Most organic matter is biodegradable. The BOD values are usually measures of the oxygen required for carbonaceous (Ajayi AA et al., 2016). The National Water Quality Standards has set the threshold level for Malaysia surface water is 6 mg/L.

2.6.2.5 Chemical Oxygen Demand (COD)

COD is the amount of oxygen consumed when the substance in water is oxidized by a strong chemical oxidant (Alam, 2015). The National Water Quality Standard (NWQS) has set the threshold level of COD for surface water in Malaysia is 50.00 mg/L. According to previous study by Mir Sujaul Islam et al., 2012, COD level at Tasik Chini was suitable for the support aquatic life as well as for other purpose. The value of COD will increase as the pollution load increased.

2.6.2.6 Nitrogen as Ammoniacal Nitrogen

Presence of ammoniacal nitrogen in surface water may give harm towards the aquatic life and to human life indeed. Because, the ammonia (NH) contains highly toxic nature and normally ammonia is discharged from industrial waste, municipal and agricultural waste water in large volume. Based on the previous study, by Mir Sujaul et al., 2012, the highest concentration of NH3-N was during wet season which was 0.58 mg/L and the lowest value was 0.110 mg/L during dry season. On wet season, the Pahang River water backflow to Tasik Chini which caused more NH3-N thus stimulating water quality changes in lakes. The maximum threshold level according to National Water Quality Standard (NWQS) for Malaysia surface water is 0.90 mg/L in order to support aquatic life.

2.6.2.7 Heavy Metals

Heavy metals are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. Heavy metal poisoning could result, for instance, from drinking-water contamination.

Heavy metal pollution is caused when such metals are leached out and carried downstream as water washes over the rock surface. Although metals can become mobile in neutral pH conditions, leaching is particularly accelerated in the low pH conditions such as are created by Acid Mine Drainage. The most water pollution is from mining activities. To release heavy metals from ores, they used an acid mine because metals are very soluble in an acid solution. The heavy metal from iron ore operation will affect the environment and aquatic life in lake.

High levels of aluminium (Al) in dialysis fluid could cause a form of dementia in dialysis patients, a number of studies were carried out to determine if aluminium could cause dementia or cognitive impairment as a consequence of environmental exposure over long periods. Aluminium was identified, along with other elements, in the amyloid plaques that are one of the diagnostic lesions in the brain for Alzheimer disease, a common form of senile and pre-senile dementia (Fawell, 2010).

Cadmium (Cd) can be considered one of the most toxic heavy metals, it is found widely in nature and present in air, all soils and aquatic systems. Exposure to the cadmium may cause various health effects such as bronchitis, osteomalacia (soft bones) and kidney damage (Cobbina, Duwiejuah, Quansah, Obiri, & Bakobie, 2015).

Meanwhile, copper (Cu) at very high levels is toxic and can cause vomiting, diarrhea, loss of strength or, for serious exposure, cirrhosis of the liver. Water turns blue-green in colour as the corroded copper comes off the inside of the pipes and appears in the water as a precipitate. This reaction only occurs in a small percentage of cases.

Iron (Fe) is a heavy metal of concern, particularly because ingesting dietary iron supplements may acutely poison young children. Ingestion accounts for most of the toxic effects of iron because iron is absorbed rapidly in the gastrointestinal tract. The corrosive nature of iron seems to further increase the absorption. It can cause a rusty red or brown stain on fixtures or laundry and/or cause your water to develop a metallic taste. Target organs are the liver, cardiovascular system, and kidneys.

Manganese (Mn) is an essential element for many living organisms, including humans. However, the syndrome known as “manganism” is caused by exposure to very high levels of manganese dusts or fumes and is characterized by a “Parkinson-like syndrome”, including weakness, anorexia, muscle pain, apathy, slow speech, monotonous tone of voice, emotionless “masklike” facial expression and slow, clumsy movement of the limbs. In general, these effects are irreversible (Who, 2011).

The general population is exposed to lead (Pb) from air and food. The symptoms of acute lead poisoning are headache, irritability, abdominal pain and various symptoms related to the nervous system. Lead encephalopathy is characterized by sleeplessness and restlessness. Children may be affected by behavioural disturbances, learning and concentration difficulties. Although children are at increased risk of the effects of lead poisoning, exposure via drinking contaminated water can also result in illness in adults.

CHAPTER 3

STUDY AREA AND METHODOLOGY

3.1 Introduction

Tasik Chini is one of the two natural lakes in Peninsular Malaysia, which is located in the state of Pahang about 100 km from Kuantan, the capital of the state of Pahang. During normal season the acreage of this lake is about 202 hectares. Many visitors are attracted to this lake, not only for the tranquil and pristine environment but also the mythology of the indigenous people. The lakeshores are inhabited by the Jakun, an ethnic subgroup of the indigenous people or Orang Asli who have been lived here for generations. A barrage was constructed across Sungai Chini downstream where it meets Sungai Pahang, with the aim of maintaining the depth of the lake depth during the dry season, for ease in boating activities for tourism. However, this has disrupted the natural ecology of the lake and caused the death of trees on its shores due to elevated water level. The lake is also famous for its lotus blossoms from June to September.

In recent year state government developed areas around Tasik Chini into large plantation forest. The virgin forest surrounding this lake has been changed into oil palm and rubber plantation, with basic infrastructures for the community such as schools, housing, police station and others amenities. A lakeside resort was built to encourage tourism to the lake and the lake area. Since 2003, the Malaysian National Service camp was set up, located near this lake. The location of this camp is near to this lake which consequently adds some physical impact towards the water quality of this lake (Hamzah & Hattasrul, 2008).

3.2 Map Location

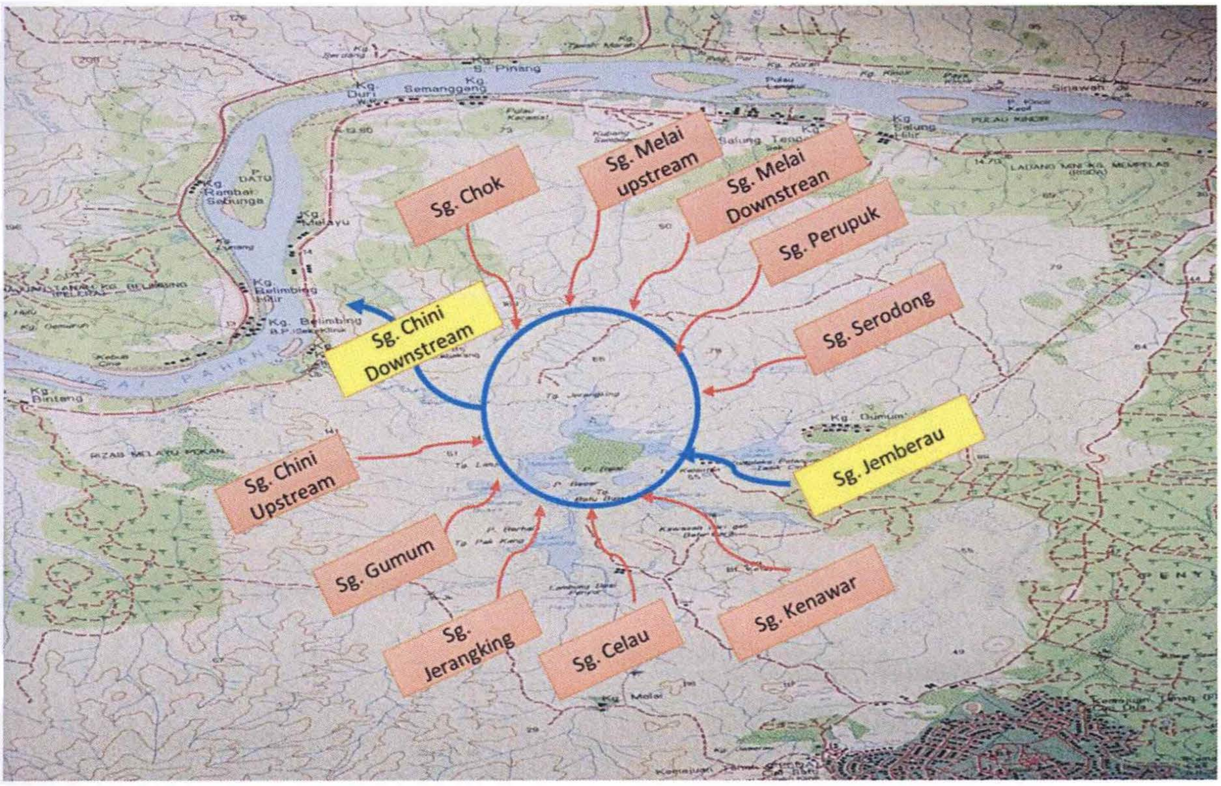


Figure 3.1 Maps of Tasik Chini, Pekan Pahang

Figure 3.1 shows the location of the study area at Tasik Chini, Pekan Pahang, East Coast, Malaysia.

3.3 Sampling Area

There are 6 stations in total to be selected within the Tasik Chini area to collect the sample which are:

i. Station 1 at Sg. Jemberau 1
ii. Station 2 at Sg. Jemberau 2
iii. Station 3 at Sg. Jemberau (taken at lake)
iv. Station 4 at Sg. Chini
v. Station 5 at Sg. Jerangking
vi. Station 6 at Sg. Gumum

3.3.1 Sungai Jemberau

Figure 3.2 Sungai Jemberau, Tasik Chini

Figure 3.2 show the view of Sg. Jemberau. The coordinate for this station is 03°25.166'' North and 102°55.859'' East.

3.3.2 Sungai Chini

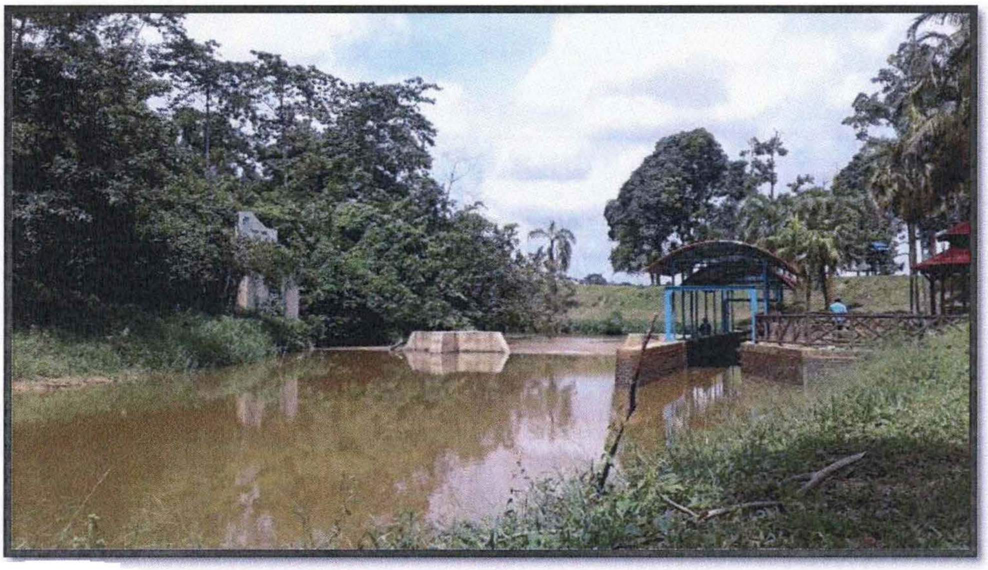


Figure 3.3 Sungai Chini, Tasik Chini

Figure 3.3 show the view of Sungai Chini at downstream. The coordinate for this station is 03°25.167''North and 102°55.860'' East in Kuantan, Pahang.

3.4 Methodology Flow Chart

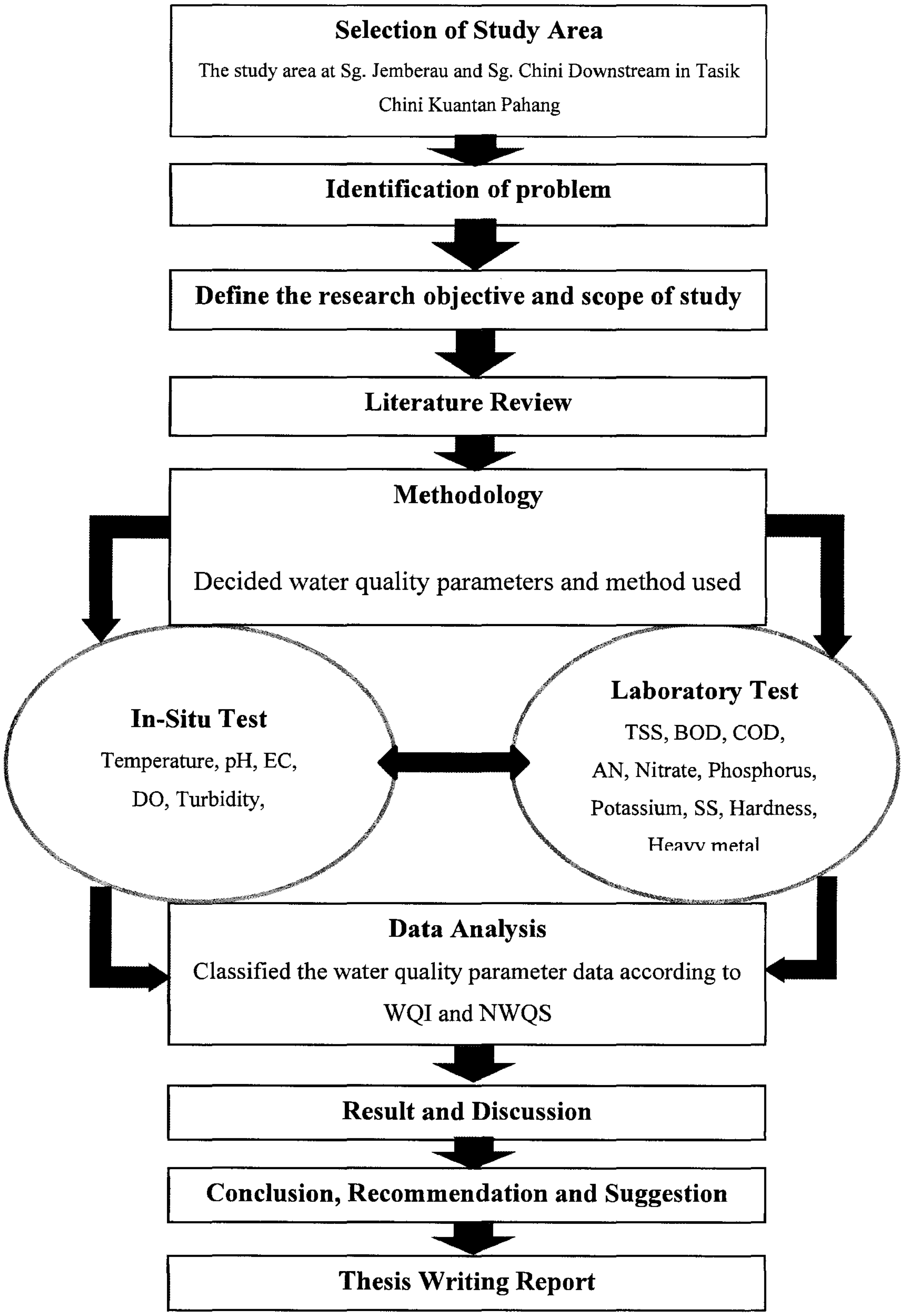


Chart 3.1: Flow of methodology

Chart 3.1 show the flow of methodology that will conduct during research. Two station which are Jemberau River and Chini Down Stream River. The water sample taken twice during wet season. The water sample for wet season was taken on November. At a station, two bottles water sample was collected at 10 cm below the surface area. There are two types of test that were conducted, in-situ test and laboratory test. For in-situ test, five parameters were measure which are temperature, pH, turbidity, electrical conductivity (EC), and Dissolved Oxygen (DO). For laboratory test, 10 test being conducted are Biological Oxygen Demand (BOD) test, Chemical Oxygen Demand (COD) test, Total Suspended Solid (TSS) test, Suspended Solid (SS), Nitrate test, Ammoniacal Nitrogen test, Phosphorus test, Potassium test, Hardness test and Heavy Metal test. After all the parameter were tested, the data will be analysed and classified based on WQI and NWQS. From the result and discussion, the water quality at Tasik Chini will be determined.

3.5 Research Method

3.5.1 Sampling Station

Six stations are selected at the rivers around Tasik Chini for this research. The location of water sample taken is identified by using Global Positioning System (GPS).

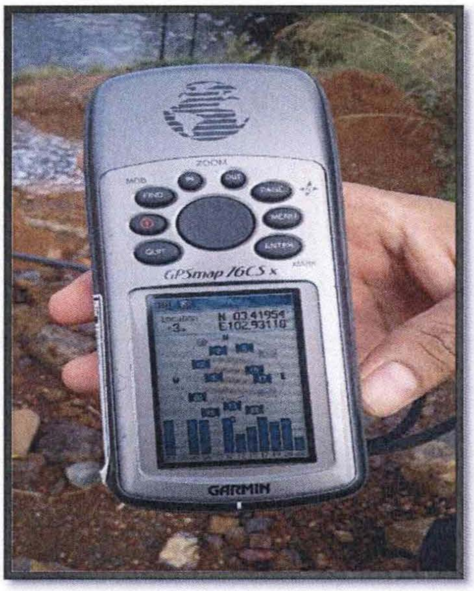


Figure 3.4 Determining position of sampling station

3.5.2 Preparation for Collecting Sample

1L HDPE bottles are cleaned before collecting the samples. Checking the functionality and accuracy of apparatus before going to the station.

Figure 3.5 1L HDPE bottles sampler is prepared

3.5.3 Sample Preservation

Water sample collected at 10cm below the surface water using HDPE bottle. The sample need to be stored in ice box at temperature 4°C and transported to laboratory for analysis. The water sample preservation technique was different based on the test that will be conducted. The preservation technique shows in table below:

Table 3.1 Preservation Techniques

Parameter	Container	Preservation	Maximum Holding Time
Inorganic Tests			
Ammoniacal Nitrogen	P,G	Cool, 4°C $H^2 SO^4$ to pH <2	28 days
Biochemical oxygen demand		Cool, 4°C	48 hours
Chemical oxygen demand	P,G	Cool, 4°C $H^2 SO^4$ to pH <2	28 days
Hardness	P,G	HNO_3 to pH <2	6 months
Nitrate	P,G	Cool, 4°C	48 hours
Phosphate	G	Cool, 4°C	48 hours
Residue, non- filterable (TSS)	P,G	Cool, 4°C	28 days
Adopted from Environmental Protection Agency Guidelines for handling and preserving samples, P=plastic, G= glass			

3.6 In-situ Test

In- situ test was conducted to determine five parameter which are pH, electrical conductivity (EC), dissolved oxygen (DO), temperature, and turbidity.

