DETERMINATION OF WATER QUALITY STATUS AND HEAVY METALS FOR SELECTED RIVER AT TASIK CHINI DUE TO LAND USE ACTIVITIES

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ABSTRAK

Tujuan kajian ini dijalankan adalah untuk mengkaji tahap kualiti air pada masa sekarang di sungai sekitar Tasik Chini iaitu Sungai Jemberau dan Sungai Chini pada musim kemarau tahun 2018 dan musim hujan tahun 2019. Terdapat tiga belas jenis parameter kualiti air dan tujuh jenis logam berat yang telah dibuat ujikaji dan dikelaskan berdasarkan Indeks Kualiti Air iaitu daripada Jabatan Alam Sekitar (DOE-WQI) dan Piawai Interim Kualiti Air Kebangsaan, Malaysia (INWQS). Antara parameter kimia dan fizikal yang telah dianalisis ialah pH, suhu, kekeruhan, Kekonduksian Elektrik (EC), Pepejal Terampai (SS), Jumlah Pepejal Terampai (TSS), Oksigen Terlarut (DO), Permintaan Oksigen Biokimia (BOD), Permintaan Oksigen Kimia (COD), Nitrogen Ammonia (NH3-N), Kalium (K), Nitrat (N) dan Fosforus (P) yang telah dianalisis di lokasi sampel diambil dan ujikaji di makmal juga dilakukan. Selain daripada itu, terdapat tujuh jenis logam berat yang telah diujikaji di makmal untuk mengenalpsti kepekatan logam berat yang terdapat di dalam sampel air daripada Sungai Chini dan Sungai Jemberau. Kuprum (Cu), Kromium (Cr) Kadmium (Cd), Ferrum (Fe), Zink (Zn), Mangan (Mn) dan Plumbum (Pb) telah diuji menggunakan alat yang terdapat di makmal iaitu Atomic Absorption Spectroscopy (AAS). Di samping itu, kepekatan logam berat untuk sampel tanah semasa musim hujan yang diambil berhampiran Sungai Jemberau telah diuji di Makmal Berpusat Universiti Malaysia Pahang dengan menggunakan alat Inductively Coupled Plasma Mass Spectrometry (ICP-MS), manakala sampel air dari Sungai Jemberau dan Sungai Chini semasa musim kering telah diuji dengan menggunakan kepekatan logam berat untuk sampel tanah yang diambil berhampiran Sungai Jemberau telah dibuat ujikaji di Makmal Berpusat Universiti Malaysia Pahang dengan menggunakan alat Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Menurut hasil kajian yang telah dibuat mengikut Indeks Kualiti Air (WQI), kualiti air di lokasi terpilih iaitu Sungai Jemberau dan Sungai Chini yang terletak berhampiran Tasik Chini telah dikelaskan sebagai Kelas III yang bermaksud air di sungai tersebut memerlukan rawatan secara meluas untuk memastikan kualiti air kembali bersih dan selamat digunakan sebagai air minuman kepada penduduk tempatan di masa hadapan. Menurut hasil kajian yang telah dijalankan, terdapat aktiviti yang dilakukan di sekitar Tasik Chini yang telah menyebabkan berlakunya pencemaran air yang melibatkan pelepasan logam berat. Antara aktiviti yang telah dikenalpasti sebagai penyebab utama pencemaran air di Tasik Chini ialah perlombongan besi, pertanian, pembalakan haram dan pembuangan sisa buangan daripada kawasan penempatan seperti tapak Program Latihan Khidmat Negara (PLKN).

ABSTRACT

The purpose of this study is to investigate the current water quality levels in the rivers around Lake Chini namely Jemberau River and Chini River during the dry season of 2018 and the rainy season of 2019. There are thirteen types of water quality parameters and seven types of heavy metals have been made experimental and classified based on the Water Quality Index which is from the Department of Environment (DOE-WQI) and the National Water Quality Interim Standard, Malaysia (INWQS). There are chemical and physical parameters that have been analyzed such as pH, temperature, turbidity, Electrical Conductivity (EC), Suspended Solids (SS), Total Suspended Solids (TSS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammonia Nitrogen (NH3-N), Potassium (K), Nitrate (N) and Phosphorus (P) were analyzed at the sample site and laboratory experiments were also performed. In addition, there are seven types of heavy metals that have been tested in the laboratory to determine the concentration of heavy metals contained in the water samples from the Chini River and the Jemberau River. Copper (Cu), Chromium (Cr) Cadmium (Cd), Iron (Fe), Zinc (Zn), Manganese (Mn) and Lead (Pb) were tested using laboratory tools named as Atomic Absorption Spectroscopy (AAS). In addition, heavy metal concentrations for soil samples during rainy season taken near the Jemberau River were tested at the University Malaysia Pahang Central Laboratory using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), while water sample from Jemberau River and Chini River during dry season were tested by using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Based on the results of the study conducted according to the Water Quality Index (WQI), the water quality at selected locations which are Jemberau River and Chini River located near Lake Chini was classified as Class III which means water in the river requires extensive treatment to ensure water quality return clean and safe to use as drinking water to the locals in the future. According to the results of the study, there are activities conducted around Lake Chini which have caused water pollution which involves the release of heavy metals. Among the activities identified as the main cause of water pollution in Lake Chini are iron mining, agriculture, illegal logging and waste disposal from residential areas such as the National Service Training Program (PLKN).

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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
ICP-OES	Inductively Coupled Plasma-Optical Emission 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
μs/cm	Microsiemens per centimetre
WQI	Water Quality Index

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Water is very important to human daily life. The quality of water that free from heavy metals from rivers, lakes, streams and ocean is very important for human in order to do their daily routine especially for drinking. Lakes are important source of freshwater which account only the very small part of around 0.01 percent of the global amount of water. Lakes are one of major water source in Malaysia as freshwater because they are often fed by rivers, rain and springs. The lake is very sensitive area because of the potential exposure pollutants from many sources. For example, pollution can flow through the water body of the lake by connecting to the river, water from runoff and from the deposition of atmospheric. The limited water movement within the lake affects the level pollution in the lake environment. Moreover, high concentrations pollutants can reduce the biodiversity of the lake ecosystem and change the physical environment around the lake.

In Malaysia, Tasik Chini which is located within the state of Pahang on the east coast of Peninsular Malaysia is the second largest natural lake in Malaysia after Tasik Bera. Surface area of the Tasik Chini covers 12,565 acres and it was surrounded by natural forest and aboriginal settlements. Tasik Chini has a unique shape that consists of 12 small lakes that local people called as “Laut” which is interconnected by natural channels. Tasik Chini has recreational value and ecological importance in terms of its biodiversity as this area richly endowed with biological resources and some 288 species of plants, 21 species of aquatic plants, 92 species of birds, and 144 species of freshwater fish.