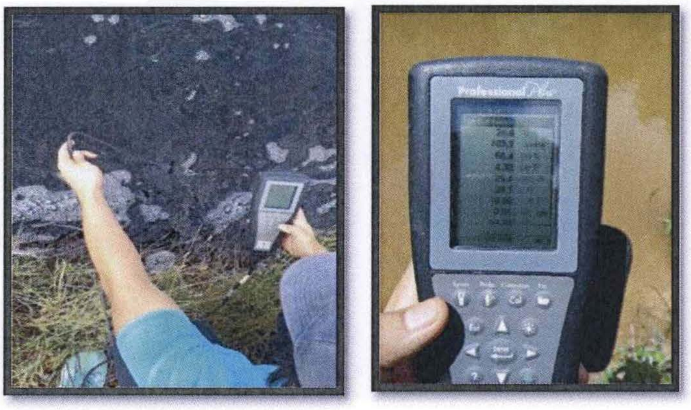


Figure 3.6 In-situ Parameters Measurement

3.7 Laboratory Test

Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) test, Total Suspended Solid (TSS) test, Suspended Solid (SS) test, Phosphorus test, Potassium test, Nitrate test, Ammoniacal Nitrogen test, Hardness test and heavy metal test were conduct at Environmental Laboratory.

3.8 Procedure for Laboratory Test

3.8.1 Physical Parameter

Physical parameter is the physical characteristics of the water such as temperature, turbidity and clarity, colour, salinity, suspended solids, total suspended solids and dissolved solids.

3.8.1.1 Turbidity

The turbidity of river was measured by multipurpose parameter water quality equipment. The sensor of the multipurpose parameter water quality equipment was dropped into the river and the value of turbidity will be recorded.

Figure 3.7 Recording of Turbidity Value

3.8.1.2 Temperature

The temperature of river was measured by multipurpose parameter water quality equipment. The sensor of the multipurpose parameter water quality equipment was dropped into the river and the value of temperature will be recorded.

3.8.1.3 Total Suspended Solid (TSS)

The Total Suspended Solid (TSS) procedure were traceable to APHA 2540 D standard (21st Edition), Standard Method for the Examination of Water and Wastewater. The filter disc was inserted onto the base and clamped on the funnel. While vacuum was applied, the disc was washed with three (3) successive 20 mL distilled water. All traces of water was removed by continuing to apply vacuum after water passed through. The aluminium was dried onto the oven at 103°C to 105°C for one hour. Then the dish was put into desiccator about 30 minutes and then weighted. After that, a sample volume (max of 200 mL) was selected and yield not more than 200mg of total suspended solids. The filter was placed on the base and clamped on funnel while vacuum was applied. The filter was wet with small volume of distilled water to seal the filter against base. Then the sample was shake vigorously and 100 mL of sample was quantitatively transferred to the filter. All traces of water was removed by continuing to apply vacuum after sample passed through. The pipette and funnel was rinsed onto the filter with small volume of distilled water. Finally, the disc filter was carefully removed from the base then the filter was dried for at least one hour at 103°C to 105°C. After that, it is was cooled in desiccators and weighted. The same procedure were repeated for sample at the other stations and result was recorded.

Total Suspended Solid:

$$\text{TSS (mg/l)} = \frac{(A - B) \times 10^6}{S} \qquad \text{Equation 3.1}$$

Where;

A = weight of dried residue + dish, mg

B = weight of dish, mg and

S = sample volume, 100ml

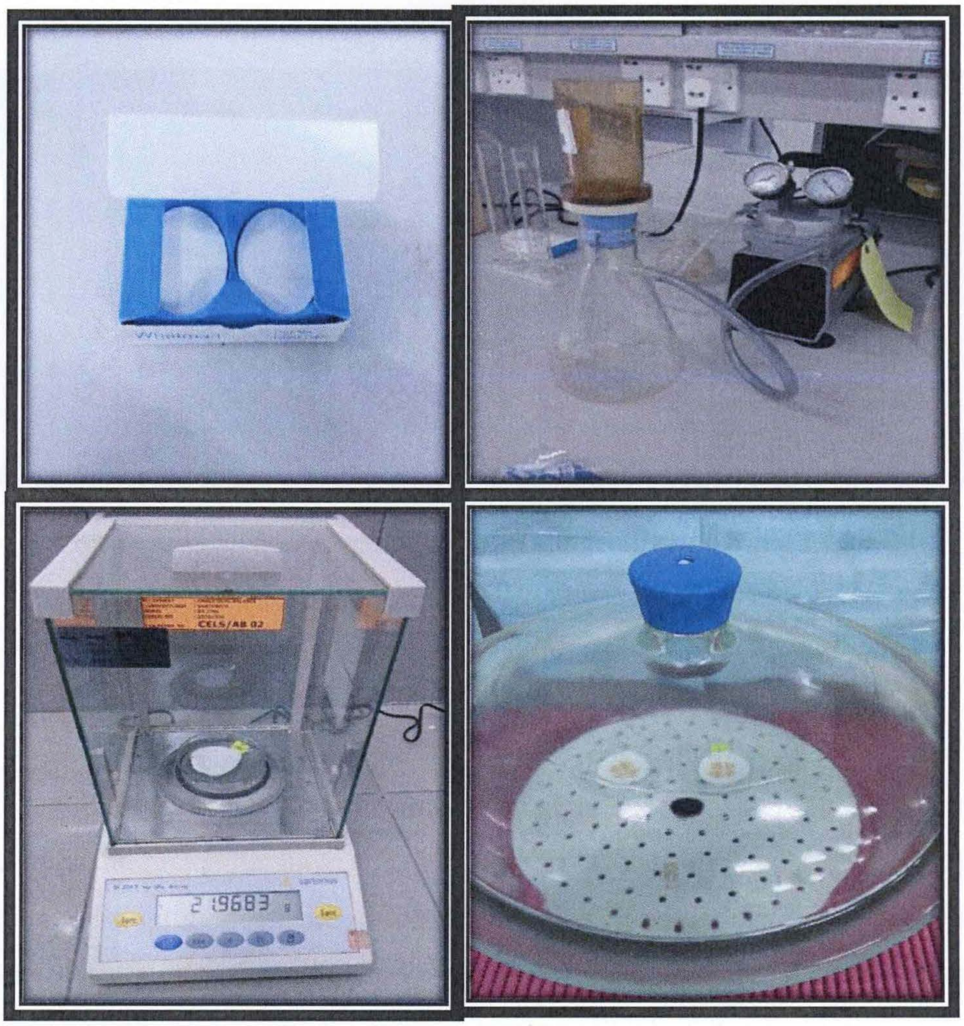


Figure 3.8 Measurement of Total Suspended Solids

3.8.1.4 Suspended Solid (SS)

The Suspended Solid was followed Photometric Method1 (5 to 750 mg/L) based on HACH DR5000 Method 8006. Select and start the 630 Suspended Solid program on the spectrophotometer. Press button Start to start the test. The sample 500 ml was blend using a blender at high speed for exactly two minutes. Blender sample was pour into a 600 ml beaker. The sample was stir and immediately pour 25 ml of the blended sample into a sample cell (the prepared sample). Next for the second cell with 25 ml of tap water will fill or deionized water (the blank). The gas bubbles in the water was removed by swirling or tapping the bottom of the cell on a table. After that, the blank was placed into the cell holder and then touch zero. The display will show 0 mg/l Suspended Solid. Swirl the prepared sample to remove any gas bubble and uniformly suspend any residue. The reading at spectrophotometer was recorded.

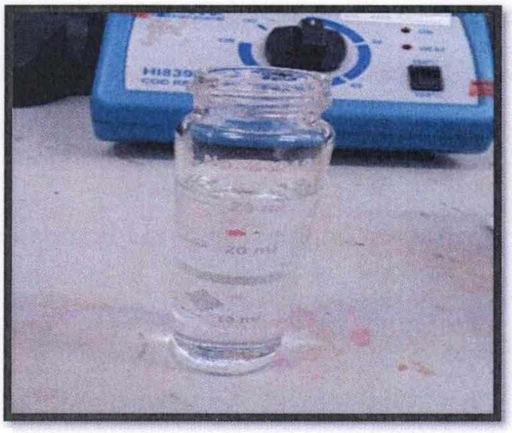
 

Figure 3.9 Measurement of Suspended Solids using DR5000

3.8.2 Chemical Parameter

Chemical parameter is the chemical characteristics of water which in contact with the soils and rocks that have absorb the chemical particles and minerals which come from agriculture, industries, disposal and urban runoff transfer into the water by erosion and weathering of geological formation. There are six forms of analysis to the water quality which Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen, Nitrate, Potassium, and Phosphorus.

3.8.2.1 Biochemical Oxygen Demand (BOD)

The Biochemical Oxygen Demand (BOD) was followed by the standard of In House method based on APHA 5210B (21^{st} Edition), Standard Method for the Examination of Water and Wastewater. The pH of water samples for all station was checked before testing unless previous experience indicates that pH is within acceptable range. If samples containing caustic alkalinity or acidity, neutralize the sample to pH around 6.5 to 7.5 using 1N sodium hydroxide (NaOH) or sulfuric acid (H_2SO_4). The sample were measured 100ml each and 400ml of dilution was poured into clean beaker each and pour into BOD bottle. After that, the initial DO was determined immediately after the BOD bottle were filled by the diluted samples. If a rapid initial DO uptake is significant, the time period between preparing dilution and measuring initial DO is not critical but should not exceed 30 min. The BOD bottles which contain sample and dilution water of all stations were incubated in refrigerator with 20°C. BOD bottle containing sample and dilution water. The sample were remove from incubator after day 5 incubation and left to reach room temperature. The DO in the sample dilutions were determined by DO meter and result was recorded.

Biochemical Oxygen Demand (BOD)

$$BOD_t = (DO_i - DO_5 / (P) \quad \text{Equation 3.2}$$

Where:

DO_i = DO of diluted sample about 15 min. after preparation, mg/L
DO_5 = DO of diluted sample after 5 days incubation at 20°C, mg/L
P = decimal volumetric fraction of sample used.

$$P = \frac{\forall_S}{\forall_S + \forall_{DW}} \quad \text{(Dilution factor)} \quad \text{Equation 3.3}$$

$$BOD_t = L_O (1 - 10^{-KT})) \quad \text{Equation 3.4}$$

Where

BOD_t = biochemical oxygen demand at time mg/L
L_O = ultimate BOD , mg/L
T = time , days
K = reaction rate constant , day^{-1}

Reaction rate constant:

$$K_T = K_{20} \times \theta^{T-20} \quad \text{Equation 3.5}$$

Where

K_T	= reaction rate constant at temperature T ,per day
K_{20}	= reaction rate constant at 20˚C , per day
θ	= temperature coefficient , 1.047
T	= temperature of biological reaction , ˚C

Ultimate BOD (L_0)

$$ {}_{T}L_0 = {}_{20}L_0\,[1+0.02(T-20)] \qquad \text{Equation 3.6} $$

Where

${}_{T}L_0$	= ultimate BOD at temperature T, mg/L
${}_{20}L_0$	= ultimate BOD at 20˚C, mg/L

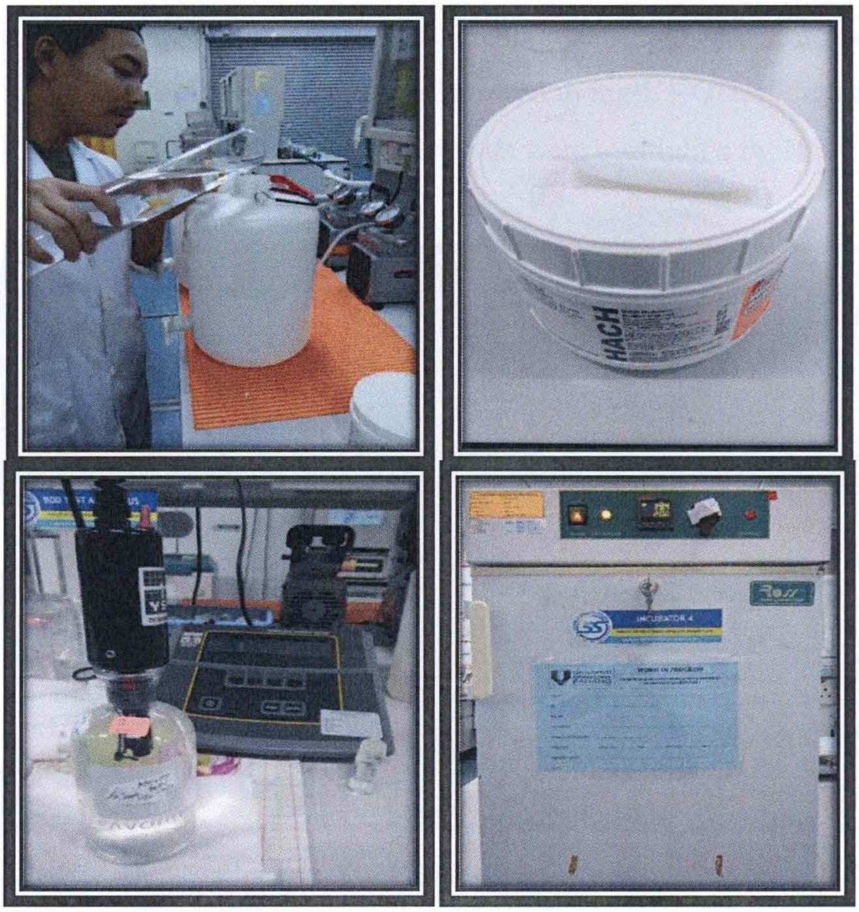


Figure 3.10 BOD Experiment

3.8.2.2 Chemical Oxygen Demand (COD)

The Chemical Oxygen Demand (COD) was followed by the standard of In House method based on HACH DR 5000 Method 8000. The COD Reactor was turned on and preheating to 150 ° C. The COD Reactor was seen for selecting pre-programmed temperature applications. One vial was held at 45 –degree angle. A clean volumetric pipet was used to add 2.00 mL of sample to the vial. A micro pipet was used to add 0.20mL for the 200-15,000 mg/ L Low range for samples from station 1, and 2. After that, the vials caped tightly. Then, the vials rinsed with water and wiped with clean paper towel. The vials were held by the cap over a sink. The vials then were inverted gently for several times to mix. The vials were inserted in the preheated COD reactor for two hour. The vials were placed into a rack and cool to room temperature for 20 minutes. For the colorimetric determination method, select low range test was made based on the sample. The outside of the vials was cleaned with a damp towel followed by a dry one. The blank was inserted into 16-mm cell holder. The "Zero" button was pressed and displayed show 0.0 mg/L COD. Finally, the sample vial was inserted into the 16-mm cell holder and the results were displayed in mg/L COD. If high range plus COD digestion reagent vials were used, the results were multiplied by 10.

Figure 3.11 COD Experiment

3.8.2.3 Nitrate

The Nitrate was followed Cadmium Reduction Method LR (0.01 to 0.50 mg/L NO3-N) based on HACH DR5000 Method 8155. Select and start the 351 N, Nitrate LR program on the spectrophotometer. And then touch start button to start the timer. Then 25 ml graduated mixing cylinder was filled with 15 ml of sample. The contents of one NitraVer 6 Reagent Powder Pillow was added to the cylinder and used stopper to close it. The timer icon was touch and OK. After that the cylinder vigorously was shake for three minutes. When the timer beeps, touch the timer icon again and touch OK. 2 minutes reaction period will begin. When the timer beeps, carefully pour 10 ml on the sample into a clean, round sample cell. Do not transfer any cadmium particles to the samples cell. The contents of one NitriVer 3 Nitrite Reagent Powder Pillow was added to the sample cell and cap the sample cell. Touch the timer icon and Touch OK. Shake the sample cell gently for 30 seconds and then a pink colour will develop if nitrate is present. Touch the timer icon and 15 minute reaction period will begin. When the timer beeps, a second sample cell with 10 ml will fill of original sample (this is the blank).Cap the sample cell. The blank was placed into the cell holder. Touch Zero. The display will Show 0.00 mg/L NO_3-N. The prepared sample was placed into the cell holder. The result will appear in mg/L NO_3-N.

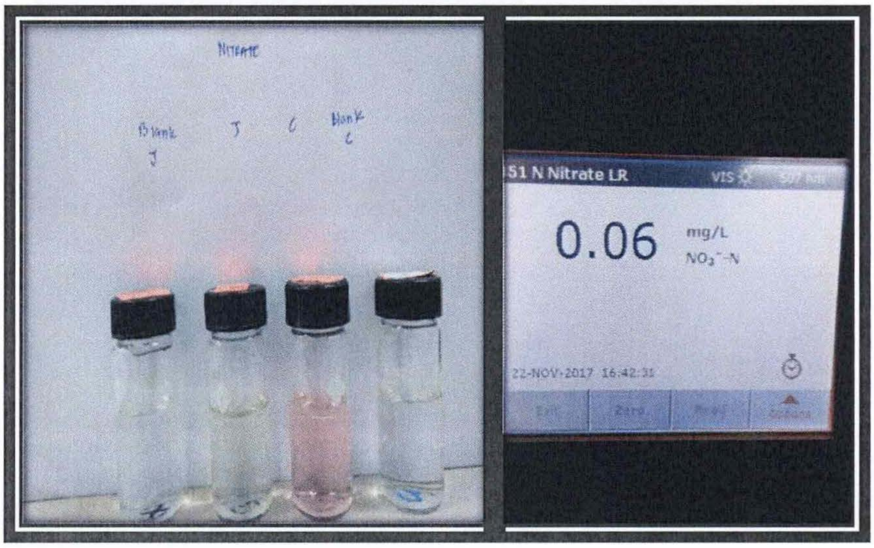


Figure 3.12 Nitrate Reading by Using DR5000

3.8.2.4 Ammoniacal Nitrogen

The Ammoniacal Nitrogen was followed Salicylate Method1 (0.01 to 0.50 mg/L NH3–N) based on HACH DR5000 Method 8155. Select and start the 385 Ammonia, Salic program on the spectrophotometer. Prepare the clean round sample for all sample include blank. A 10ml of each sample was filled in a round sample cell each. While 10ml deionized water was filled in another round cell for blank sample. The contents of Ammonia Salicylate Powder Pillow will add to each cell. The cell caped and were shaken to make sure the powder were dissolved. Then, three-minute reaction period counted by touch the timer on the spectrophotometer will begin. After the beep sound, add the contents of one Ammonia Cyanurate Reagent Powder Pillow to each cell. The cell caped and were shaken to dissolve the reagent. The reaction period were counted for 15-minutes by the spectrophotometer's timer. The green colour will develop if there were ammonia-nitrogen is present. The blank placed into the cell holder when timer beeps. The 0.00 mg/L NH3–N were displayed. The sample wipe and placed into a cell holder and the results were recorded as in mg/L NH3–N.