1.2 Problem Statement

Tasik Chini is an ecological area which is importance due to large biodiversity and it is also very important for local parties' economy. The mainstay economy is mainly forest-based and agriculture-based activities (Habibah et al., 2013). These activities could be the source for pollution to the lake. There is logging, iron ore mining, rubber plantation, palm oil plantation and residential area. There is presence of heavy metals that come from iron ore mining activities which gives bad effect to water quality of Tasik Chini. Accumulation of metals and organic pollutants in the sediments may have long-term adverse effects on aquatic organisms (Sun et al., 2018).

Heavy metals concentration such as Lead (Pb), Iron (Fe), Manganese (Mn), Cadmium (Cd), Zinc (Zn) and Chromium (Cr) become increasing due mining activities. Heavy metals are a metallic element that has a relatively high density, specific gravity, or atomic weight and has toxic effects (Jamshaid et al., 2018). Meaning that, if there are unwell-operated for mining activity, it will causes increasing of heavy metal concentrations in water body because lake is a stagnant water area surrounding by land which is term water pollution refers to any types of aquatic pollution between two extremes of a highly productive body of water poisoned by toxic chemicals that eliminates living organisms. Water quality is among the most important environmental issues related to sustainable development, especially to ensure national drinking water safety (Gao et al., 2019). So that, it is important to maintain a good quality of water in our life.

1.3 Research Objectives

i. To evaluate the characteristics of each water quality parameters and to analyze the current status of water quality at Jemberau River and Chini River during rainy season in 2018 and dry season in 2019.

ii. To identify current heavy metals level in Jemberau River and Chini River.

1.4 Scope of Study

This research is conducted on October 2018 until February 2019. The location of study area is at Tasik Chini, Pahang. The scope of study in this research is about effect from land use activities to the water quality at Jemberau River and Chini River that are currently facing problem due to mining activity, logging activity and agricultural activity. All of this activity can contribute to the increasing of heavy metal concentration and will give worse effect to the water quality at rivers. The increase in water demands causes more conflict between the human system and the river ecological system (Yan et al., 2018). There are two types of test that were conducted which are in-situ test and laboratory test in order to identify the water quality of selected river near the Tasik Chini. There are 5 in situ tests have been conducted which are temperature, pH, electrical conductivity, dissolved oxygen (DO) and turbidity. For laboratory test, 10 tests are conducted which are Biological Oxygen Demand (BOD_5) 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 of selected rivers at Tasik Chini will be determined based on the classification from Interim National Water Quality Standards for Malaysia (NWQS) and Water Quality Index (WQI). The data and result that has been collect and carried out from this research will be useful for water quality record in future studies. This is a good result to safeguard the safety of drinking water in future. Furthermore, by examining the quality of water, it raises awareness among the people surrounding Tasik Chini on the hygiene of their domestic water use. This research will give people surrounding Tasik Chini an understanding on how to protect their daily health and maintain good environment with great ecosystems.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Maintaining a good water quality is essential since every day we use water at our home for cooking, cleaning, bathing, laundry and especially drinking water is important for our health and wellbeing. There is increasing concern about the presence of micropollutants, such as pharmaceuticals, pesticides and industrial compounds, in drinking water, with micropollutants detected in both source water and treated drinking water around the world (Neale and Escher, 2018). So that, requirements to provide high quality drinking water continues to be challenged by the increase in the amount of the substance enter the river system. Therefore, river water needs progressively treated more sophisticated procedures to achieve full purification. Moreover, our body comprises about 70% of the water and it is required to maintain the health of a human being that is entirely dependent on access available to adequate water supply.

In this research, Jemberau River and Chini River nearby Tasik Chini was selected as a study area to determine the water quality. There are land use activities near the lake such as logging, mining and agriculture which create pollution and caused problems for local residents. This activity will give negative effect for local community. For example, children bathing in the lake complain of itching, fish caught in the lake has become unsuitable to eat and indigenous people cannot do their routine to go to the area to collect roots that used in traditional medicine as the area has been closed for mining.

Measurement of water quality cannot be neglected as it will show the quality level either safe for us to use or not at certain areas. Life as we know it cannot be grown without water and will die without it. Water is essential for human survival, and access to potable public water supply is crucial for household health (Fakere et al., 2018). A lot of water supply is one of most important factors in order to develop a peaceful society. The disease burden through water results from water-associated communicable and non-communicable diseases and is influenced by water pollution with chemicals, solid waste (mainly plastics), pathogens, insects and other disease vectors (Boelee et al., 2019). Disease related to polluted water such as waterborne diseases which is caused by drinking contaminated water, Cholera and Guinea worm disease can be avoid if a good water resources management is apply all the time.

2.2 Surface Water

Surface water is water on the surface of the earth as in rivers, lakes, wetlands, or oceans. Eutrophication of inland waters, with symptoms such as high nutrients, excess primary production and deoxygenation of the hypolimnion, is one of the major man-made environmental problems (Tang et al., 2018). Eutrophication restricts the use of surface water for aesthetics, fisheries, recreation, industry, and beverages and thus has a serious local population and regional economic impact. Warming and eutrophication have emerged as the most severe environmental problems in coastal ecosystems worldwide, with variation in phytoplankton size scaling usually related to temperature and nutrients (Jiang et al., 2019). Increasing water pollution that comes from agricultural activity may contributes the raise of nutrients input into the lakes and hence stimulate the eutrophication problem. So that, a great progress to avoid waste disposal from agricultural activity must be done in order to control the point sources of pollution into the lakes.

2.3 Lake

The lake is serves to refill underground water, affect the water quality of the groundwater catchment, and maintain the biodiversity and habitat of the area. Dam, reservoirs and lakes are important in the conservation of basic national resource-water (Baharim et al., 2012). The two largest freshwater lakes in Malaysia which are Tasik Chini and Tasik Bera are located on the same river basin known as Pahang River Basin. Reservoirs are built for water supply storage, hydroelectric generation, flood controls and silt retention are part of many other major river basins in the country. As a lake also part of the catchment basin, integrated river basin management will also be able to maintain lake environment contained in it. Thus, it is necessary to find ecologically sound ways to conserve and protect valuable water resource of the lakes (El-Serehy et al., 2018). The complexity of the physical–chemical–biological ecosystem processes and relationships requires tool development to assess lake condition.

2.4 Tasik Chini

Tasik Chini is the study area for this research. Tasik Chini is the second largest natural lake in Peninsular Malaysia which is located at Pahang. This lake plays vital role as a natural wetland ecosystem due to its presences that can decrease the velocity, frequency and level of floods and riverbank erosion. This lake is important for local people for providing the fish source and basic facility for transportation such as boating. Since Tasik Chini flows to the main river which is Pahang River, it is influence by the intertidal monsoon season.