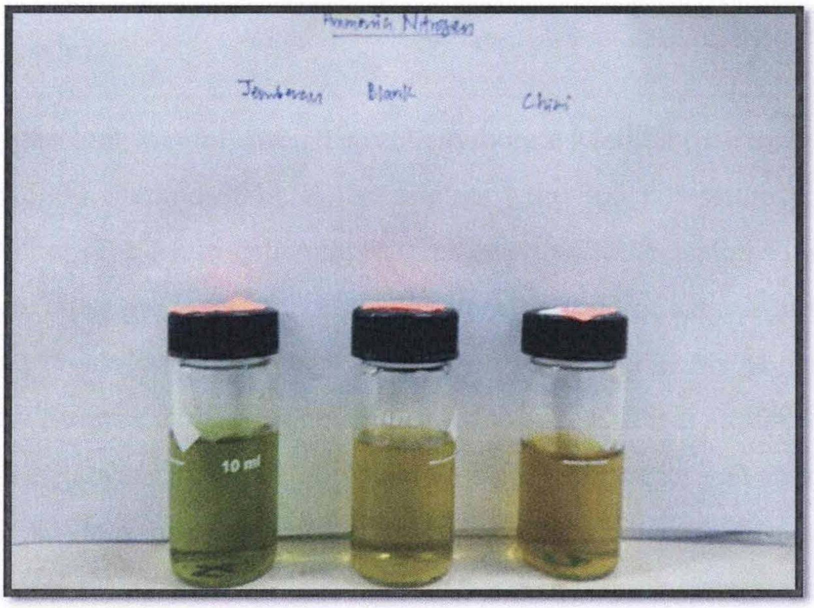


Figure 3.13 Ammoniacal Nitrogen Reading by Using DR5000

3.8.2.5 pH

The pH was followed procedure from APHA $4500H^{+}$ B (21st Edition), Standard Method for the Examination of Water and Wastewater. PH meter must calibrate before use to make it stable. Each buffer solution was poured into 50 ml beaker respectively. Button 'ON/OFF' was press to start. Then press 'CAL' button to calibrate. The display will prompt for Standard 1. Place pH electrode in one of the buffer. Press 'READ' button to read the pH value. Wait until the electrode has stabilized. The display will prompt for Standard 2. Rinse the electrode with the deionized water. Place the electrode in the second buffer and then Press 'READ' button. When the reading is stable, the slope and **/A** will appear. To save the calibration, press READ for a few second and hold. After that, to prepared Sample measurement, shake the sample well, pour about 35 ml of sample into 50 ml clean beaker. Determine the pH without dilution until constant reading achieved. Place pH electrode in the beaker. Press 'ON/OFF' button and press 'READ' button. The display will shows pH reading and temperature. Record the pH reading to nearest 0.01 and temperature of the sample. Press 'ON/OFF' button when finish.

3.8.2.6 Potassium

The Potassium was followed Tetraphenylborate Method (0.1 to 7.0 mg/L) based on HACH DR5000 Method 8049. Select and start the 905 Potassium program on the spectrophotometer. The Multi-cell Adapter was insert with the 1-inch square cell holder facing the user. Fill a graduated mixing cylinder with 25ml of sample and then add the contents of one Potassium 1 Reagent Pillow. Next add the contents of one Potassium 2 Reagent Pillow Stopper and invert several times to mix. After that add the contents of one Potassium 3 Reagent Pillow after the solution clears. Stopper and shake the solution for 30 second. A white turbidity will form if potassium is present. Then press timer OK and a three-minute reaction period will begin. After that, sample were prepared with pour at least 10-mL of the solution from the cylinder into a square sample cell. Blank Preparation will do When the timer expires, fill the second square sample cell with 10 mL of sample. The blank were wipe and insert it into the cell holder with the fill line facing the user. Press ZERO the display will show 0.0 mg/L K. Within seven minutes after the timer expires, wipe the prepared sample and insert it into the cell holder with the fill line facing the user. Results were recorded as in mg/L K.

Figure 3.14 Potassium Experiment by Using DR5000

3.8.2.7 Heavy Metals

For heavy metals, there are two method conducted in this research. First one is by using Atomic Absorption Spectroscopy (AAS) which is used for a few targeted heavy metals which are Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb) and Nickel (Ni). For getting more accurate and faster results for many heavy metals element, another method is done by using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS).

Figure 3.15 Heavy Metals Test by Using Method of AAS

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter show the result for each parameter of finding will be analyse and discuss on this chapter. The main objective is to determine the water quality by using physical and chemical parameter based on Water Quality Index (DOE-WQI) and Interim National Water Quality Standard, Malaysia (INWQS) at Sg. Jemberau and Sg.Chini Downstream. Other reason we conduct these project are also to identify the condition on Sg. Jerangking and Sg. Gumum. All of these station are located around Tasik Chini.

There are two test that had been done which are in-situ test and laboratory test. Parameter that had been test for physical parameter are, temperature, turbidity, and total suspended solid (TSS). Chemical parameter that had been test are pH, nitrate (NO^-3), phosphorus (P), electrical conductivity, ammoniacal nitrogen (NH_3-N), dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD). All the data were gathered from in-situ and laboratory test with both season seasons which are wet season and dry season are analysed. From the data, the graphs are plotted by using Microsoft Excel program and result for each parameter should be within range that has been classified in Water Quality Index, so that it can be conclude as safe for ecosystem at the area.

4.2 Water Quality Parameters in 2017

4.2.1 In-Situ Test Result

4.2.1.1 pH

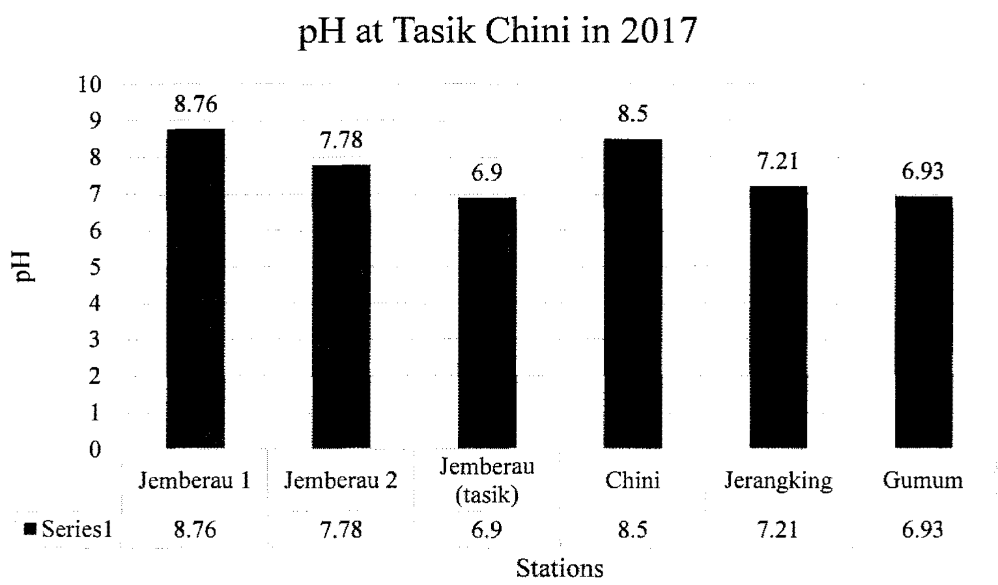


Figure 4.1 Graph for pH in 2017

Figure 4.1 shows the range of average pH varies from 6.9 to 8.76. The highest pH value was recorded at Sg. Jemberau 1 which is pH 8.76 while the lowest value is pH 5.11 at Sg. Jemberau (tasik). The NWQS threshold range of pH for river in Malaysia is from 5.00-9.00. According to National Water Quality Standard for Malaysia, all stations are classified in Class II. Basically, pH value is controlled by dissolved carbon dioxide, which is from carbonic acid in water.

4.2.1.2 Electrical Conductivity

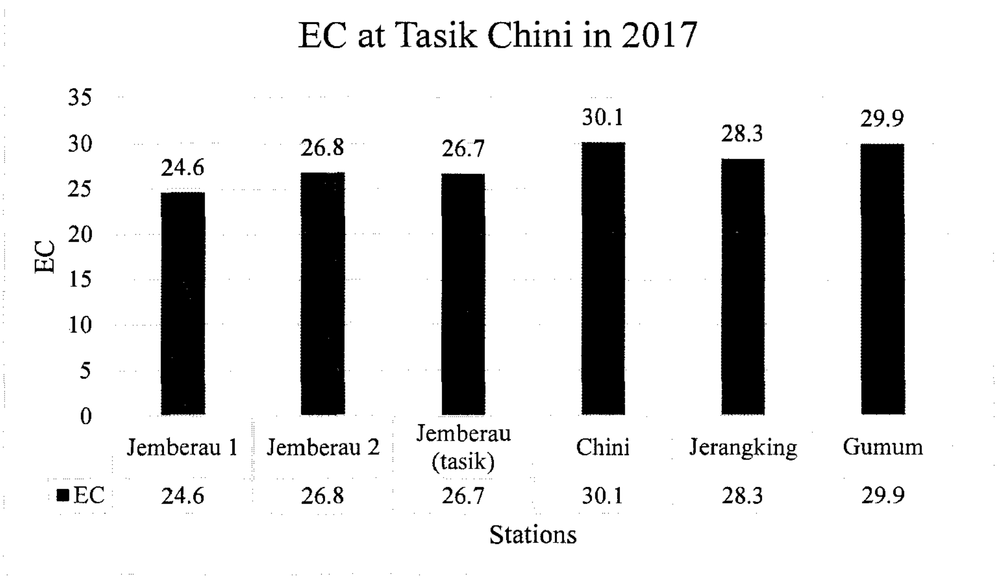


Figure 4.2 Graph for Electrical Conductivity in 2017

Based on Figure 4.2, the range of electrical conductivity in 2017 is varies from 24.6 μS/cm to 61.5 μS/cm at all stations around Tasik Chini. The lowest value is 24.6 μS/cm at Sg. Jemberau 1 and the highest value recorded is 29.9 μS/cm at Sg. Chini which is near to the mining activities and caused by the run-off from the mining activities at the station. According to National Water Quality Standard for Malaysia (NWQS), all stations are Class I because the value of electrical conductivity (EC) are not more than permitted threshold level which is 1000 μS/cm.

4.2.1.3 Turbidity

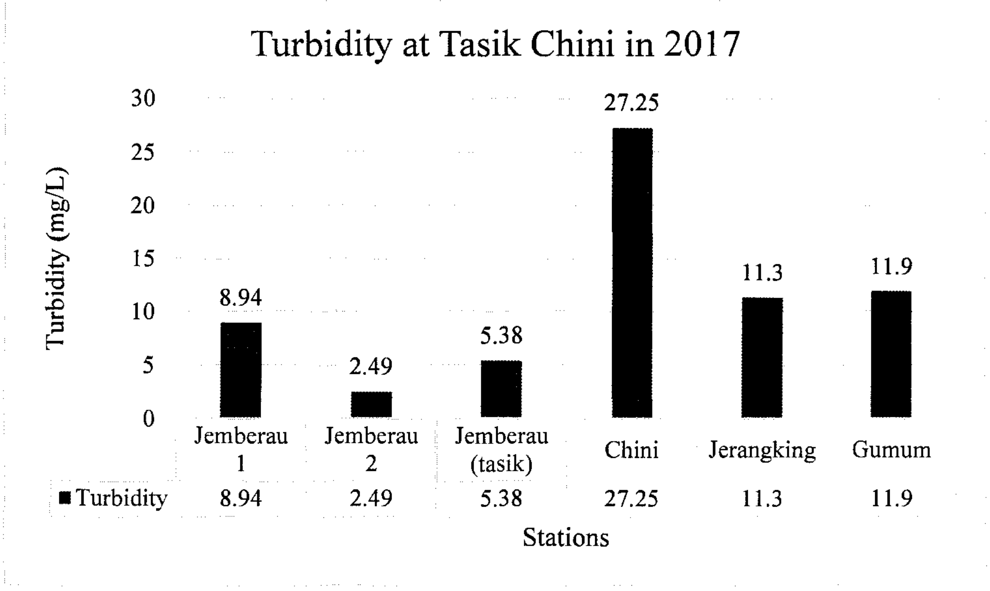


Figure 4.3 Graph for Turbidity in 2017

Based on Figure 4.3, range value for turbidity at Tasik Chini in 2017 were between 2.49 NTU to 27.25 NTU depends on sampling location. The highest value for turbidity was at Sg. Chini during wet season in 2017, where the value was 27.25 NTU. Turbidity value was highest at Sg. Chini because there is mining activities nearby. According to National Water Quality Standard for Malaysia (NWQS), all samples from the sampling locations are classified in Class II. Based on NWQS, conventional treatment is required and it is not harmful for recreational use with body contact.

4.2.1.4 Dissolved Oxygen

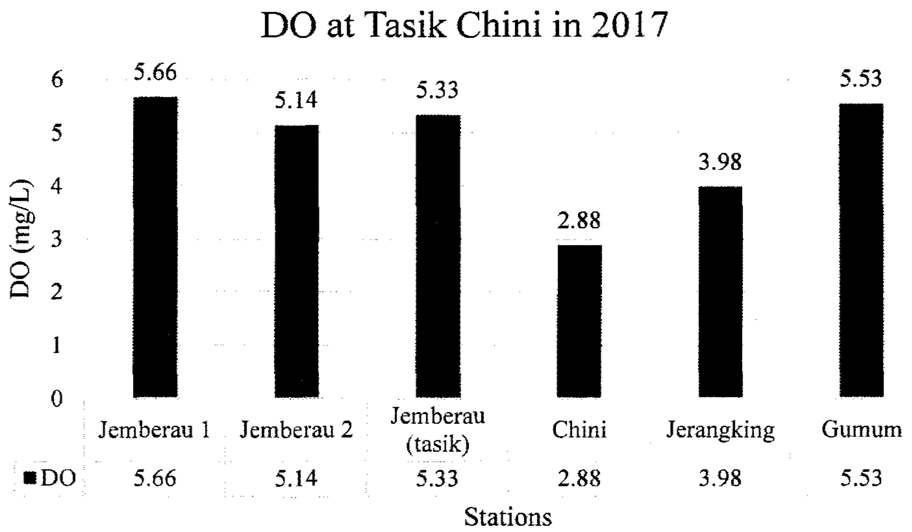


Figure 4.4 Graph for Dissolved Oxygen in 2017

Figure 4.4 shows the range of dissolved oxygen concentration at Tasik Chini in 2017 were from 2.88 mg/L to 5.66 mg/ during wet season. The highest dissolved oxygen concentration is at Sg. Jemberau 1 while the lowest concentration is at Sg. Chini. Basically dissolved oxygen is affected by photosynthetic activities. According to NWQS, most of the station were classified as Class II except for sample taken from station at Sg. Jerangking was classified as Class III according to NWQS and DOE-WQI and sample from Sg. Chini was in category of Class IV both in NWQS and DOE-WQI.

4.2.1.5 Temperature

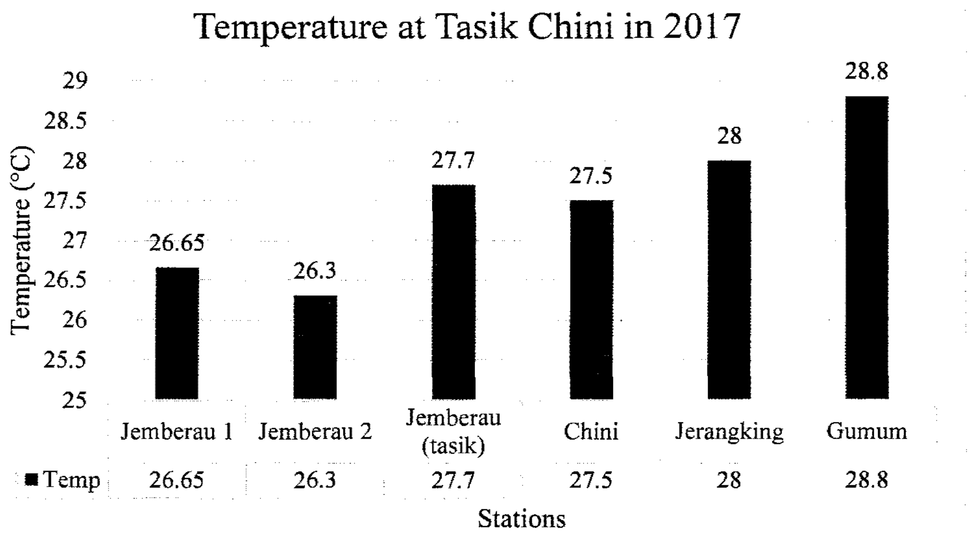


Figure 4.5 Graph for Temperature in 2017

Based on Figure 4.5, the average temperature for selected rivers around Tasik Chini are around 26.3 °C to 28.8 °C. The highest temperature recorded was at Sg. Jerangking which is 28.8 °C while the lowest reading is at Sg. Jemberau. According to National Water Quality Standard for Malaysia (NWQS), the temperature for all station is considered normal for equatorial climate of Tasik Chini.

4.2.2 Laboratory Test Result

4.2.2.1 Biochemical Oxygen Demand (BOD)

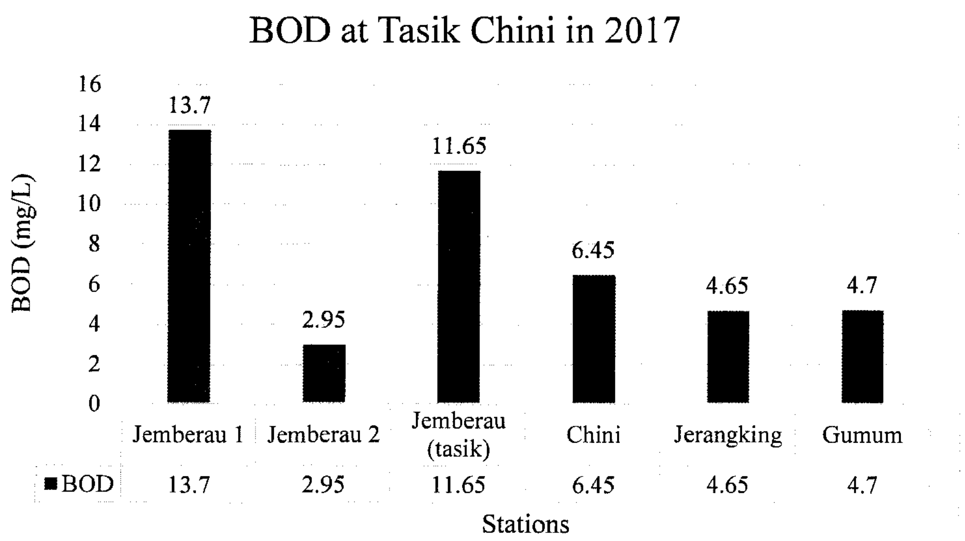


Figure 4.6 Graph for Biochemical Oxygen Demand (BOD) in 2017

Figure 4.6 summarize the range of value for Biochemical Oxygen Demand (BOD) around Tasik Chini were between 2.95 mg/L to 13.7 mg/L during wet season in 2017. The value was highest at the location of Sg. Jemberau 1 because it is located at river outflow. According to National Water Quality Standard for Malaysia (NWQS), most of the samples tested were classified into Class IV where the water condition is irritated while sample from Sg. Jerangking and Sg. Gumum are better which is in Class III and need extensive treatment.

4.2.2.2 Chemical Oxygen Demand (COD)

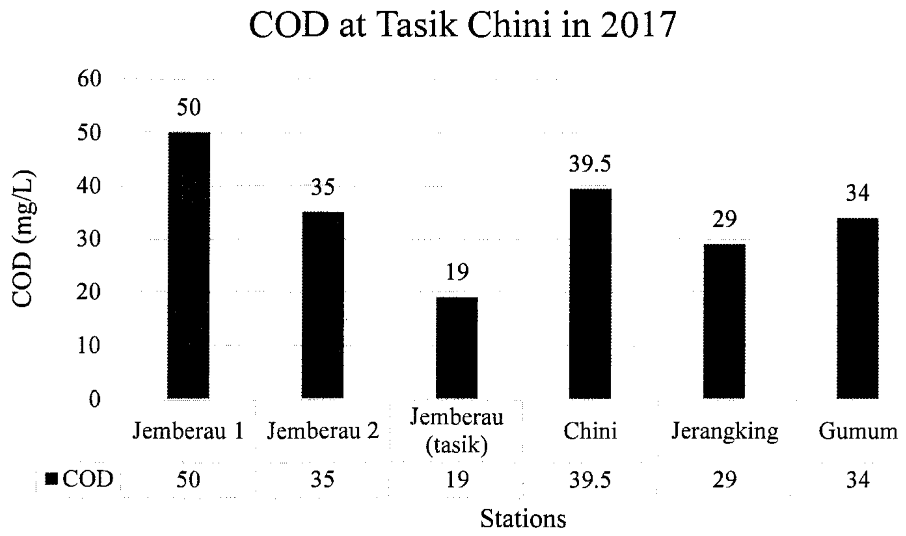


Figure 4.7 Graph for Chemical Oxygen Demand (COD) in 2017

Figure 4.7 shows the range of average Chemical Oxygen Demand (COD) at selected rivers around Tasik Chini were from 19 mg/L to 50.0 mg/L in 2017. The highest COD value was recorded at Sg. Jemberau 1 which is 50.0 mg/L while the lowest value is 9.75 mg/L at Sg. Jemberau (tasik) which is in different location. The value is higher at Sg. Jemberau 1 because it is located near with logging area. The surrounding area with active logging activity becomes the major contribution to the highest COD value at Sg. Jemberau which is believed as the main factor of effluent from mining area had been discharge to lake. While in Sg. Jemberau (tasik) location is located a bit far from the activity area. According to National Water Quality Standard for Malaysia (NWQS) and DOE-Water Quality Index (WQI), most of the sample taken from the selected stations are classified in class III during wet season 2017.

4.2.2.3 Ammoniacal Nitrogen

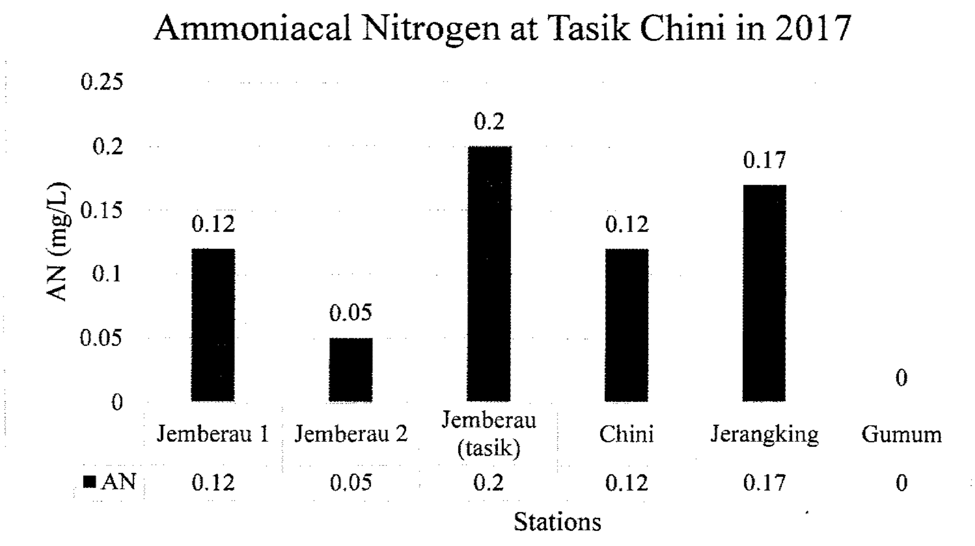


Figure 4.8 Graph for Ammoniacal Nitrogen (NH3-N) in 2017

Figure 4.8 shows that the range of Ammoniacal Nitrogen (NH3-N) recorded was from 0 mg/L to 0.17 mg/L. The highest reading was recorded at Sg. Jerangking which is 0.17 mg/L, while the lowest reading is at Sg. Gumum which is 0 mg/L during wet season in the same year. Based on data obtained, all value for NH3-N were below 0.3 mg/L which is classified into Class II based on NWQS and for this class only conventional treatment is required and it also can support aquatic life.

4.2.2.4 Nitrate

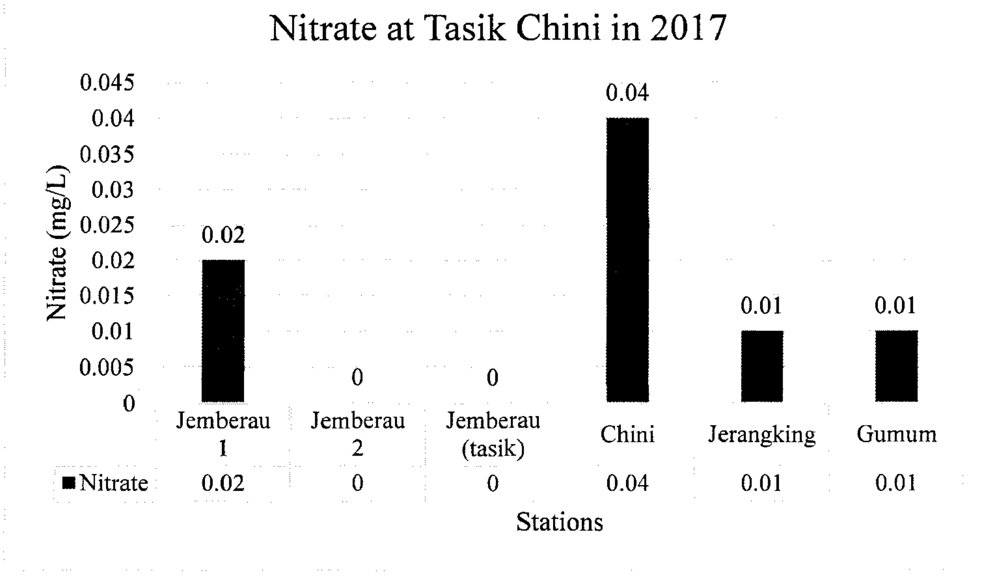


Figure 4.9 Graph for Nitrate in 2017

From Figure 4.9, the range value of nitrate concentration is summarized for the selected rivers were from 0 mg/L to 0.04 mg/L. The highest concentration of nitrate was at Sg. Chini during wet season in 2017 which is 0.08 mg/L. Nitrate nitrogen is product organic matter decomposition by bacteria. Nitrate ion usually derived from anthropogenic sources like domestic sewage and agriculture fields. It is affected by discharge from logging activity, palm oil and rubber plantation at the area. According to National Water Quality Standard for Malaysia (NWQS), all stations were classified into Class II because the values of nitrate concentration was in range of 0 mg/L to 7 mg/L.

4.2.2.5 Total Suspended Solid (TSS)

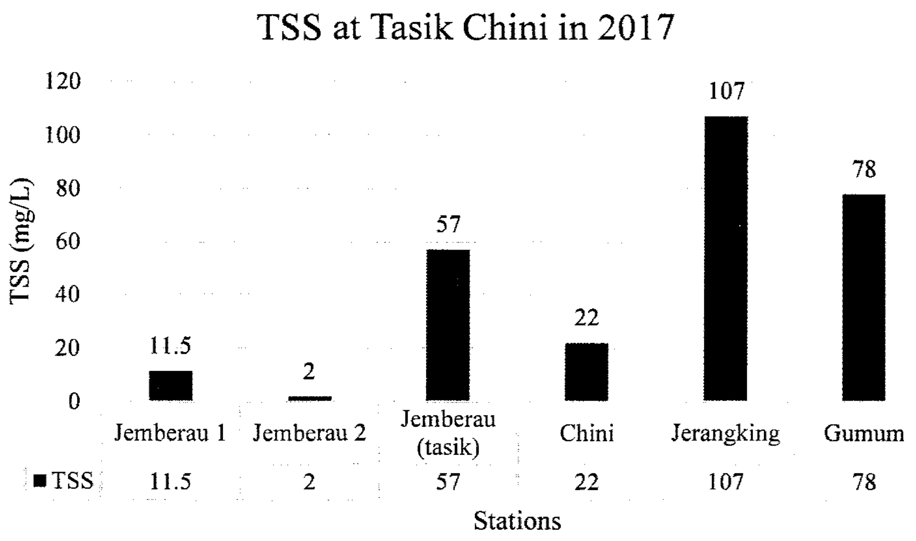


Figure 4.10 Graph for Total Suspended Solid (TSS) in 2017

Figure 4.10 shows the range of Total Suspended Solid (TSS) is from 2 mg/L to 107 mg/L. The highest reading was recorded at Sg. Jerangking which is 107 mg/L, while the lowest reading is at Sg. Jemberau 2 which is 2 mg/L during wet season 2017. Based on the National Water Quality Standard for Malaysia (NWQS), the level of TSS for supporting aquatic life in fresh water ecosystem is below than 150 mg/L (DOE, 2006). According to NWQS, sample taken from stations at Sg. Jemberau 1, Sg. Jemberau 2 and Sg. Chini were classified as class II while sample from Sg. Jemberau (tasik), Sg. Jerangking and Sg. Gumum were categorized in Class III.

4.2.2.6 Phosphorus

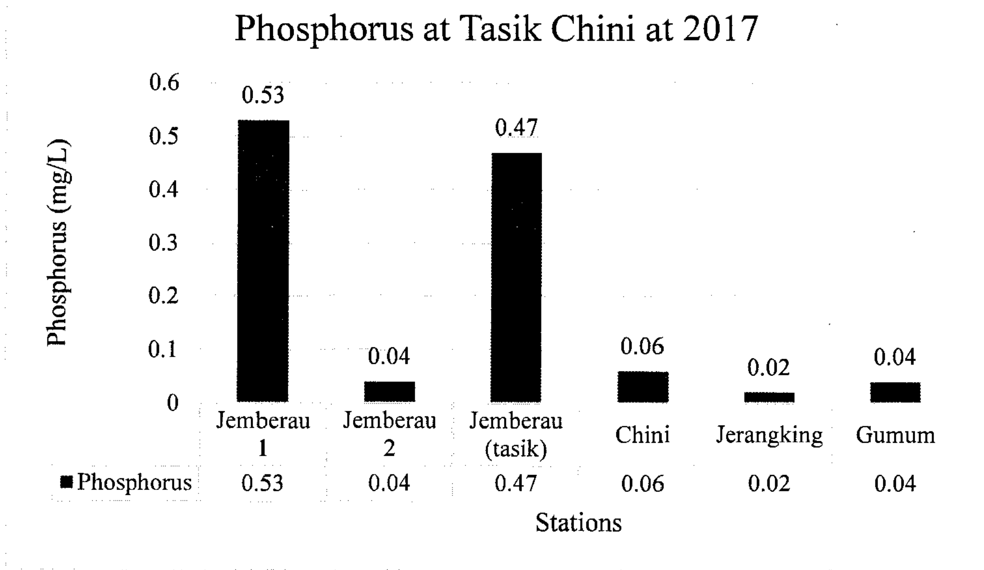


Figure 4.11 Graph for Phosphorus in 2017

Figure 4.11 shows the range of average Phosphorus concentration is from 0.02 mg/L to 0.53 mg/L. The highest Phosphorus concentration value was recorded at Sg. Jemberau 1 which is 0.53 mg/L while the lowest value is 0.02 mg/L at Sg. Jerangking. The highest phosphorus at Sg. Jemberau is caused by the river located near palm plantation. As the result, the agricultural activities near Tasik Chini will cause agricultural run-off into Tasik Chini which will pollute the lake. Agricultural run-off consists of fertilizers, pesticides and domestic discards which will affects the quality of water and aquatic life (V & S, 2013). According to NWQS, all sample is classified in Class III except for data in Sg. Jemberau during wet season 2017 which is in Class I.

4.2.2.7 Potassium

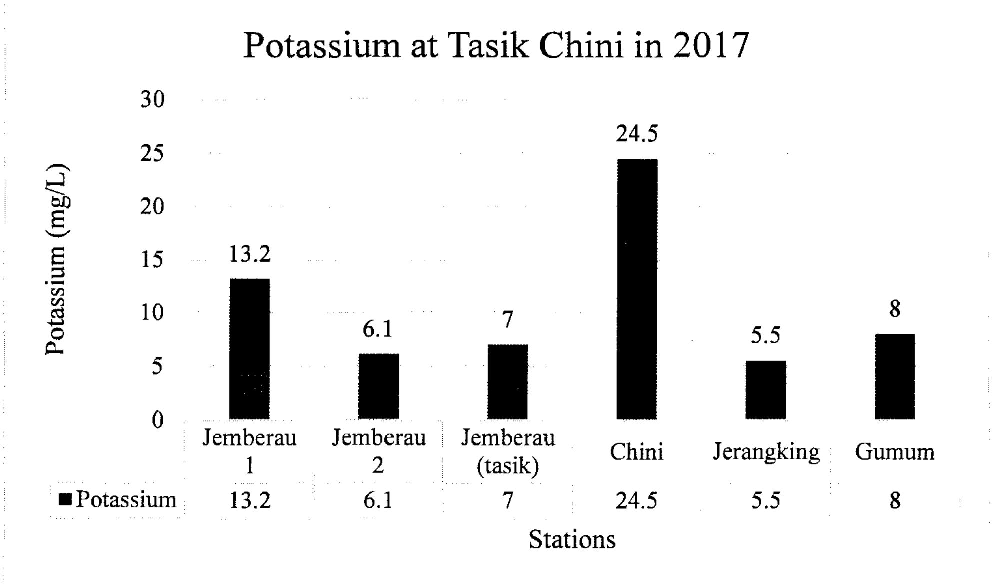


Figure 4.12 Graph for Potassium in 2017

Based on Figure 4.12, average Potassium concentration for every sample taken in 2017 are varies from 5.5 mg/L to 24.5 mg/L. The highest Potassium concentration value was recorded at Sg. Chini which is 24.5 mg/L while the lowest value is 5.5 mg/L at Sg. Jerangking during wet season 2017. The higher concentration is affected by discharge of iron from mining activity around that area.