Tasik Chini is drained by Chini River, which is winding up 4.8 km before flowing into Pahang River which is the longest river in Peninsular Malaysia. In recent year, Tasik Chini undergoes major development in agricultural and re-activation of iron mine. Other than that, large areas of forest already convert to oil palm plantation and logging activities which caused losing of forest area and land degradation. Due to uncontrolled flowing-in of pollutants such as organics, nitrogen, phosphorus, receiving water bodies often experience algal blooming, floating, and deterioration of biodiversity, eventually negatively-affecting human life (Boelee et al., 2019). The worse effect from these changes were damages to the plant community, aquatic ecosystem and raise the sedimentations level in the lake.

2.5 Pollution of Lake

In recent years, specific concerns about the impacts of climate change on water eutrophication, which causes global environmental challenges regarding the management of water resources, have been raised (Nazari-Sharabian, Ahmad and Karakouzian, 2018). There are 4 types of lakes as known as oligotrophic lake, mesotrophic lake, eutrophic lake, and hypereutrophic lake. Firstly, oligotrophic lakes are lakes with low primary productivity, resulting from low nutrient content. The lake has low algae production, and as a result it often has very clear waters, with high water quality. Underwater lake usually has enough oxygen, so that lake often supports many species of fish which require cold water and oxygen. The oxygen content may be higher in deep lakes as the amount is higher than the hypolimnetic. The oligotrophic lakes are most common in cold areas under frozen rocks.

Secondly, mesotrophic lake is a lake with a middle level of productivity. These lakes are usually lakes and freshwater ponds with the sinking of aquatic plants and medium nutrients stage. The term mesotrophic also applies to terrestrial habitats which is mesotrophic soils has a moderate level of nutrients. Thirdly, eutrophic water bodies, usually lakes that have high biological productivity. Because of excessive nutrients, especially nitrogen and phosphorus, these water bodies are able to support many aquatic plants. Usually the water body will be controlled either by aquatic plants or algae. When aquatic plants dominate the water tend to be clear. When an alga dominates the water tend to become darker. These algae are involved in photosynthesis that supplies oxygen to the fish and biota that inhabit these waters. Sometimes, the blooming algae will occur and can eventually because fish kills due to respiration by algae and bacteria below. The eutrophication process can occur naturally and by human impact on the environment.

Lastly, the hypereutrophic lake is a rich nutrient lake characterized by disturbance and algae larvae and low transparency. The hypereutrophic lake has a depth of less than 3 feet, they have more than 40 micrograms/litre of chlorophyll and greater than 100 micrograms/litre phosphorus. Excessive algae flowers reduce the level of oxygen and prevent life from functioning at lower depths until the zone dies beneath the surface. Likewise, large algae flowers can cause bio dilution which is a drop-in pollutant concentration with tropical levels. This is contrary to biomagnification and due to a reduced algae concentration.

2.5.1 Point Source Pollution

Pollution of water means contamination of water or changing in physical, chemical or biological properties of water bodies. There are point sources pollution and non-point sources for pollutants in water. Point source is the cause of a single pollution, such as a pipe or drain. The waste from industry is normally discharged to rivers and the sea. For example, the leaking sewage pipes from factories and agricultures activities. Its source can be easily identified, which makes pollution issues easier to detect.

2.5.2 Non-point Source Pollution

Although buffer zones around aquatic areas are a useful method for controlling non-point source pollution and restoring natural ecosystem services, proper delineation methods for lakes remain poorly defined, restricting their protection and the rational utilization of resources (Li et al., 2019). The non-point source occurs through a combination of pollutants from a large area. Non-point source pollution is generally caused by land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. Nonpoint source pollution, unlike pollutants from industrial and sewage treatment plants, comes from many sources of resin. Non-point source pollution is caused by rain or snow moving upwards and through the ground. When the runoff moves, it takes and carries artificial and man-made pollutants, eventually putting it into lakes, rivers, groundwater and wetlands.

2.5.3 Run-0ff

Agricultural land use on slope areas is susceptible to nutrition loss via surface runoff, which would result in negative impacts on downstream waters (Wang et al., 2019). Surface runoff also known as overland flow is a water flow that occurs when excess rainfall, water, or other sources flows on the surface of the earth. This may occur because the saturated soil is full capacity, because the rain arrives faster than the soil that can absorb it, or because the non-resistant area (roof and sidewalk) sends their runoff to the surrounding soil that cannot absorb it Surface runoff is a main component of the water cycle which is the main agent in soil erosion by water.

2.6 Water Quality

The water quality pollutants, such as organic pollutants (permanganate index), nutrients (total phosphorus), total suspended solid, and chlorophyll-a were significantly influenced by the proportion of forest and grass land and the consumption of phosphate fertilizers in tributaries (Tian et al., 2019). Water quality can be defined as the chemical, physical, biological, and radiological characteristics of water. This is a measure of water conditions over the requirements of one or more biotic species and or to any human purpose. This is most often used with reference to a set of standards for which compliance, generally achieved through water treatment that can be assessed. The most commonly used standards for assessing water quality are ecosystem health, human safety, and drinking water. The water quality parameters for the lake, 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 National Water Quality Standards6

National Water Quality Standards For Malaysia

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

Notes

* = At hardness 50 mg/l $CaCO_3$

= Maximum (unbracketed) and 24-hour average (bracketed) concentrations

N = Free from visible film sheen, discolouration and deposits

Sourse : EQR2006

Table 2.2 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
Biological 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

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: Benchmarking River Water Quality in Malaysia 2010.

Table 2.4 Water Quality Formula

Sub-indices DO (% saturation)	
$x \leq 8$	SIDO = 0
$x \geq 92$	SIDO = 100
$8 < x < 92$	$SIDO = -0.395 + 0.03x^2 - 0.0002x^3$
Sub-indices BOD (mg/L)	
$x \leq 5$	$SIBOD = 100.4 - 4.23x$
$x > 5$	$SIBOD = 108^{-0.055x} - 0.1x$
Sub-indices COD (mg/L)	
$x \leq 20$	$SICOD = -1.33x + 99.1$
$x > 20$	$SICOD = 103e^{-0.0157x} - 0.04x$
Sub-indices ammonia, AN (mg/L N)	
$x \leq 0.3$	$SIAN = 100.5 - 105x$
$0.3 < x < 4$	$SIAN = 94e^{-0.573x} - 5\|x-2\|$
$x \geq 4$	SIAN = 0
Sub-indices TSS (mg/L)	
$x \leq 100$	$SITSS = 97.5e^{-0.00676x} + 0.05x$
$100 < x < 1000$	$SITSS = 71e^{-0.0016x} - 0.015x$
$x \geq 1000$	SITSS = 0
Sub-indices pH	
$x < 5.5$	$SIpH = 17.2 - 17.2x + 5.02x^2$
$x \leq x < 7$	$SIpH = -242 + 95.5x - 6.67x^2$
$7 \leq x < 8.75$	$SIpH = -181 + 82.4x - 6.05x^2$
$x \geq 8.75$	$SIpH = 536 - 77x + 2.76x^2$

WQI = 0.22*SIDO + 0.19*SIBOD + 0.16*SICOD + 0.15*SIAN + 0.16*SISS + 0.12*SIPH Equation 2.1

2.6.1 Physical Parameter

Physical and chemical parameters of the clean water are tracked and acquired in order to maintain the water quality (Miljojkovic, Trepsic and Milovancevic, 2019). Physical parameter can be determined as a feature of water that responds to the senses of sight, touch, taste or smell. Physical parameters can affect the quality of aquatic life associated with flow conditions, substrate properties and heat pollution.