4.2.2.8 Heavy Metal (AAS)

Table 4.1 Result for Heavy Metal using AAS (mg/L)

JEMBERAU 1	Cadmium (Cd)	Lead (Pb)	Chromium (Cr)	Copper (Cu)	Nickel (Ni)
November	0	1.107	0.452	0.078	0.015
January	0.004	0	0.016	0.041	-
Average	0.004	1.107	0.234	0.060	0.015
CHINI	Cadmium (Cd)	Lead (Pb)	Chromium (Cr)	Copper (Cu)	Nickel (Ni)
November	0	0.958	0.426	0.081	0.023
January	0.001	0	0	0.040	-
Average	0.001	0.958	0.426	0.061	0.023

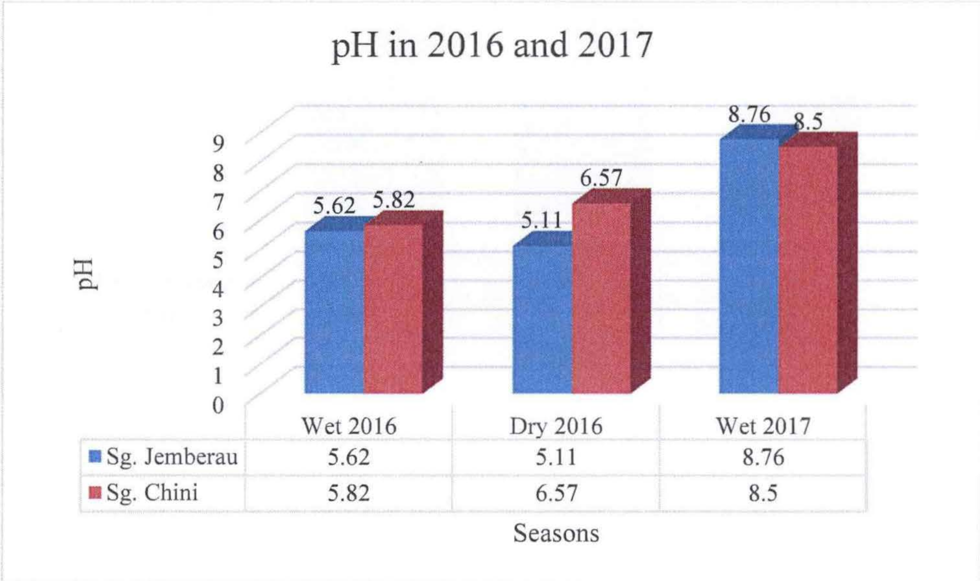
Table 4.1 shows the concentration in mg/L for five parameters of heavy metals in sample obtained at Sg. Jemberau and Sg. Chini during wet season 2017. The levels of these heavy metals were determined by Atomic Absorption Spectroscopy (AAS). Five parameters conducted in laboratory by using AAS are Cadmium (Cd), Lead (Pb), Chromium (Cr), Copper (Cu) and Nickel (Ni).

Based on the result obtained, the heavy metals concentration in water sample have slightly higher according to permissible range from NWQS. This indicated that it was resulted from mining activity nearby affecting the increment of water pollution in that area.

4.3 Comparison of Water Quality during 2016 And 2017

4.3.1 In-Situ Test Result

4.3.1.1 pH



	Wet 2016	Dry 2016	Wet 2017
Sg. Jemberau	5.62	5.11	8.76
Sg. Chini	5.82	6.57	8.5

Figure 4.13 Graph for pH in 2016 and 2017

Based on Figure 4.13, the range of average pH for Sg. Jemberau are 5.62 to 8.76 and Sg. Chini are from 5.82 to 8.5 varies in different seasons. The highest pH value was recorded at Sg. Jemberau which is pH 8.76 in wet seasons 2017 while the lowest value is pH 5.11 Sg. Jemberau during dry season 2016. The NWQS threshold range of pH for river in Malaysia is from 5.00-9.00. The pH value decrease from November to January for Sg. Chini Downstream and Sg. Jemberau. According to National Water Quality Standard for Malaysia, all station are classified in Class II.

4.3.1.2 Electrical Conductivity

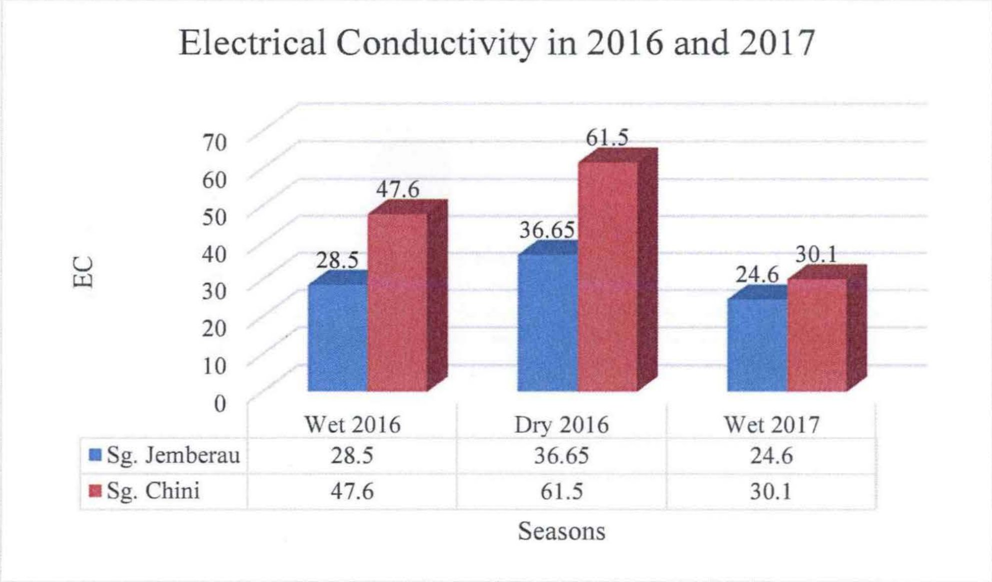


Figure 4.14 Graph for Electrical Conductivity in 2016 and 2017

Figure 4.14 shows that the range of electrical conductivity are from 28.5 μS/cm to 61.5 μS/cm at Sg. Jemberau and Sg. Chini Downstream. The lowest and the highest value recorded were 28.5 μS/cm in wet season at Sg. Jemberau and 61.5 μS/cm in dry season at Sg. Chini Downstream respectively. The electrical conductivity reading were higher at Sg. Chini Downstream because the station is near to the mining activities and caused by the runoff from the mining activities at the station. According to National Water Quality Standard for Malaysia (NWQS), all stations are Class I because the value of electrical conductivity (EC) are not more than permitted threshold level which is 1000 μS/cm.

4.3.1.3 Turbidity

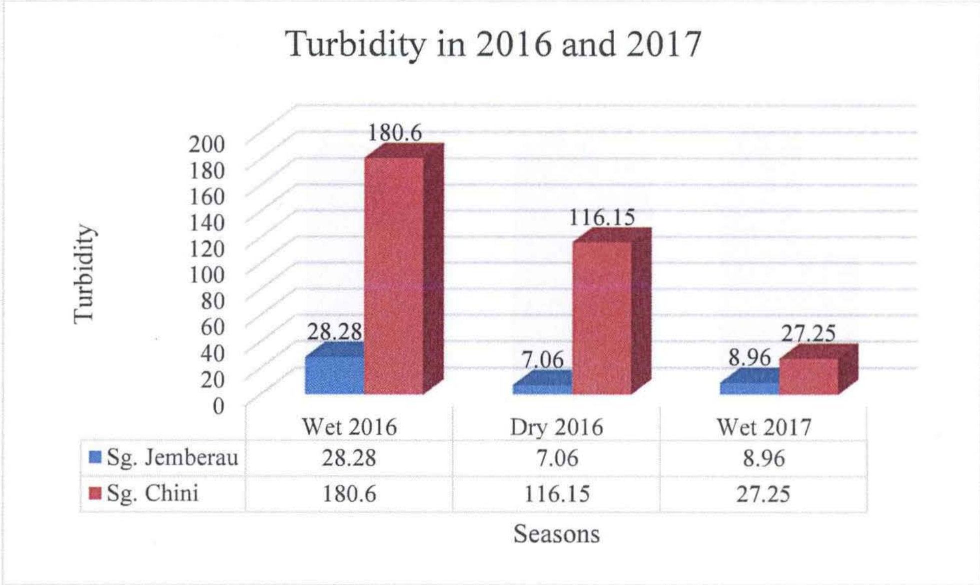
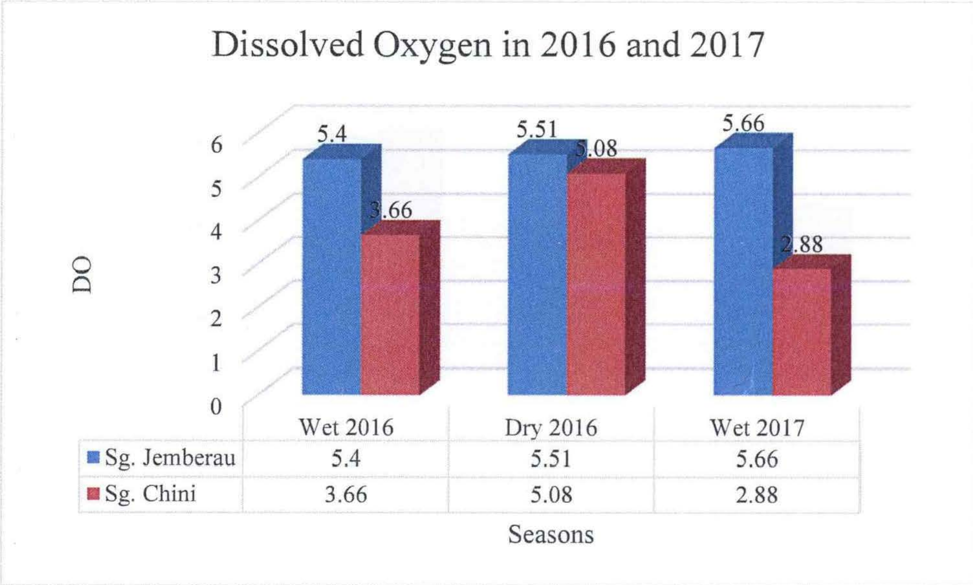


Figure 4.15 Graph for Turbidity in 2016 and 2017

According to Figure 4.15, range value for turbidity at Sg. Jemberau were between 8.94 NTU to 28.28 NTU. Meanwhile, the range value for Sg. Chini Downstream were from 27.25 NTU to 180.6 NTU. Based on data recorded, the value of turbidity is decreasing from 2016 to 2017. The highest value for turbidity was at Sg. Chini Downstream during wet season in 2016, the value was 180.6 NTU. Comparatively, turbidity value was highest at Sg. Chini Downstream during wet and dry season. This is because mining activities is located near Sg. Chini which is contributed to pollution of the river.

4.3.1.4 Dissolved Oxygen



	Wet 2016	Dry 2016	Wet 2017
Sg. Jemberau	5.4	5.51	5.66
Sg. Chini	3.66	5.08	2.88

Figure 4.16 Graph for Dissolved Oxygen in 2016 and 2017

Figure 4.16 above show that the dissolved oxygen concentration at Sg. Jemberau were in range from 5.4 mg/L to 10.08 mg/L while the dissolved oxygen concentration at Sg. Chini Downstream were in range from 2.88 mg/L to 5.08 mg/L. The highest dissolved oxygen value was recorded at Sg. Jemberau which is 10.08 mg/L during wet season in 2017. While the lowest value was during wet season 2017 at Sg. Chini Downstream which is 2.88 mg/L. Basically dissolved oxygen affected by photosynthetic activities. According to NWQS, most of the station were classified as Class II while station at Sg. Jemberau during wet season 2017 is in Class I.

4.3.1.5 Temperature

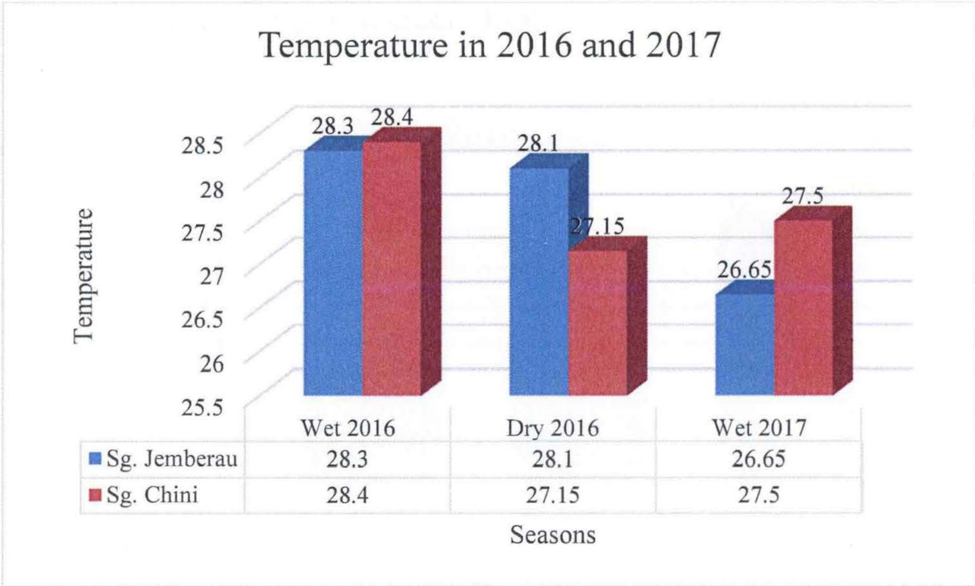


Figure 4.17 Graph for Temperature in 2016 and 2017

Figure 4.17 show that, the average temperature was recorded from 27.15 °C to 28.4 °C. The highest reading was recorded at Sg. Chini Downstream during wet season 2016 which is 28.4 °C while the lowest reading is at Sg. Chini Downstream during dry season in the same year. According to National Water Quality Standard for Malaysia (NWQS), the temperature for all station is considered normal for equatorial climate of Tasik Chini.

4.3.2 Laboratory Test Result

4.3.2.1 Biochemical Oxygen Demand (BOD)

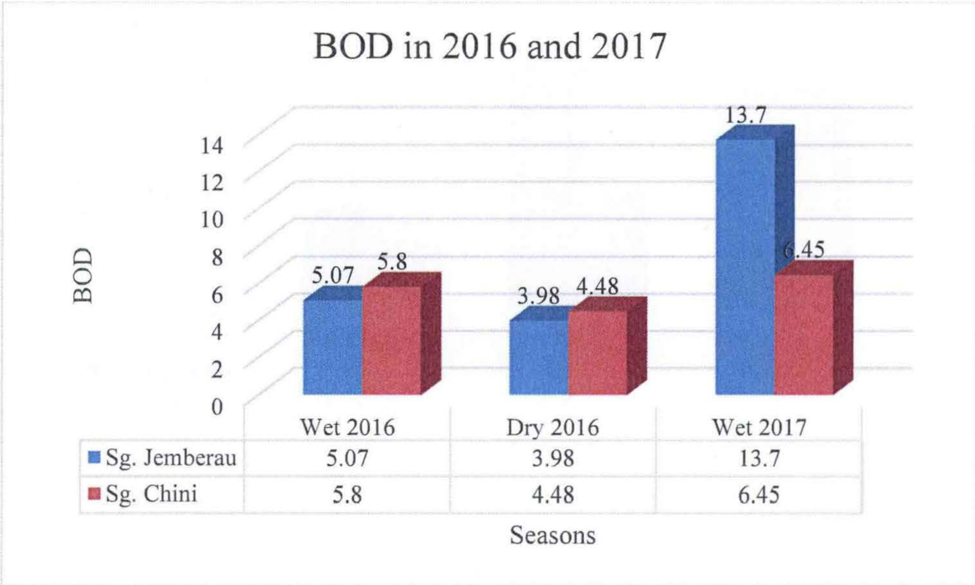


Figure 4.18 Graph for Biochemical Oxygen Demand (BOD) in 2016 and 2017

According to Figure 4.18, range of value for Biochemical Oxygen Demand (BOD) were between 3.98 mg/L to 13.7 mg/L. The highest value for BOD was at Sg. Jemberau during wet season 2017 and the value is 5.80 mg/L. The value of BOD recorded show that it was lower during dry season for both stations. Overall, BOD value were higher during wet season than in the dry season. Based on data recorded, the value of BOD have were increased in 2017 caused by organic waste from living in nearby forest. According to National Water Quality Standard for Malaysia (NWQS), all samples tested were classified into Class III.

4.3.2.2 Chemical Oxygen Demand (COD)

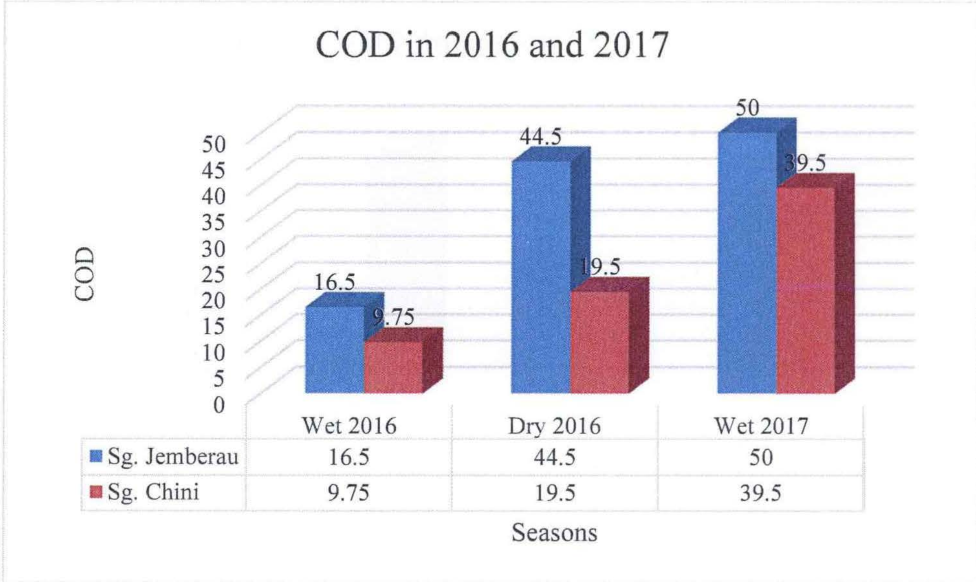


Figure 4.19 Graph for Chemical Oxygen Demand (COD) in 2016 and 2017

Based on Figure 4.19, the range of average Chemical Oxygen Demand (COD) are from 9.75 mg/L to 50.0 mg/L. The highest COD value was recorded at Sg. Jemberau which is 50.0 mg/L during wet season in 2017 while the lowest value is 9.75 mg/L at Sg. Chini Downstream during wet season in 2016. The surrounding area with the activation of logging activity becomes the major contribution to the highest COD value at Sg. Jemberau. This is mainly due to the reactivation iron-mining activity which believed that effluent from mining area had been discharge to lake. According to National Water Quality Standard for Malaysia (NWQS) and DOE-Water Quality Index (WQI), during wet and dry season, COD reading at all sampling station are classify in Class II, except for Sg. Chini Downstream is Class I during wet season 2016 and Sg. Jemberau in Class III during wet season 2017.

4.3.2.3 Ammoniacal Nitrogen

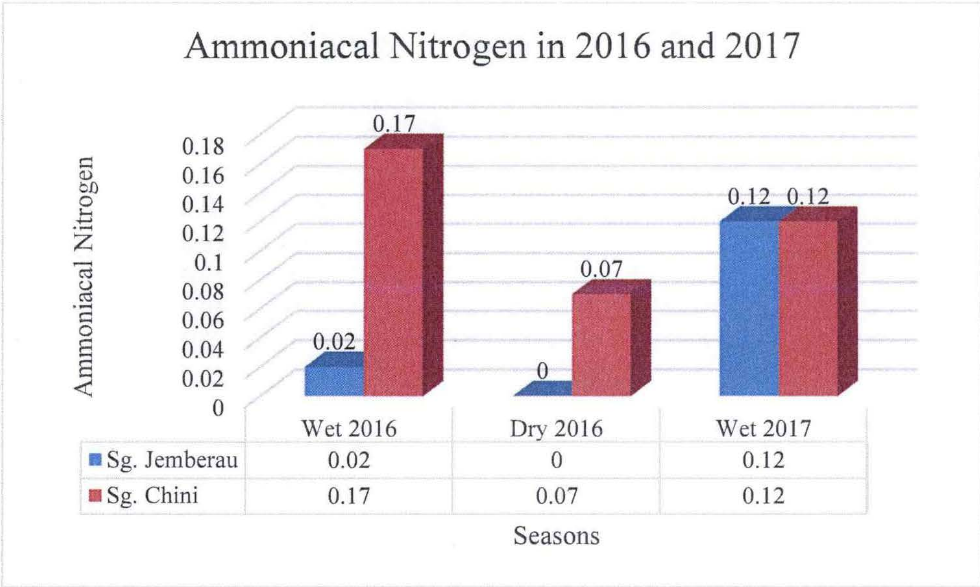


Figure 4.20 Graph for Ammoniacal Nitrogen (NH3-N) in 2016 and 2017

Figure 4.20 show that, range of Ammoniacal Nitrogen (NH3-N) were recorded from 0 mg/L to 0.17mg/L. The highest reading was recorded at Sg. Chini Downstream during wet season 2016 which is 0.17mg/L, while the lowest reading at Sg. Jemberau which is 0 mg/L during dry season in the same year. All the samples collected during wet and dry season contained less ammoniacal nitrogen which is less than the maximum limit set by the World Health Organization (WHO). Based on data obtained, all value for NH3-N were below 0.3 mg/L which classified into Class II based on NWQS and for this class conventional treatment is required and also can support aquatic life.

4.3.2.4 Nitrate

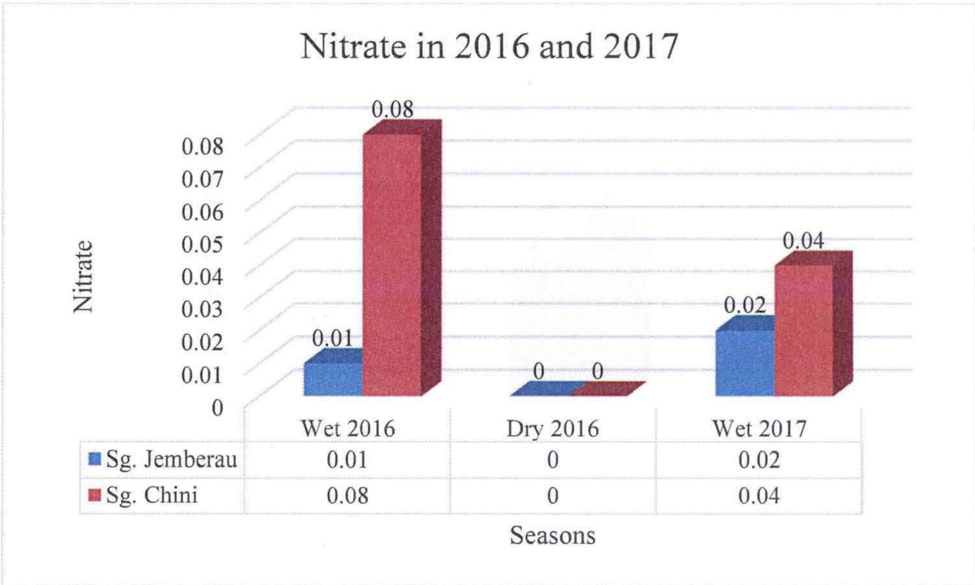


Figure 4.21 Graph for Nitrate in 2016 and 2017

Figure 4.21 show the range value of nitrate concentration readings during wet season were 0.0 mg/L to 0.08 mg/L. While during the dry season in 2016, the nitrate concentration were 0 mg/L. The highest concentration of nitrate was during wet season in 2016 at Chini Downstream which is 0.08 mg/L whereas, the lowest level of nitrate is 0 mg/L at Sg. Jemberau and Chini Downstream during dry season. Nitrate nitrogen is product organic matter decomposition by bacteria. Nitrate ion usually derived from anthropogenic sources like domestic sewage and agriculture fields. The graph shows the increase of nitrate ion during wet season at Chini Downstream and Sg. Jemberau, effect by discharge from logging activity, palm oil and rubber plantation at the area. According to National Water Quality Standard for Malaysia (NWQS), all stations were classified into Class II because the values of nitrate concentration in ranged 0 to 7 mg/L.

4.3.2.5 Total Suspended Solid (TSS)

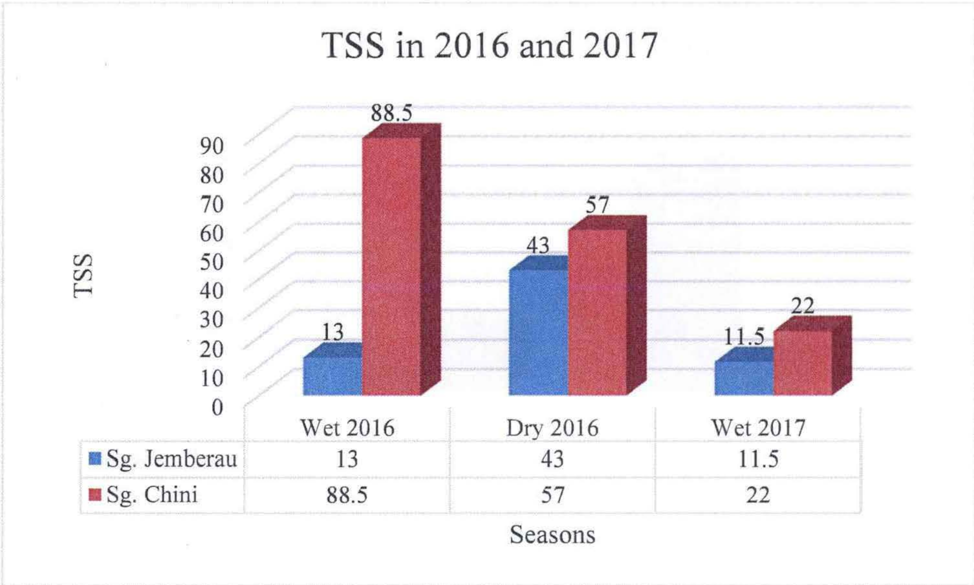


Figure 4.22 Graph for Total Suspended Solid (TSS) in 2016 and 2017

Figure 4.22 shows the range of Total Suspended Solid (TSS) is from 13 mg/L to 88.5 mg/L. The highest reading was recorded at Sg. Chini Downstream during wet season 2016 which is 88.5 mg/L, while the lowest reading is at Sg. Jemberau during wet season 2017 which is 11.5 mg/L. TSS value is comparatively due to currently active logging activities nearby Sg. Jemberau. Gasim et al. (2009) stated that the overall of the TSS concentration at Tasik Chini was considered low as the acceptable range of TSS value is from 25 to 50 mg/L for Malaysia Rivers. This has showed the same finding in this study as well. The National Water Quality Standard for Malaysia (NWQS), threshold level of TSS for supporting aquatic life in fresh water ecosystem is 150 mg/L (DOE, 2006). According to National Water Quality Standard for Malaysia (NWQS), most stations were classified into Class II, while Sg. Chini Downstream during wet season and dry season in 2016 were classified as class III.

4.3.2.6 Phosphorus

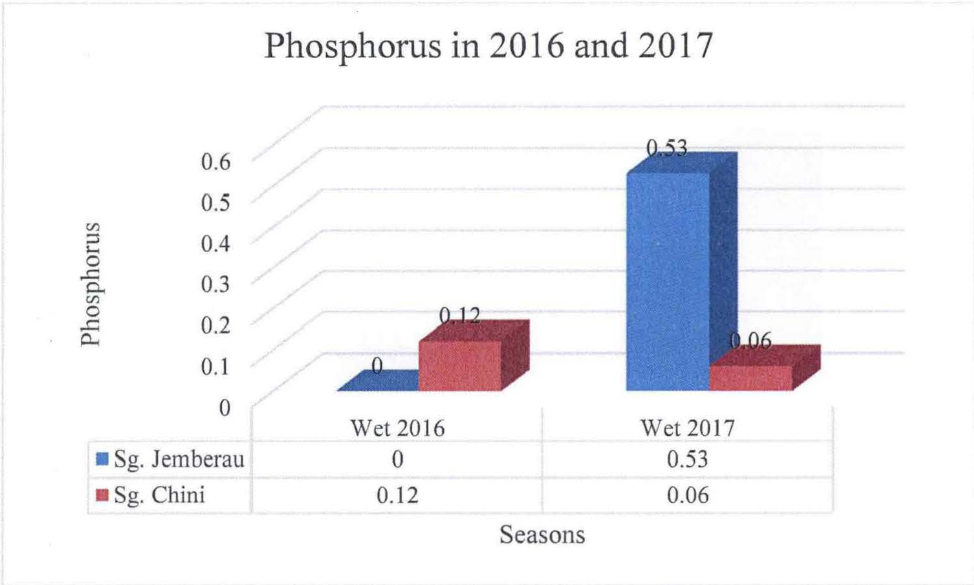


Figure 4.23 Graph for Phosphorus during wet seasons in 2016 and 2017

Based on Figure 4.23, the range of average Phosphorus concentration for wet season is from 0 mg/L to 0.53 mg/L. The highest Phosphorus concentration value was recorded at Sg. Jemberau which is 0.53 mg/L while the lowest value is 0 mg/L both in wet season 2016 and 2017. The highest phosphorus at Sg. Chini Downstream is caused by the river located near palm plantation. In addition, the palm plantation which used heavy pesticides and fertilizers has contributed in highest level of phosphorus. (Sujaul Islam et al., 2012). The agriculture runoff first will flow into the Sg. Chini Downstream, then will spread off to the whole Tasik Chini. There is a little potential for phosphorus to leach through soil into groundwater. According to NWQS, all sample is classified in Class III except for data in Sg. Jemberau during wet season 2017 which is in Class I.

4.3.2.7 Potassium

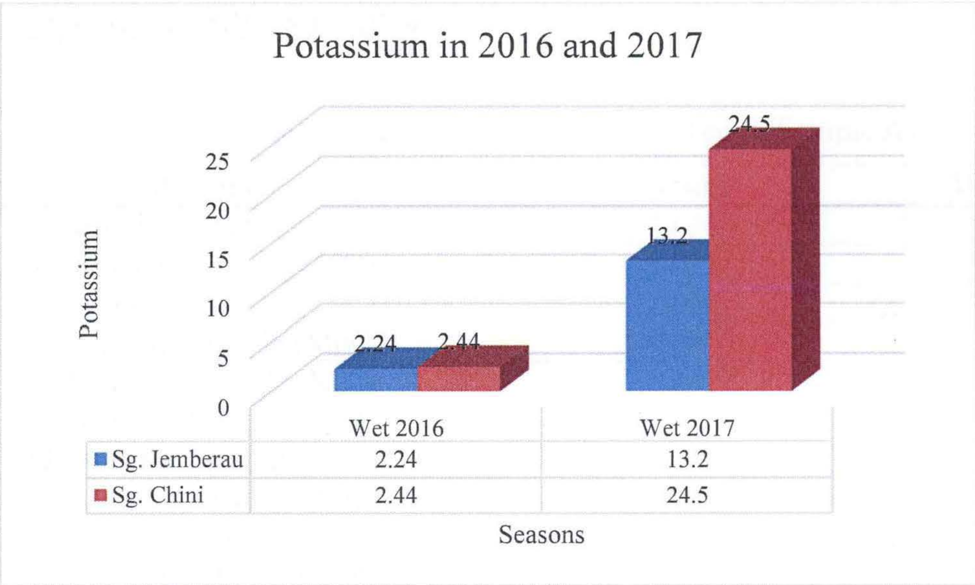


Figure 4.24 Graph for Potassium during wet seasons in 2016 and 2017

Figure 4.24 show the range of average Potassium concentration for wet season in 2016 and 2017 are from 2.24 mg/L to 24.5 mg/L. The highest Potassium concentration value was recorded at Sg. Chini which is 24.5 mg/L during wet season 2017 while the lowest value is 2.24 mg/L at Sg. Jemberau during wet season 2016. The higher concentration is affected by discharge from logging activity, palm oil and rubber plantation at the area.

4.3.2.8 Heavy Metal (ICP-MS)

RESULTS FOR SAMPLES IN 2016

Table 4.2 Heavy Metal Results for Sg. Jemberau (Sample A)

No	Parameter	Results	Unit
1	Iron (III) Oxide (Fe_2O_3)	29.36	%
2	Silicon Dioxide (SiO_2)	14.35	%
3	Aluminium Oxide (Al_2O_3)	10.09	%
4	Manganese Oxide (MnO_3)	1.39	%
5	Potassium Oxide (K_2O)	1.08	%
6	Titanium Dioxide (TiO_2)	1.08	%
7	Phosphorus Pentoxide (P_2O_5)	0.46	%
8	Barium Oxide (BaO)	0.27	%
9	Lead Oxide (PbO)	0.24	%
10	Calcium Oxide (CaO)	0.15	%
11	Sulphur Trioxide (SO_3)	0.09	%
12	Zinc Oxide (ZnO)	0.07	%
13	Magnesium Oxide (MgO)	0.06	%
14	Zirconium Dioxide (ZrO_2)	0.05	%
15	Vanadium (V) Oxide (V_2O_5)	0.05	%
16	Chromium (III) Oxide (Cr_2O_3)	0.03	%
17	Chlorine (Cl)	0.02	%
18	Copper Oxide (CuO)	0.02	%
19	Arsenic Trioxide (As_2O_3)	87	ppm
20	Gallium (III) Oxide (Ga_2O_3)	48	ppm
21	Rubidium Oxide (Rb_2O)	37	ppm
22	Nickel Oxide (NiO)	33	ppm
23	Niobium Pentoxide (Nb_2O_5)	25	ppm

Table 4.3 Heavy Metal Results for Sg. Jemberau (Sample B)

No	Parameter	Results	Unit
1	Iron (III) Oxide (Fe2O3)	24.09	%
2	Silicon Dioxide (SiO2)	14.30	%
3	Aluminium Oxide (Al2O3)	11.56	%
4	Manganese Oxide (MnO3)	2.89	%
5	Potassium Oxide (K2O)	1.25	%
6	Titanium Dioxide (TiO2)	0.99	%
7	Lead Oxide (PbO)	0.59	%
8	Phosphorus Pentoxide (P2O5)	0.47	%
9	Barium Oxide (BaO)	0.35	%
10	Calcium Oxide (CaO)	0.15	%
11	Zinc Oxide (ZnO)	0.09	%
12	Sulphur Trioxide (SO3)	0.07	%
13	Zirconium Dioxide (ZrO2)	0.05	%
14	Chromium (III) Oxide (Cr2O3)	0.03	%
15	Copper Oxide (CuO)	0.02	%
16	Strontium Oxide (SrO)	60	ppm
17	Rubidium Oxide (Rb2O)	53	ppm
18	Nickel Oxide (NiO)	38	ppm
19	Gallium (III) Oxide (Ga2O3)	36	ppm
20	Niobium Pentoxide (Nb2O5)	25	ppm

RESULTS FOR SAMPLES IN 2017

Table 4.4 Heavy Metal Results for Sg. Jemberau 12/11/2017 (Liquid)

No	Parameter	Results	Unit
1	Beryllium (Be)	Not Detected (Less than 0.5)	ppb
2	Sodium (Na)	103.2	ppm
3	Magnesium (Mg)	Not Detected (Less than 0.1)	ppm
4	Aluminium (Al)	118.5	ppb
5	Potassium (K)	Not Detected (Less than 0.1)	ppm
6	Calcium (Ca)	Not Detected (Less than 0.1)	ppm
7	Vanadium (V)	Not Detected (Less than 0.5)	ppb
8	Chromium (Cr)	Not Detected (Less than 0.5)	ppb
9	Manganese (Mn)	155.1	ppb
10	Iron (Fe)	Not Detected (Less than 0.1)	ppm
11	Cobalt (Co)	Not Detected (Less than 0.5)	ppb
12	Nickel (Ni)	Not Detected (Less than 0.5)	ppb
13	Copper (Cu)	Not Detected (Less than 0.5)	ppb
14	Zinc (Zn)	150.9	ppb
15	Arsenic (As)	Not Detected (Less than 0.5)	ppb
16	Selenium (Se)	Not Detected (Less than 0.5)	ppb
17	Molybdenum (Mo)	Not Detected (Less than 0.5)	ppb
18	Silver (Ag)	Not Detected (Less than 0.5)	ppb
19	Cadmium (Cd)	Not Detected (Less than 0.5)	ppb
20	Antimony (Sb)	Not Detected (Less than 0.5)	ppb
21	Barium (Ba)	77.8	ppb
22	Lead (Pb)	22.8	ppb

Table 4.5 Heavy Metal Results for Sg. Jemberau 12/11/2017 (Digest)