2.6.1.1 Temperature

Water temperature is an important variable for aquatic ecosystems (Ouellet-Proulx et al., 2017). Water temperature is a physical property that shows how hot or cold water is. Because heat and cold are both arbitrary terms, temperature can further be defined as the average heat energy measurement of a substances. Thermal energy is the kinetic energy of atoms and molecules, so the next temperature measures the average kinetic energy of atoms and molecules. This energy can be transferred between substances as heat flow. Heat transfer, whether from the air, sunlight, another water source or thermal pollution can change the water temperature. Temperature becomes vital indicator for identifying healthy or poor water conditions. Temperature at Tasik Chini during wet and dry season was normally climatic.

2.6.1.2 Turbidity

Turbidity is defined as the decrease in transparency or clarity of a solution due to the presence of suspended and colloidal materials such as sand, clay, silt, organic and inorganic matter, algae or other microorganisms (Yeoh et al., 2019). Measurement of turbidity is a major test of water quality. Fluids may contain suspended solids consisting of different particle sizes. While some suspended substances will be large enough and heavy enough to quickly resolve to the bottom of the container if the sample of the liquid is left standing, very small particles will resolve very slow or not at all if the sample is frequently disturbed. This small solid particle causes the liquid to appear turbid.

Turbidity in open water may be due to phytoplankton growth. Land use activities that disturb land, such as mining, construction and agriculture can cause high levels of sediment entering the body of water during a rainstorm due to storm water runoff. Areas exposed to high bank erosion rates as well as urban areas also contribute large amounts of turbidity to nearby waters through rainwater pollution from paved surfaces for example bridges, roads and parking lots. Industries such as mining, quarry and coal recovery can produce extremely high levels of turbidity from colloidal particles.

2.6.1.3 Total Suspended Solid (TSS)

Total suspended solids (TSS) are considered to be one of the major pollutants that contributes to the deterioration of water quality, contributing to higher costs for water treatment, decreases in fish resources, and the general aesthetics of the water (Verma, Wei and Kusiak, 2013). Meaning that, it is also can be understand as the dry-weight of suspended, non-dissolved particles in a water sample that can be trapped by filters that are analyzed using filtering tools. It is a water quality parameter used to assess the specimen quality of each type of water such as ocean water or wastewater after treatment at a wastewater treatment plant. The amount of dissolved solids is another parameter taken through a separate analysis which is also used to determine the water quality based on the amount of soluble solids in water rather than suspended particles.

2.6.2 Chemical Parameter

Chemical parameter is related to chemical compounds or combinations of compounds that are considered toxic to human and aquatic life, or have potential to occur in a water environment at a dangerous level. It is necessary to know details about different physico-chemical parameters such as colour, temperature, acidity, hardness, pH, sulphate, chloride, DO, BOD, COD, alkalinity used for testing of water quality. Heavy metals such as Lead (Pb), Chromium (Cr), Iron (Fe), Mercury (Hg) and others are special attention because they produce chronic poisoning in aquatic animals. Some water analyses are reports with physics chemistry parameters have been given for studying the parameters of the study. Guidelines of different physic-chemical parameters also have been given for comparing the value of real water sample value.

2.6.2.1 Electrical Conductivity (EC)

An Electric Conductivity (EC) meter measure the potential electric current to be transported through water known as molar conductivity (electrolytic conductivity) and expressed as siemens (S). Electron flow from one set of electrodes to another in water across a space not due to water molecules but due to ions in water. Ions transport electrons and limit the number of electrons that can travel space with the amount of ions available or able to transport which is the higher the concentration the greater the flow.

The pure water itself is a worse conductor, therefore the EC meter will read 0.0 in rainwater, reverse osmosis water or de-mineral water. Instead, saline seawater is a better conductor. It has various applications in engineering and research, with common use in hydroponics, aquaponics, aquaculture and freshwater systems to monitor the amount of salts, nutrients or impurities in the water

2.6.2.2 pH

Generally, water with pH less than 7 is considered as acidic and with pH more than 7 is considered as alkaline. The normal range for pH in surface water systems is 6.5 to 8.5 while for groundwater systems is 6.0 to 8.5. Alkaline is a measure of the water's ability to resist pH changes that tend to make the water more acidic. Measurement of the alkalinity and pH needed to determine water corrosivity.

In general, water with low pH which is less than 6.5 can be acidic and corrosive. Therefore, water can release metal ions such as lead, zinc, iron, copper and manganese from the aquifer, pipe fixtures, and piping. Therefore, low water with pH may contain high toxic metals, causing premature damage to metal pipes, and has the same aesthetic problems as metal or sour taste and clothing dyes. The primary way to treat a low pH water problem is to use a neutralizer. The feeder provides a solution to water to prevent the water from reacting with a home tap or contributing to electrolytic corrosion. The usual neutralized chemicals are ashtrays which is if neutralized with soda ash can increases the sodium content of the water.

2.6.2.3 Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand (BOD) is the amount of dissolved oxygen required for aerobic biological organisms in a water body to break the organic components available in a given water sample at certain temperature over a particular time period (Ahmed, Mustakim and Shah, 2017). The BOD readings, tells how much the oxygen is used. The BOD level during the dry season is higher than the rainy season. This is because the large amount of fresh water that dilutes the organic matter at the surface of the water which causes the BOD to decrease during the dry season. The BOD values are usually the amount of oxygen needed for carbonate. The National Water Quality Standards have set the threshold level for Malaysia surface water is 6 mg/L.

2.6.2.4 Dissolved Oxygen (DO)

The dissolved oxygen is the amount of oxygen gas (O_2) dissolved in water. Oxygen enters water through direct absorption from the atmosphere, with rapid movement or as residual product of plant photosynthesis. Additionally, DO is essential for the survival of aquatic organisms (van der Lee et al., 2018). The temperature of the water and the amount of water moving can affect the level of dissolved oxygen. Soluble oxygen is easier in cold water than warm water. Sufficient dissolved oxygen is essential for good water quality and is necessary for all forms of life. The dissolved oxygen rate below 5.0 mg/L causes pressure to aquatic life. Lower concentration causes higher pressure, while the oxygen levels below 1-2 mg/L for several hours can cause large fish kill because dissolved oxygen level is too high or too low may harm aquatic life.