No	Parameter	Results	Unit
1	Beryllium (Be)	15.7	ppb
2	Sodium (Na)	Not Detected (Less than 0.1)	ppm
3	Magnesium (Mg)	Not Detected (Less than 0.1)	ppm
4	Aluminium (Al)	57688.02	ppm
5	Potassium (K)	179.1	ppm
6	Calcium (Ca)	Not Detected (Less than 0.1)	ppm
7	Vanadium (V)	64.25	ppm
8	Chromium (Cr)	5.70	ppm
9	Manganese (Mn)	229985.99	ppm
10	Iron (Fe)	54329.8	ppm
11	Cobalt (Co)	79.4	ppb
12	Nickel (Ni)	Not Detected (Less than 0.5)	ppb
13	Copper (Cu)	82.11	ppm
14	Zinc (Zn)	839.56	ppm
15	Arsenic (As)	11.94	ppm
16	Selenium (Se)	Not Detected (Less than 0.5)	ppb
17	Molybdenum (Mo)	2.92	ppm
18	Silver (Ag)	1.84	ppm
19	Cadmium (Cd)	2.30	ppm
20	Antimony (Sb)	4.04	ppm
21	Barium (Ba)	2144.46	ppm
22	Lead (Pb)	1477.18	ppm

Table 4.6 Heavy Metal Results for Sg. Jemberau 30/1/2018 (Liquid)

No	Parameter	Results	Unit
1	Beryllium (Be)	Not Detected (Less than 0.5)	ppb
2	Sodium (Na)	13.8	ppm
3	Magnesium (Mg)	Not Detected (Less than 0.1)	ppm
4	Aluminium (Al)	37.5	ppb
5	Potassium (K)	Not Detected (Less than 0.1)	ppm
6	Calcium (Ca)	Not Detected (Less than 0.1)	ppm
7	Vanadium (V)	Not Detected (Less than 0.5)	ppb
8	Chromium (Cr)	Not Detected (Less than 0.5)	ppb
9	Manganese (Mn)	198.6	ppb
10	Iron (Fe)	703.2	ppm
11	Cobalt (Co)	Not Detected (Less than 0.5)	ppb
12	Nickel (Ni)	Not Detected (Less than 0.5)	ppb
13	Copper (Cu)	Not Detected (Less than 0.5)	ppb
14	Zinc (Zn)	477.7	ppb
15	Arsenic (As)	Not Detected (Less than 0.5)	ppb
16	Selenium (Se)	Not Detected (Less than 0.5)	ppb
17	Molybdenum (Mo)	Not Detected (Less than 0.5)	ppb
18	Silver (Ag)	Not Detected (Less than 0.5)	ppb
19	Cadmium (Cd)	Not Detected (Less than 0.5)	ppb
20	Antimony (Sb)	Not Detected (Less than 0.5)	ppb
21	Barium (Ba)	121.8	ppb
22	Lead (Pb)	9.1	ppb

Table 4.7 Heavy Metal Results for Sg. Jemberau 30/1/2018 (Digest)

No	Parameter	Results	Unit
1	Beryllium (Be)	4.6	ppb
2	Sodium (Na)	Not Detected (Less than 0.1)	ppm
3	Magnesium (Mg)	Not Detected (Less than 0.1)	ppm
4	Aluminium (Al)	62975.87	ppm
5	Potassium (K)	173.3	ppm
6	Calcium (Ca)	Not Detected (Less than 0.1)	ppm
7	Vanadium (V)	68.32	ppm
8	Chromium (Cr)	9.13	ppm
9	Manganese (Mn)	98647.34	ppm
10	Iron (Fe)	5338.2	ppm
11	Cobalt (Co)	65.2	ppb
12	Nickel (Ni)	Not Detected (Less than 0.5)	ppb
13	Copper (Cu)	2.78	ppm
14	Zinc (Zn)	17.12	ppm
15	Arsenic (As)	14.61	ppm
16	Selenium (Se)	Not Detected (Less than 0.5)	ppb
17	Molybdenum (Mo)	2.87	ppm
18	Silver (Ag)	416.9	ppb
19	Cadmium (Cd)	385.7	ppb
20	Antimony (Sb)	5.24	ppm
21	Barium (Ba)	1610.77	ppm
22	Lead (Pb)	1155.14	ppm

Table 4.8 Heavy Metal Results for Sg. Chini 12/11/2017 (Liquid)

No	Parameter	Results	Unit
1	Beryllium (Be)	Not Detected (Less than 0.5)	ppb
2	Sodium (Na)	120.5	ppm
3	Magnesium (Mg)	Not Detected (Less than 0.1)	ppm
4	Aluminium (Al)	216.6	ppb
5	Potassium (K)	38.2	ppm
6	Calcium (Ca)	Not Detected (Less than 0.1)	ppm
7	Vanadium (V)	3.2	ppb
8	Chromium (Cr)	Not Detected (Less than 0.5)	ppb
9	Manganese (Mn)	189.3	ppb
10	Iron (Fe)	Not Detected (Less than 0.1)	ppm
11	Cobalt (Co)	Not Detected (Less than 0.5)	ppb
12	Nickel (Ni)	Not Detected (Less than 0.5)	ppb
13	Copper (Cu)	Not Detected (Less than 0.5)	ppb
14	Zinc (Zn)	649.4	ppb
15	Arsenic (As)	Not Detected (Less than 0.5)	ppb
16	Selenium (Se)	Not Detected (Less than 0.5)	ppb
17	Molybdenum (Mo)	Not Detected (Less than 0.5)	ppb
18	Silver (Ag)	Not Detected (Less than 0.5)	ppb
19	Cadmium (Cd)	Not Detected (Less than 0.5)	ppb
20	Antimony (Sb)	Not Detected (Less than 0.5)	ppb
21	Barium (Ba)	62.7	ppb
22	Lead (Pb)	29.1	ppb

Table 4.9 Heavy Metal Results for Sg. Chini 12/11/2017 (Digest)

No	Parameter	Results	Unit
1	Beryllium (Be)	102.8	ppb
2	Sodium (Na)	15.0	ppm
3	Magnesium (Mg)	113.6	ppm
4	Aluminium (Al)	52924.73	ppm
5	Potassium (K)	560.3	ppm
6	Calcium (Ca)	123.0	ppm
7	Vanadium (V)	3.99	ppm
8	Chromium (Cr)	3.95	ppm
9	Manganese (Mn)	350.39	ppm
10	Iron (Fe)	2142.4	ppm
11	Cobalt (Co)	55.5	ppb
12	Nickel (Ni)	323.6	ppb
13	Copper (Cu)	713.1	ppb
14	Zinc (Zn)	5.02	ppm
15	Arsenic (As)	941.4	ppm
16	Selenium (Se)	Not Detected (Less than 0.5)	ppb
17	Molybdenum (Mo)	274.6	ppb
18	Silver (Ag)	594.1	ppb
19	Cadmium (Cd)	110.0	ppb
20	Antimony (Sb)	348.4	ppb
21	Barium (Ba)	159.11	ppm
22	Lead (Pb)	16.74	ppm

Table 4.10 Heavy Metal Results for Sg. Chini 30/1/2018 (Liquid)

No	Parameter	Results	Unit
1	Beryllium (Be)	Not Detected (Less than 0.5)	ppb
2	Sodium (Na)	Not Detected (Less than 0.1)	ppm
3	Magnesium (Mg)	Not Detected (Less than 0.1)	ppm
4	Aluminium (Al)	71.6	ppb
5	Potassium (K)	18.0	ppm
6	Calcium (Ca)	Not Detected (Less than 0.1)	ppm
7	Vanadium (V)	Not Detected (Less than 0.5)	ppb
8	Chromium (Cr)	Not Detected (Less than 0.5)	ppb
9	Manganese (Mn)	455.6	ppb
10	Iron (Fe)	Not Detected (Less than 0.1)	ppm
11	Cobalt (Co)	Not Detected (Less than 0.5)	ppb
12	Nickel (Ni)	Not Detected (Less than 0.5)	ppb
13	Copper (Cu)	Not Detected (Less than 0.5)	ppb
14	Zinc (Zn)	520.6	ppb
15	Arsenic (As)	Not Detected (Less than 0.5)	ppb
16	Selenium (Se)	Not Detected (Less than 0.5)	ppb
17	Molybdenum (Mo)	Not Detected (Less than 0.5)	ppb
18	Silver (Ag)	Not Detected (Less than 0.5)	ppb
19	Cadmium (Cd)	Not Detected (Less than 0.5)	ppb
20	Antimony (Sb)	Not Detected (Less than 0.5)	ppb
21	Barium (Ba)	71.0	ppb
22	Lead (Pb)	14.1	ppb

Based on the result obtained from Table 4.4 to Table 4.10, the heavy metals concentration in water sample are higher for aluminium (Al), manganese (Mn), iron (Fe), Barium (Ba) and lead (Pb) in the ground surface. Meanwhile, samples from Sg. Chini is higher in concentration of aluminium (Al), manganese (Mn) and zinc (Zn) in water content also high iron (Fe) concentration for addition in ground surface. This indicated that the higher concentration for these heavy metals element was resulted from mining activity nearby affecting the increment of water pollution in that area.

4.4 Water Quality Index (WQI)

Six parameters were chosen for the WQI; Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Suspended Solid (SS), Ammoniacal Nitrogen (AN) and pH. Calculations are performed not on the parameters themselves but on their sub-indices. The sub-indices are named SIDO, SIBOD, SICOD, SIAN, SISS and SIPH (Zainudin, 2010).

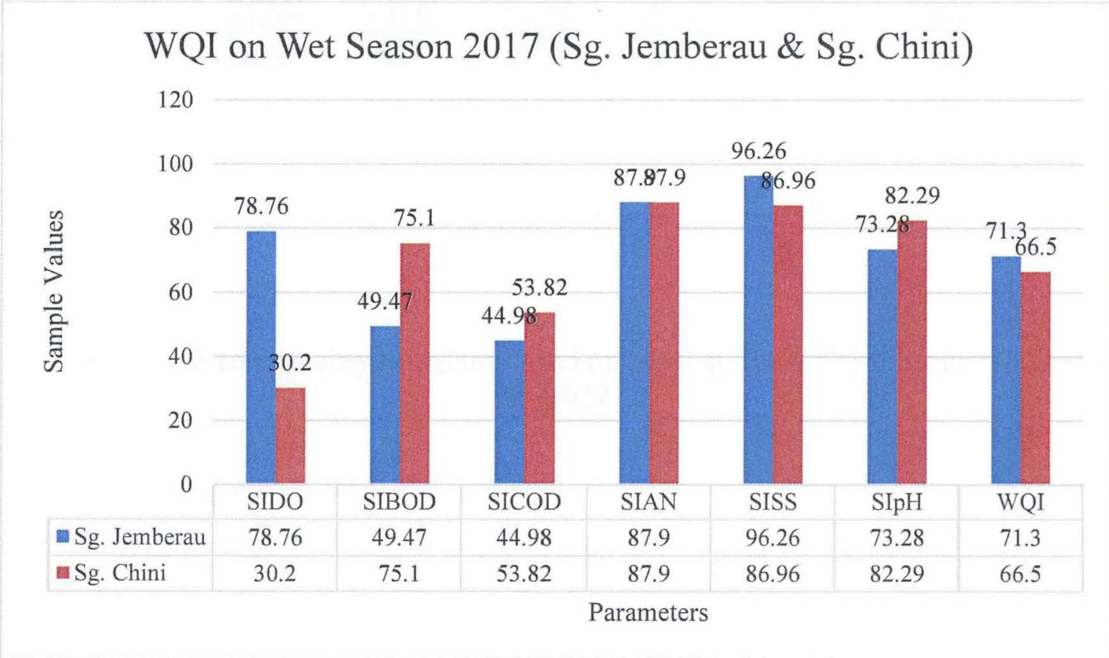


Figure 4.25 Water Quality Index at Sungai Jemberau and Sungai Chini during wet season 2017

Figure 4.25 show the Water Quality Index (WQI) for Sg. Jemberau and Sg. Chini. According to the DOE-WQI, the selected station which include Sg. Jemberau and Sg. Chini are classified as Class III which ranges from 51.9 to 76.5 while the WQI for Sg. Jemberau and Sg. Chini are 71.3 and 66.5 respectively. From this data, it means that the water quality of the Tasik Chini is varied with the location of sampling stations.

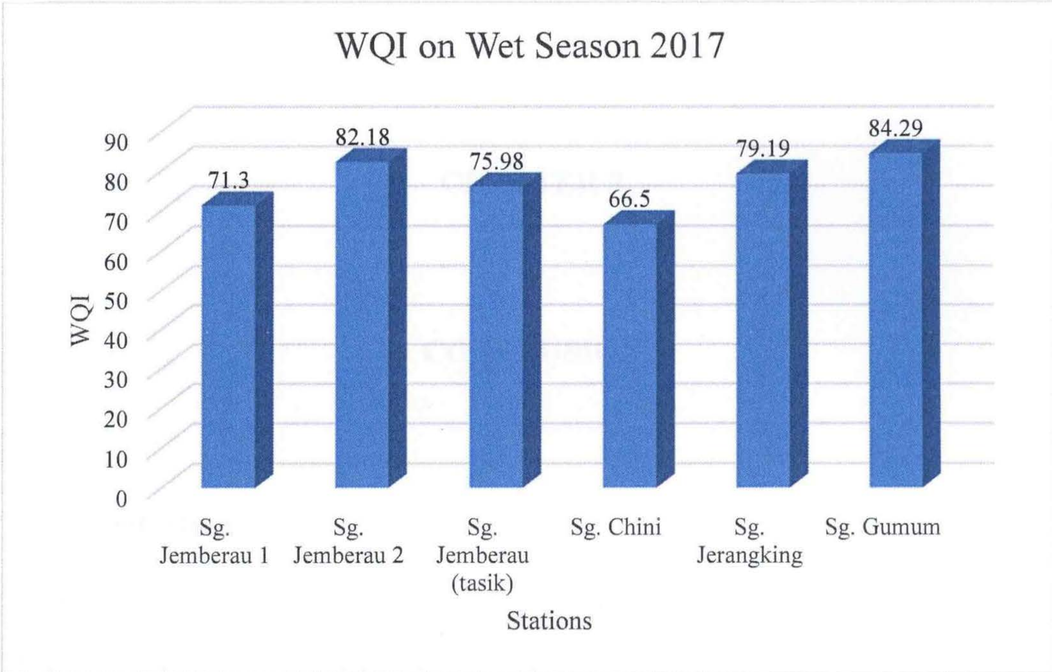


Figure 4.26 Water Quality Standard based on WQI at Tasik Chini during wet season in 2017

Figure 4.26 shows the water quality for all sampling stations at Tasik Chini. Water quality obtained from all stations is determined according to DOE-WQI and NWQS. Station at Sungai Jemberau 1 is classified as Class III while station at Sungai Jemberau 2 which is located at river outflow is in Class II. Sample obtained from station Sungai Jemberau (Tasik) is classified as Class III because the lake has slow movement of water and it is located nearby with mining area. At station Sungai Chini, it is in Class III which is slightly polluted. This is because that river is located around agricultural activities. It is believed that at the catchment studied, higher concentrations of DO, for example, was triggered by intensive agriculture activities. For Sungai Jerangking and Sungai Gumum, both of those location are identified as Class II which is in clean condition.

CHAPTER 5

CONCLUSION

5.1 Introduction

Water quality obtained from all stations is determined according to DOE-WQI and NWQS. Based on analysis, station at Sungai Jemberau 1 is classified as Class III while station at Sungai Jemberau 2 which is located at river outflow is in Class II. Sample obtained from station Sungai Jemberau (Tasik) is classified as Class III because the lake has slow movement of water and it is located nearby with mining area. At station Sungai Chini, it is in Class III which is slightly polluted. This is because that river is located around agricultural activities. It is believed that at the catchment studied, higher concentrations of DO, for example, was triggered by intensive agriculture activities (Mir, Gasim, Rahim, & Toriman, 2010). For Sungai Jerangking and Sungai Gumum, both of these location are identified as Class II which is in clean condition.

From the result of heavy metals concentration in water sample have slightly higher in concentration. Based on the result, we can conclude that mining activity is main source of pollution in Tasik Chini. The analysis of water quality showed that, the parameter concentration varied by location and season. The readings are affected by the land use at certain location. According to DOE-WQI, Tasik Chini is not suitable for drinking uses and needed extensive treatment. For fishery activities it is common of economic value and tolerant species. Water quality at Tasik Chini also classified as Class III according to (NWQS) for Malaysia in most stations.

5.2 Recommendations

Based on results and conclusion that have been made, mining and agricultural activities are the main source of water pollution at Tasik Chini. It is because the highest value of heavy metal concentration were found in the water sample. It is probably because the water sample taken nearest the mining activity discharge.

Here some recommendation to prevent the water quality at Tasik Chini deterioration according to mining activities and agriculture activities can be used in futures studies which are:

i. To get more accurate data, the water sample should be collect near to the activity area.

ii. Location for researched sample must be taken inside Tasik Chini main lake itself which the area is close with recreational activity.

iii. Sample analysis can be done or conduct more than 4 times to get a more accurate value for effluent quality and accurately studied.

iv. Follow the preservation test carefully to get more correct data.

v. To prevent Tasik Chini from any further damage, environmental preservation should be implemented by all involved parties.