2.6.2.5 Chemical Oxygen Demand (COD)

COD is the amount of oxygen uses when the in water is oxidized by a strong oxidant chemical. The National Water Quality Standard (NWQS) set the level of COD threshold for surface water in Malaysia is 50.00 mg/L. COD testing can be used to easily measure organic amounts in water. The most common use of COD is to measure the amount of oxidized pollutants present on the surface of the water such as lakes and rivers. COD is useful in terms of water quality by providing a metric to determine effluent effect on the receiving body such as biochemical oxygen demand (BOD).

2.6.2.6 Heavy Metals

The term heavy metal refers to a metallic chemical element having a relatively high density and toxic at low concentrations. There are some examples of heavy metals such as mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), and lead (Pb).

Heavy metals are natural components of the Earth's crust. They cannot be insulted or destroyed. They enter our bodies through drinking water, food and air. As trace elements, some heavy metals such as copper, selenium and zinc are important for maintaining human body metabolism. However, at higher concentrations heavy metals can cause poisoning. Heavy metal poisoning can cause for example, from drinking water pollution such as main pipes, high ambient air concentrations near discharge sources or intake through food chains.

Sediment pollution is an important environmental problem, and the remediation of heavy metal contaminated sediments is crucial to river ecosystem protection, especially in mining regions (Ma et al., 2019). Heavy metals are harmful because they tend to bioaccumulate. Bioaccumulation can be understood as increasing in chemical concentration in biological organism over time, compared to the chemical concentration in the environment. Components accumulate in living things whenever they are taken and stored faster than broken down. Human impacts on the environment or anthropogenic effect on the environment include changes to the biophysical environments, biodiversity, ecosystem and natural resources caused directly or indirectly by humans, including global warming, degradation such as ocean acidification, mass extinction and loss of biodiversity, ecological crisis, and ecological collapse. Changing the environment to meet the needs of the community causes severe consequences, which is even worse as an issue of raising the human population. Some human activities that cause damage which is either directly or indirectly to the environment on a global scale including human reproduction, excessive use, exploitation, pollution, and deforestation.

2.6.2.7 Nitrogen as Ammoniacal Nitrogen

Presence of ammoniacal nitrogen in surface water can endanger aquatic life and human life. The presence of ammonia in surface water is an indication of pollution (Chaneam et al., 2018). Due to the ammonia (NH) contains highly toxic properties and usually ammonia is removed from industrial wastes, municipal and agricultural wastes in bulk. In the rainy season, Pahang River water flow to Tasik Chini causes more NH3-N thus stimulate water quality change in the 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.

CHAPTER 3

STUDY AREA AND METHODOLOGY

3.1 Introduction

Tasik Chini is the second largest natural lake in Peninsular Malaysia, located in Pahang state about 100 km from Kuantan which is the capital of Pahang. This lake covers 12,565 acres and consists of various flora and fauna (Mohd Jaafar, S., 2013). Tasik Chini consists of 12 lakes or open water bodies that are recognized as 'seas' by local residents. The 12 'seas' are, Melai Upstream, Melai Downstream, Perupuk, Serodong, Jemberau, Kenawar, Celau, Jerangking, Gumum, Chini Upstream, Chini Downstream and Chok. Basically, the lake is surrounded by low hills and corrugated soils that form catchment areas. The area of Tasik Chini varies from 150 to 350 hectares, depending on seasonal change and 700 hectares of swamp forest and freshwater swamp. Tasik Chini is typical of the equatorial climate of Peninsular Malaysia, which is characteristic by moderate average annual rainfall, temperature and humidity.

This lake plays an important role as a natural wetland ecosystem as its presence decreases the frequencies, stages and flood barriers and erosion of river banks. Other vital roles provided by the lake include fish resources for the local communities, basic amenities for life and as a mean transportation such as boating. Since Tasik Chini flows into the main river which is Pahang River, it is very influential by the intertidal monsoon season. The strong river flowing from the Pahang River which is a lake through the Chini River in the high monsoon season carries high suspended solids and other pollutants such as ammonia-N. Tasik Chini is flowed by the Chini River, which meanders as far as 4.8 km before flowing into the Pahang River, the longest river in

Peninsular Malaysia. In 1995, a small barrage about 2 m height was constructed downstream of Chini River to accommodate the lake for tourism purposes.

Therefore, the water level at the lake has increased and became stagnant. This has changed the Lake Chini ecosystem from the half-lentic system to lenticular. In recent years, the hinterland of Tasik Chini undergoes major development in agriculture and other activities such as building infrastructure for the National Service Centre located near the Lake riparian zone and reactivating the iron mines. Large forest area conversion to oil palm plantation and illegal logging has contributed to the loss of forest land and land degradation. The bad effects for this change are damages to plants community were damages to the plant community, aquatic ecosystems and sedimentation rates increase in lakes.

3.2 Map Location

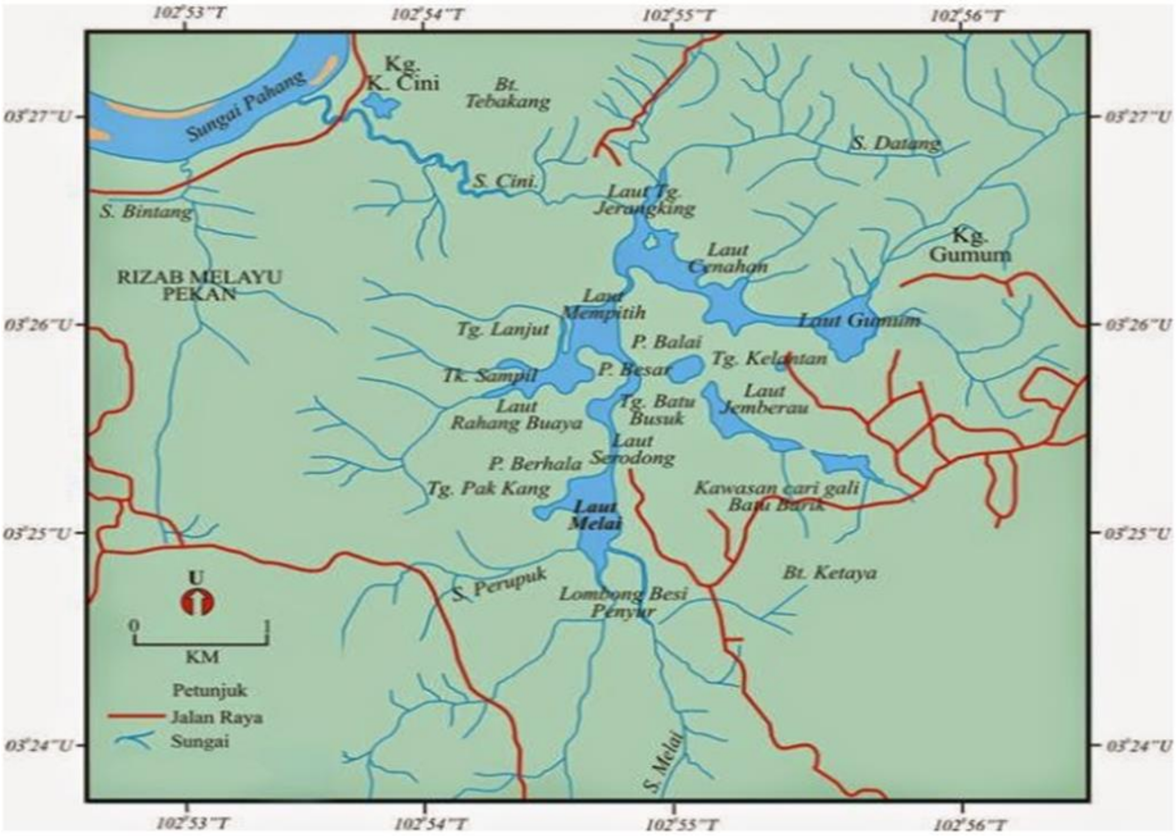


Figure 3.1 Maps of Tasik Chini, Pekan Pahang

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

3.3 Sampling Area

There are 2 stations in total to be selected within the Tasik Chini area to collect the sample during rainy season and dry season which are:

i. Station 1 at Jemberau River
ii. Station 2 at Chini River

3.3.1 Jemberau River

Figure 3.2 Jemberau River, Tasik Chini

Figure 3.3 Coordinate for Jemberau River

Figure 3.2 show the view of Jemberau River. The coordinate for this station is 03˚41.952'' North and 102˚93.121'' East as shown in Figure 3.3.

3.3.2 Chini River

Figure 3.4 Chini River, Tasik Chini

Figure 3.5 Coordinate for Chini River

Figure 3.4 show the view of Chini River. The coordinate for this station is 03˚45.091’’North and 102˚89.194’’ East in Kuantan, Pahang as shown in Figure 3.5.

3.4 Methodology Flow Chart

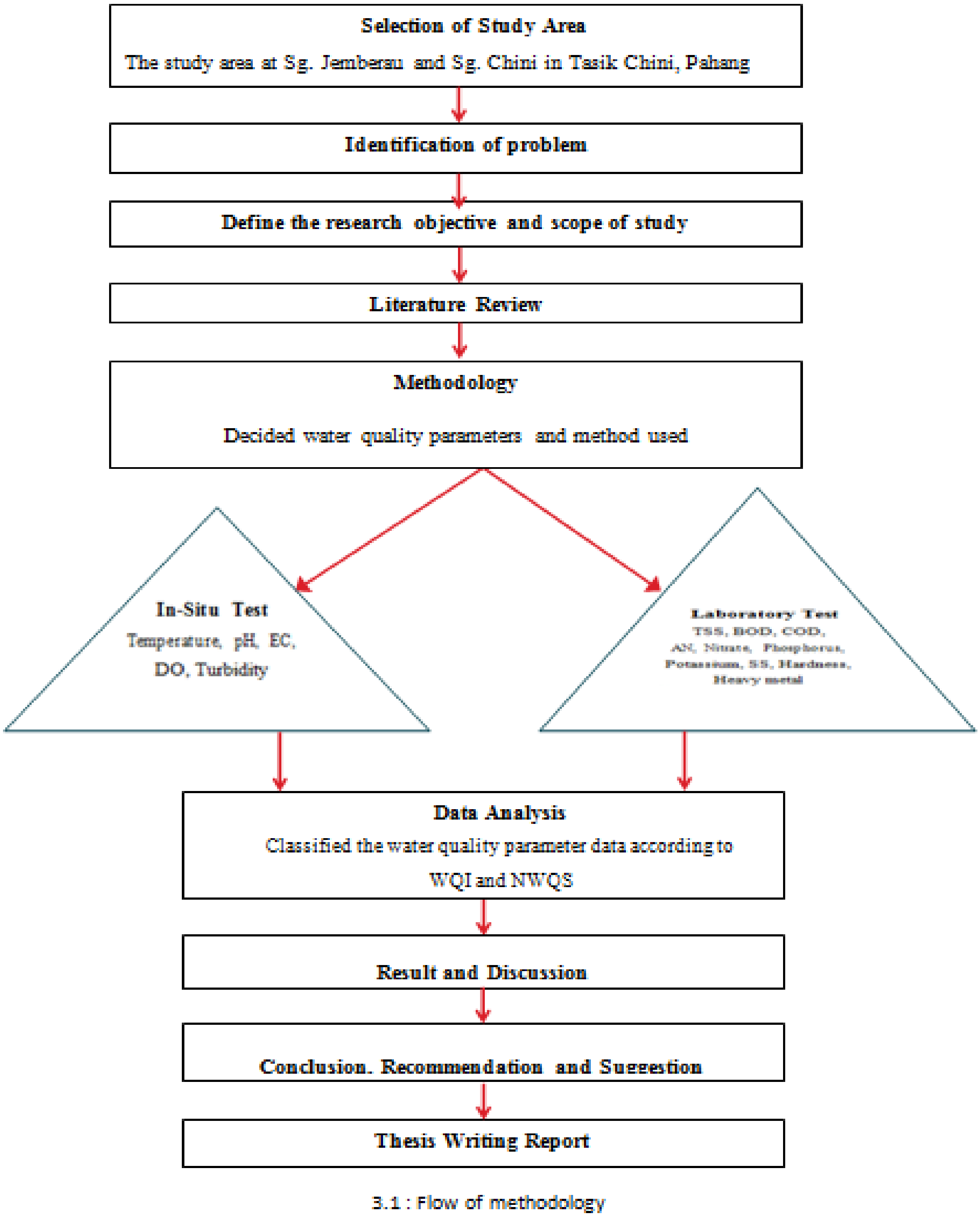


Chart 3.1 Flow of methodology

Chart 3.1 show the methodology flow to be carried out during the research. Two stations are Jemberau River and Chini River. Water samples are taken twice during the rainy season and dry season. Water samples for the rainy season were taken on October 2018, while samples for dry season were taken on February 2019. At each station, three bottles of 500 ml for water sample was collected at 10 cm below the surface area. There are two types of test carried out which are in-situ tests and laboratory tests. For in-situ tests, five parameters are measure such as temperature, pH, turbidity, electrical conductivity (EC), and Dissolved Oxygen (DO). While for laboratory test, 10 tests were conducted on 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. Once all the parameters are tested, the data will be analyzed and classified based on WQI and NWQS. From the result and discussion, the water quality of Jemberau River and Chini River at Tasik Chini will be determined.