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APPENDIX A1
IN-SITU TEST RESULTS

Table A1: Result of pH at Tasik Chini during wet season 2017

	Jemberau 1	Jemberau 2	Jemberau (tasik)	Chini	Jerangking	Gumum
November	9.96	-	-	10.23	-	-
January	7.55	7.78	6.90	6.76	7.21	6.93
Average	8.76			8.50		

Table A2: Electrical Conductivity (EC) in µS/cm at Tasik Chini during wet season 2017

	Jemberau 1	Jemberau 2	Jemberau (tasik)	Chini	Jerangking	Gumum
November	22.80	-	-	28.10	-	-
January	26.40	26.80	26.70	32.00	28.30	29.90
Average	24.60			30.10		

Table A3: Turbidity in NTU at Tasik Chini during wet season 2017

	Jemberau 1	Jemberau 2	Jemberau (tasik)	Chini	Jerangking	Gumum
November	15.10	-	-	33.30	-	-
January	2.77	2.49	5.38	21.20	11.30	11.90
Average	8.94			27.25		

Table A4: Dissolved Oxygen in mg/L at Tasik Chini during wet season 2017

	Jemberau 1	Jemberau 2	Jemberau (tasik)	Chini	Jerangking	Gumum
November	6.27	-	-	4.21	-	-
January	5.05	5.14	5.33	1.55	3.98	5.53
Average	5.66			2.88		

Table A5: Temperature in °C at Tasik Chini during wet season 2017

	Jemberau 1	Jemberau 2	Jemberau (tasik)	Chini	Jerangking	Gumum
November	26.9	-	-	28.4	-	-
January	26.4	26.3	27.7	26.6	28.0	28.8
Average	26.65			27.5		

APPENDIX A2
LABORATORY TEST RESULTS

Table A6: Biochemical Oxygen Demand (BOD) in mg/L during wet season 2017

	Jemberau 1	Jemberau 2	Jemberau (tasik)	Chini	Jerangking	Gumum
November	17.35	-	-	9.50	-	-
January	10.05	2.95	11.65	3.40	4.65	4.70
Average	13.70			6.45		

Table A7: Chemical Oxygen Demand (COD) in mg/L during wet season 2017

	Jemberau 1	Jemberau 2	Jemberau (tasik)	Chini	Jerangking	Gumum
November	68.00	-	-	59.00	-	-
January	32.00	35.00	19.00	20.00	29.00	34.00
Average	50.00			39.50		

Table A8: Ammoniacal Nitrogen (NH3-N) in mg/L during wet season 2017

	Jemberau 1	Jemberau 2	Jemberau (tasik)	Chini	Jerangking	Gumum
November	0	-	-	0	-	-
January	0.12	0.05	0.20	0.12	0.17	0.00
Average	0.12			0.12		

Table A9: Nitrate (NO3-) in mg/L during wet season 2017

	Jemberau 1	Jemberau 2	Jemberau (tasik)	Chini	Jerangking	Gumum
November	0.01	-	-	0.06	-	-
January	0.02	0.00	0.00	0.02	0.01	0.01
Average	0.02			0.04		

APPENDIX A3
LABORATORY TEST RESULTS

Table A10: Total Suspended Solid (TSS) in mg/L during wet season 2017

	Jemberau 1	Jemberau 2	Jemberau (tasik)	Chini	Jerangking	Gumum
November	17.00	-	-	23.00	-	-
January	6.00	2.00	57.00	21.00	107.00	78.00
Average	11.50			22.00		

Table A11: Suspended Solid (SS) in mg/L during wet season 2017

	Jemberau 1	Jemberau 2	Jemberau (tasik)	Chini	Jerangking	Gumum
November	1.0	-	-	20.0	-	-
January	3.0	3.0	27.0	17.0	7.0	7.0
Average	2.0			18.5		

Table A12: Phosphorus (P) in mg/L during wet season 2017

	Jemberau 1	Jemberau 2	Jemberau (tasik)	Chini	Jerangking	Gumum
November	0.83	-	-	0.09	-	-
January	0.22	0.04	0.47	0.02	0.02	0.04
Average	0.53			0.06		

Table A13: Potassium (K) in mg/L during wet season 2017

	Jemberau 1	Jemberau 2	Jemberau (tasik)	Chini	Jerangking	Gumum
November	20.0	-	-	26.0	-	-
January	6.4	6.1	7.0	23.0	5.5	8.0
Average	13.2			24.5		

APPENDIX A4
LABORATORY TEST RESULTS

Table A14: Hardness in mg/L during wet season 2017

	Jemberau 1	Jemberau 2	Jemberau (tasik)	Chini	Jerangking	Gumum
November (Mg / Ca)	1.19 / 1.95	-	-	2.28 / 1.95	-	-
January (Mg / Ca)	1.32 / 2.28	1.33 / 1.94	1.38 / 1.60	1.90 / 0.81	1.46 / 2.12	1.87 / 0.91
Average	1.26 / 2.12			2.09 / 1.38		

Table A15: Heavy Metal (AAS) in mg/L during wet season 2017

JEMBERAU 1	Cadmium (Cd)	Lead (Pb)	Chromium (Cr)	Copper (Cu)	Nickel (Ni)
November	0	1.107	0.452	0.078	0.015
January	0.004	0	0.016	0.041	-
Average	0.004	1.107	0.234	0.060	0.015
CHINI	Cadmium (Cd)	Lead (Pb)	Chromium (Cr)	Copper (Cu)	Nickel (Ni)
November	0	0.958	0.426	0.081	0.023
January	0.001	0	0	0.040	-
Average	0.001	0.958	0.426	0.061	0.023

APPENDIX A5
WATER QUALITY INDEX (WQI)

Table A16: Water Quality Index (WQI) during wet season 2017

STATION	DO	D0%	SIDO	BOD	SIBOD	COD	SICOD	AN	SIAN	SS	SISS	pH	SIpH	WQI	Class	Category
Sg. Jemberau 1	5.66	70.60	78.76	13.70	49.47	50.00	44.98	0.12	87.90	2.00	96.26	8.76	73.28	71.30	III	Slightly polluted
Sg. Jemberau 2	5.14	63.70	69.64	2.95	87.92	35.00	58.06	0.05	95.25	3.00	95.69	7.78	93.88	82.18	II	Clean
Sg. Jemberau (Tasik)	5.33	67.70	75.05	11.65	55.74	19.00	73.83	0.20	79.50	27.00	82.58	6.90	99.39	75.98	III	Slightly polluted
Sg. Chini	2.88	36.75	30.20	6.45	75.10	39.50	53.82	0.12	87.90	18.50	86.96	8.50	82.29	66.50	III	Slightly polluted
Sg. Jerangking	3.98	60.80	65.55	4.65	80.73	29.00	64.17	0.17	82.65	7.00	93.34	7.21	98.60	79.19	II	Clean
Sg. Gumum	5.53	71.60	79.99	4.70	80.52	34.00	59.04	0.00	100.5	7.00	93.34	6.93	99.49	84.29	II	Clean

APPENDIX A6
WATER CLASSIFICATION BASED ON WQI AND NWQS

LOCATION: Station 1 (Sg. Jemberau 1)

COORDINATE: N 03°25.166" E 102°55.859"

WEATHER: Wet season

	PARAMETER	UNIT	SAMPLE VALUE	WQI CLASS	NWQS CLASS
1	Temperature	°C	26.65	-	II
2	DO	mg/L	5.66	II	II
3	pH	-	8.76	I	II
4	EC	µS/cm	24.60	-	I
5	Turbidity	NTU	8.94	-	II
6	BOD	mg/L	13.70	V	III
7	COD	mg/L	50.00	III	III
8	NH3-N	mg/L	0.12	II	I
9	TSS	mg/L	11.50	I	I

APPENDIX A7
WATER CLASSIFICATION BASED ON WQI AND NWQS

LOCATION: Station 2 (Sg. Jemberau 2)

COORDINATE: N 03°25.166" E 102°55.859"

WEATHER: Wet season

	PARAMETER	UNIT	SAMPLE VALUE	WQI CLASS	NWQS CLASS
1	Temperature	°C	26.30	-	II
2	DO	mg/L	5.14	II	II
3	pH	-	7.78	I	I
4	EC	µS/cm	26.80	-	I
5	Turbidity	NTU	8.94	-	II
6	BOD	mg/L	2.95	II	II
7	COD	mg/L	35.00	III	III
8	NH3-N	mg/L	0.05	I	I
9	TSS	mg/L	2.00	I	I

APPENDIX A8
WATER CLASSIFICATION BASED ON WQI AND NWQS

LOCATION: Station 3 (Sg. Jemberau at Tasik)

COORDINATE: N 03°25.166" E 102°55.859"

WEATHER: Wet season

	PARAMETER	UNIT	SAMPLE VALUE	WQI CLASS	NWQS CLASS
1	Temperature	°C	27.70	-	II
2	DO	mg/L	5.33	II	II
3	pH	-	6.90	II	I
4	EC	µS/cm	26.70	-	I
5	Turbidity	NTU	5.38	-	II
6	BOD	mg/L	11.65	IV	IV
7	COD	mg/L	19.00	II	III
8	NH3-N	mg/L	0.20	II	II
9	TSS	mg/L	57.00	III	III

APPENDIX A9
WATER CLASSIFICATION BASED ON WQI AND NWQS

LOCATION: Station 2 (Sg. Chini)

COORDINATE: N 03°25.167'' E 102°55.860''

WEATHER: Wet season

	PARAMETER	UNIT	SAMPLE VALUE	WQI CLASS	NWQS CLASS
1	Temperature	°C	27.50	-	II
2	DO	mg/L	2.88	IV	IV
3	pH	-	8.50	I	I
4	EC	µS/cm	30.10	-	I
5	Turbidity	NTU	27.25	-	II
6	BOD	mg/L	6.45	IV	IV
7	COD	mg/L	39.50	III	III
8	NH3-N	mg/L	0.12	II	II
9	TSS	mg/L	22.00	I	I

APPENDIX A10
WATER CLASSIFICATION BASED ON WQI AND NWQS

LOCATION: Station 5 (Sg. Jerangking)

COORDINATE: N 3°23'11.7'' E 102°14'09.4''

WEATHER: Wet season

	PARAMETER	UNIT	SAMPLE VALUE	WQI CLASS	NWQS CLASS
1	Temperature	°C	28.00	-	II
2	DO	mg/L	3.98	III	III
3	pH	-	7.21	I	I
4	EC	µS/cm	28.30	-	I
5	Turbidity	NTU	11.30	-	II
6	BOD	mg/L	4.65	III	III
7	COD	mg/L	29.00	III	III
8	NH3-N	mg/L	0.17	II	II
9	TSS	mg/L	107.00	III	III

APPENDIX A11
WATER CLASSIFICATION BASED ON WQI AND NWQS

LOCATION: Station 6 (Sg. Gumum)

COORDINATE: N 3°26'16.5'' E 102°55'51.7''

WEATHER: Wet season

	PARAMETER	UNIT	SAMPLE VALUE	WQI CLASS	NWQS CLASS
1	Temperature	°C	28.8	-	II
2	DO	mg/L	5.53	II	II
3	pH	-	6.93	II	I
4	EC	µS/cm	29.90	-	I
5	Turbidity	NTU	11.90	-	II
6	BOD	mg/L	4.70	III	III
7	COD	mg/L	34.00	III	III
8	NH3-N	mg/L	0.00	I	I
9	TSS	mg/L	78.00	III	III

APPENDIX B1
NATIONAL WATER QUALITY STANDARD FOR MALAYSIA (NWQS)

PARAMETER	UNIT	CLASS				
		I	IIA/IIB	III#	IV	V
Al	mg/l	Natural levels or absent	-	(0.06)	0.5	Levels above IV
As	mg/l		0.05	0.4 (0.05)	0.1	
Ba	mg/l		1	-	-	
Cd	mg/l		0.01	0.01* (0.001)	0.01	
Cr (IV)	mg/l		0.05	1.4 (0.05)	0.1	
Cr (III)	mg/l		-	2.5	-	
Cu	mg/l		0.02	-	0.2	
Hardness	mg/l		250	-	-	
Ca	mg/l		-	-	-	
Mg	mg/l		-	-	-	
Na	mg/l		-	-	3 SAR	
K	mg/l		-	-	-	
Fe	mg/l		1	1	1 (Leaf) 5 (Others)	
Pb	mg/l		0.05	0.02* (0.01)	5	
Mn	mg/l		0.1	0.1	0.2	
Hg	mg/l		0.001	0.004 (0.0001)	0.002	
Ni	mg/l		0.05	0.9*	0.2	
Se	mg/l		0.01	0.25 (0.04)	0.02	
Ag	mg/l		0.05	0.0002	-	
Sn	mg/l		-	0.004	-	
U	mg/l		-	-	-	
Zn	mg/l		5	0.4*	2	
B	mg/l		1	(3.4)	0.8	
Cl	mg/l		200	-	80	
Cl_2	mg/l		-	(0.02)	-	
CN	mg/l		0.02	0.06 (0.02)	-	
F	mg/l		1.5	10	1	
NO_2	mg/l		0.4	0.4 (0.03)	-	
NO_3	mg/l		7	-	5	
P	mg/l		0.2	0.1	-	
Silica	mg/l		50	-	-	
SO_4	mg/l		250	-	-	
S	mg/l		0.05	(0.001)	-	
CO_2	mg/l		-	-	-	
Gross-α	Bq/l		0.1	-	-	
Gross-β	Bq/l		1	-	-	
Ra-226	Bq/l		<0.1	-	-	
Sr-90	Bq/l		<1	-	-	
CCE	µg/l		500	-	-	-
MBAS/BAS	µg/l		500	5000 (200)	-	-
O & G (Mineral)	µg/l		40; N	N	-	-
O & G (Emulsified Edible)	µg/l		7000; N	N	-	-
PCB	µg/l		0.1	6 (0.05)	-	-
Phenol	µg/l		10	-	-	-
Aldrin/Dieldrin	µg/l		0.02	0.2 (0.01)	-	-
BHC	µg/l		2	9 (0.1)	-	-
Chlordane	µg/l		0.08	2 (0.02)	-	-
t-DDT	µg/l		0.1	(1)	-	-
Endosulfan	µg/l		10	-	-	-
Heptachlor/Epoxide	µg/l		0.05	0.9 (0.06)	-	-
Lindane	µg/l		2	3 (0.4)	-	-
2,4-D	µg/l		70	450	-	-
2,4,5-T	µg/l		10	160	-	-
2,4,5-TP	µg/l		4	850	-	-
Paraquat	µg/l		10	1800	-	-

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

Source: Malaysia Environmental Quality Report 2009

APPENDIX B2
NATIONAL WATER QUALITY STANDARD FOR MALAYSIA (NWQS)

National Water Quality Standards For Malaysia

PARAMETER	UNIT	CLASS					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.3	0.9	2.7	> 2.7
Biochemical Oxygen Demand	mg/l	1	3	3	6	12	> 12
Chemical Oxygen Demand	mg/l	10	25	25	50	100	> 100
Dissolved Oxygen	mg/l	7	5 - 7	5 - 7	3 - 5	< 3	< 1
pH	-	6.5 - 8.5	6 - 9	6 - 9	5 - 9	5 - 9	-
Colour	TCU	15	150	150	-	-	-
Electrical Conductivity*	μS/cm	1000	1000	-	-	6000	-
Floatables	-	N	N	N	-	-	-
Odour	-	N	N	N	-	-	-
Salinity	%	0.5	1	-	-	2	-
Taste	-	N	N	N	-	-	-
Total Dissolved Solid	mg/l	500	1000	-	-	4000	-
Total Suspended Solid	mg/l	25	50	50	150	300	300
Temperature	°C	-	Normal + 2 °C	-	Normal + 2 °C	-	-
Turbidity	NTU	5	50	50	-	-	-
Faecal Coliform**	count/100 ml	10	100	400	5000 (20000)[a]	5000 (20000)[a]	-
Total Coliform	count/100 ml	100	5000	5000	50000	50000	> 50000

Notes :

N : No visible floatable materials or debris, no objectional odour or no objectional taste
* : Related parameters, only one recommended for use
** : Geometric mean
a : Maximum not to be exceeded

Source: Malaysia Environmental Quality Report 2009

APPENDIX B3
DOE WATER QUALITY INDEX CLASSIFICATION

DOE Water Quality Index Classification

PARAMETER	UNIT	CLASS				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	<0.1	0.1 - 0.3	0.3 - 0.9	0.9 - 2.7	>2.7
Biochemical Oxygen Demand	mg/l	<1	1 - 3	3 - 6	6 - 12	>12
Chemical Oxygen Demand	mg/l	<10	10 - 25	25 - 50	50 - 100	>100
Dissolved Oxygen	mg/l	>7	5 - 7	3 - 5	1 - 3	<1
pH	-	>7	6 - 7	5 - 6	<5	>5
Total Suspended Solid	mg/l	<25	25 - 50	50 - 150	150 - 300	>300
Water Quality Index (WQI)		<92.7	76.5 - 92.7	51.9 - 76.5	31.0 - 51.9	<31.0

Source: Malaysia Environmental Quality Report 2009

APPENDIX B4
WATER CLASSES AND USES

Water Classes And Uses

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

Source: Malaysia Environmental Quality Report 2009

APPENDIX B5
DOE WATER QUALITY CLASSIFICATION BASED ON WATER QUALITY INDEX

DOE Water Quality Classification Based On Water Quality Index

SUB INDEX & WATER QUALITY INDEX	INDEX RANGE		
	CLEAN	SLIGHTLY POLLUTED	POLLUTED
Biochemical Oxygen Demand (BOD)	91 - 100	80 - 90	0 - 79
Ammoniacal Nitrogen (NH_3-N)	92 - 100	71 - 91	0 - 70
Suspended Solids (SS)	76 - 100	70 - 75	0 - 69
Water Quality Index (WQI)	81 - 100	60 - 80	0 - 59

Source: Malaysia Environmental Quality Report 2009

APPENDIX B6
WQI FORMULA AND SUB-INDEX CALCULATION

WQI FORMULA AND CALCULATION

FORMULA

WQI = (0.22 * SIDO) + (0.19 * SIBOD) + (0.16 * SICOD) + (0.15 * SIAN) + (0.16 * SISS) + (0.12 * SIpH)

where;

SIDO = Subindex DO (% saturation)

SIBOD = Subindex BOD

SICOD = Subindex COD

SIAN = Subindex NH_3-N

SISS = Subindex SS

SIpH = Subindex pH

$0 \leq WQI \leq 100$

BEST FIT EQUATIONS FOR THE ESTIMATION OF VARIOUS SUBINDEX VALUES

Subindex for DO (in % saturation)

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

Subindex for BOD

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

Subindex for COD

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

Subindex for NH_3-N

SIAN = 100.5 - 105x	for $x \leq 0.3$
SIAN = 94 * exp(-0.573x) - 5 * I x - 2 I	for $0.3 < x < 4$
SIAN = 0	for $x \geq 4$

Subindex for SS

SISS = 97.5 * exp(-0.00676x) + 0.05x	for $x \leq 100$
SISS = 71 * exp(-0.0061x) - 0.015x	for $100 < x < 1000$
SISS = 0	for $x \geq 1000$

Subindex for pH

SIpH = $17.2 - 17.2x + 5.02x^2$	for $x < 5.5$
SIpH = $-242 + 95.5x - 6.67x^2$	for $5.5 \leq x < 7$
SIpH = $-181 + 82.4x - 6.05x^2$	for $7 \leq x < 8.75$
SIpH = $536 - 77.0x + 2.76x^2$	for $x \geq 8.75$

Note:

* means multiply with