3.5 Research Method

3.5.1 Sampling Station

Two 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 3.6 Determining position of sampling station

3.5.2 Preparation for Collecting Sample

1L High Density Polyethylene (HDPE) plastic bottles are cleaned before collecting the samples. All the apparatus was examined to check the functionality and accuracy of apparatus before taking the sample.

Figure 3.7 All apparatus are examined and prepared

3.5.3 Sample Preservation

Water samples are collected at 10cm below the surface water using HDPE bottles. The sample should be kept in the ice box at temperature 4ºC and transported to the laboratory for analysis. The preservation technique of water sample was different based on the tests that to be carried out. The preservation techniques are shown in the table below:

Table 3.1 Preservation Techniques

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

3.6 In-situ Test

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

Figure 3.8 In-situ Parameters Measurement

3.7 Laboratory Test

Phosphorus test, Potassium test, Chemical Oxygen Demand (COD) test, Biochemical Oxygen Demand (BOD) test, Total Suspended Solid (TSS) test, Suspended Solid (SS) 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 can be defined as physical characteristics of the water such as turbidity, temperature, clarity, colour, salinity, dissolved solid, suspended solids and total suspended solids.

3.8.1.1 Turbidity

Turbidity is cloudiness of a fluid caused by large numbers of individual particles that are generally invisible to the naked eye. Measurement of turbidity is a major test of water quality. Fluids may contain suspended solid consisting of different particles sizes. While some suspended substances will be large enough and heavy enough to quickly resolve to the bottom of the container if the sample of the liquid is left standing, very small particles will resolve only very slowly or not at all if the sample is frequent disturbed or particles are colloidal. These small solid particles cause the liquid to appear turbid. River turbidity is measured by multipurpose parameters of water quality equipment. Multipurpose parameter water quality equipment was drowned in the river and the frequency values will be recorded.

Figure 3.9 Recording of Turbidity Value

3.8.1.2 Temperature

Each river was taken the temperature respectively by using multipurpose parameter water quality equipment. The sensor of the multipurpose parameter water quality equipment was dropped into the river and the value of temperature was recorded.

3.8.1.3 Total Suspended Solid (TSS)

The Total Suspended Solid (TSS) procedure can be detected by APHA 2540 D standard (21st Edition), Standard Method for the Examination of Water and Wastewater. The filter disc was inserted to the base and flanked in the funnel. When the vacuum was used, the disc was washed with three distilled water of 20 mL in succession. All water trails have been removed by continuing the vacuum after the water is passed. Aluminium has been dried in the oven at temperature of 103^{o}C to 105^{o}C for one hour. Then the dish was put in the desiccators for about 30 minutes and then weighed. Subsequently, the total sample volume which is maximum of 200 mL was selected and produced not exceeding 200mg of total suspended solids. Filters are placed on the base and tied to the funnel during vacuum use. Filter was wet with small volume of distilled water to prevent filter against base. Then the sample was shaking vigorously and 100 mL of the sample quantitatively transferred to the filter. All water traces were removed by continuing the vacuum after the sample was approved. The pipette and funnel were rinsed to the filter with a small volume of distilled water. Finally, the disc filter was removed carefully from the base then the filter has been dried for at least one hour at 103^{o}C to 105^{o}C. After that, it is cooled in the desiccators and weighed. The same procedure has been repeated for samples at other stations and the result was recorded. Total Suspended Solid (TSS) formula is shown below.

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

Where;

A = weight of dried residue + dish, mg

B = weight of dish, mg and

S = sample volume, 100ml

Equation 3.1 Total Suspended Solid (TSS) formula

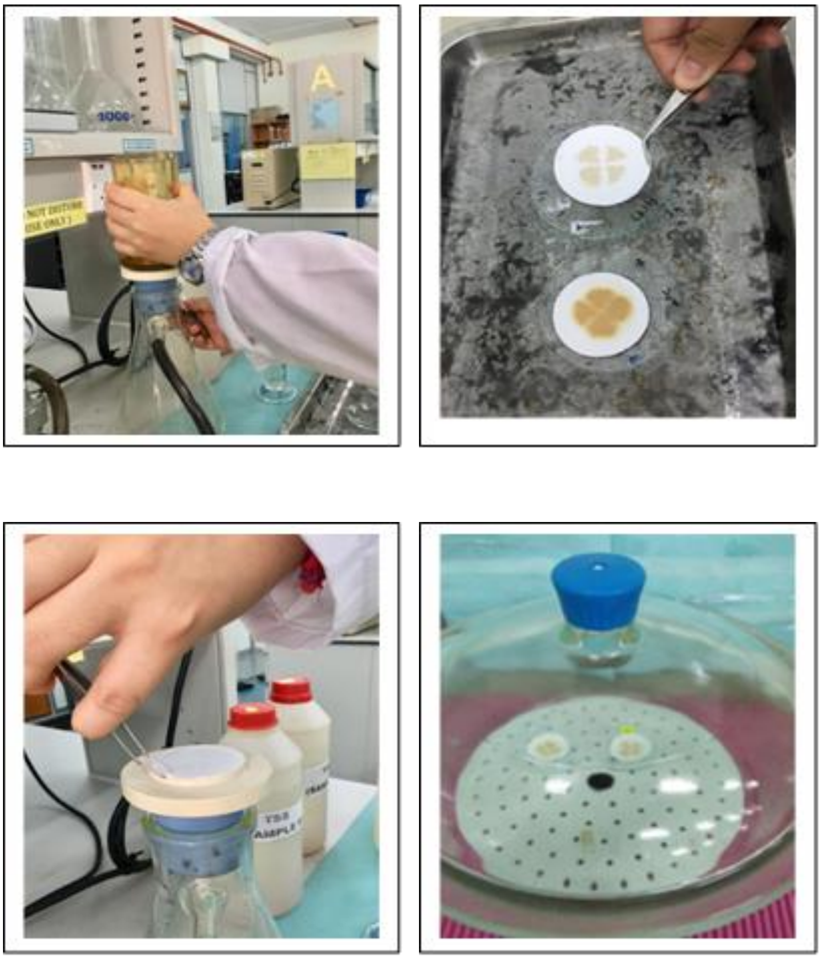


Figure 3.10 Measurement of Total Suspended Solids

3.8.1.4 Suspended Solid (SS)

Suspended Solid was followed Photometric Method1 (5 to 750 mg/L) based on HACH DR5000 Method 8006. Select and start the 630 Suspended Solid programs on the spectrophotometer. Press the "Start" button to test the function of the machine can operate well. The 500 ml sample was blend using a blender using high speed for two minutes. The sample from blender was pour into a 600 ml of beaker. The sample was stirring and immediately pours 25 ml of the blended sample into the sample cell as known as the prepared sample. Next for the second cell with 25 ml of tap water will fill or deionized water as known as the blank. The gas bubbles in the water have been removed by rotating 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.

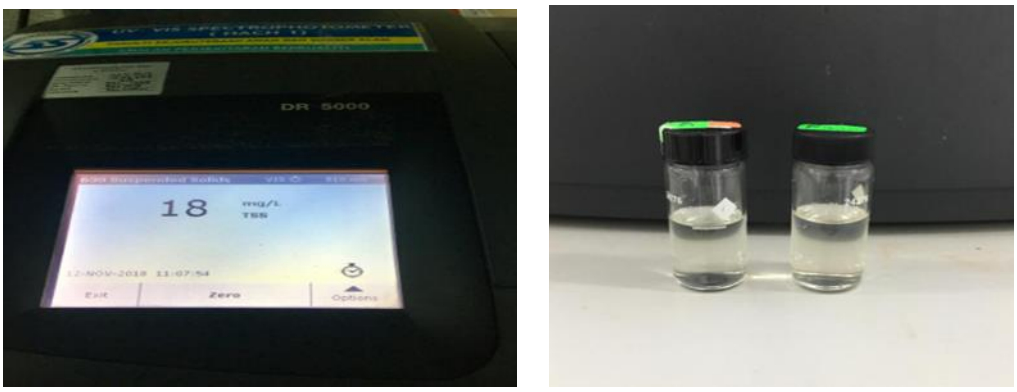


Figure 3.11 Measurement of Suspended Solids using DR5000

3.8.2 Chemical Parameter

The chemical properties of natural water are the reflection of the soils and the rocks where the water has been connected. In addition, agricultural, urban runoff and municipal and industrial treated wastewater affect water quality. Microbial and chemical transformations also affect the chemical properties of water. 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)

Biochemical Oxygen Demand (BOD) followed by the standard of In-House method based on APHA 5210B (21st Edition), Standard Method for the Examination of Water and Wastewater. The sample pH of water samples for all station was checked before test but prior experienced showed that the pH was within acceptable range. If the sample contains alkalinity or acidity, neutralize the sample to pH about 6.5 to 7.5 using 1N sodium hydroxide (NaOH) or sulfuric acid (H2SO4). Samples measured 100mL each and 400mL dilution were poured into each clean beaker and pour into a BOD bottle. Subsequently, the initial DO is determined after the BOD bottle is filled with diluted samples. In the event of rapid early DO intake is important, the time interval between preparing dilution and the initial DO measurement is not critical but should not exceed 30 minutes. The BOD bottles containing samples and dilution water of all stations were incubated in refrigerator by 20°C which are BOD bottles containing samples and dilution water. Samples were removed from the incubator after 5 days of incubation and left to reach room temperature. The DO in the dilution sample were determined by the DO meter and result was recorded. The formula for Biochemical Oxygen Demand (BOD) is shown in Equation 3.2.

$$BOD_t = (DO_i - DO_5 / (P)$$

Equation 3.2 Biochemical Oxygen Demand (BOD)

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.

$$P = \frac{\forall_S}{\forall_S + \forall_{DW}}$$

Equation 3.3 Dilution Factor formula

$$BOD_t = L_0 (1- 10^{-KT}))$$

Equation 3.4 Biochemical Oxygen Demand (BODt) formula

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}

$$K_T = K_{20} \text{ x } \theta^{T-20}$$

Equation 3.5 Reaction Rate Constant

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

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

Equation 3.6 Ultimate BOD (L_0)

Where

$_{T}L_O$ = ultimate BOD at temperature T, mg/L

$_{20}L_O$ = ultimate BOD at 20˚C, mg/L

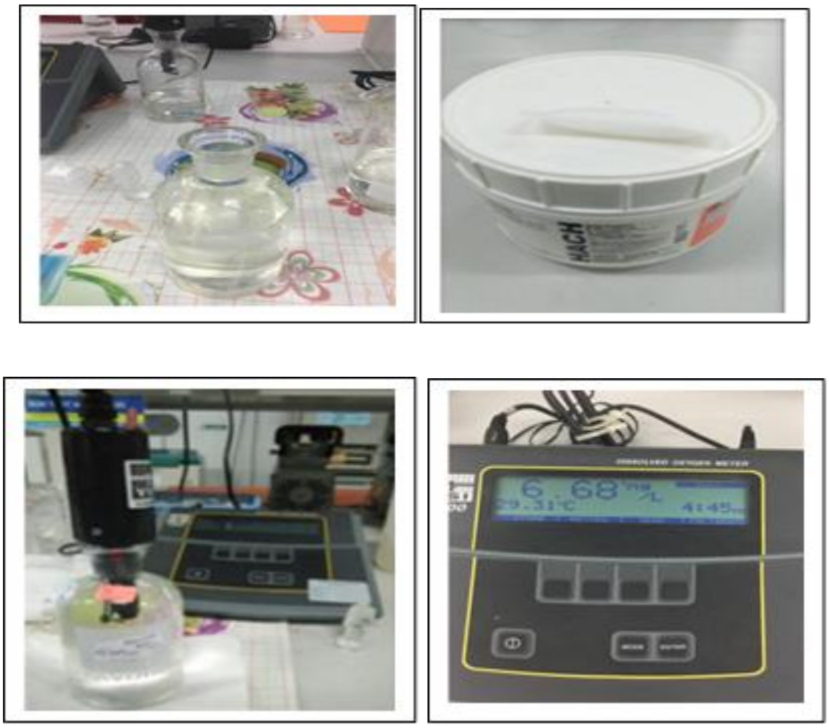


Figure 3.12 Biochemical Oxygen Demand (BOD) Experiment

3.8.2.2 Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) followed by the standard of In-House method based on HACH DR 5000 Method 8000. The COD Reactor was turned on and heated to 150˚C. The COD Reactor was seen to select pre-program temperature applications. One vial was held at a 45 –degree angle. A clean volumetric pipette was used to add a sample of 2.00 mL of into the vial. The micro pipette was used to add 0.20mL to the 200-15,000 mg/ L. Low range for the samples from station 1, and 2. After that, tight cap vials. Then, the vials were rinsed with water and rubbed with a clean paper towel. The vials were held by the cap over a sink. The vials are then turned over slowly for several times to mixed. The vials were put into a heated COD reactor for two hours. The vials were placed in the shelf and cooled to room temperature for 20 minutes. For the colorimetric determination method, select a low range test was made based on the sample. Outside 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 display shows 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 a high range plus COD digestion reagent vials were used, the results were multiplied by 10 times.

Figure 3.13 Chemical Oxygen Demand (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 minutes 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 3.14 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 NH_3–N) based on HACH DR5000 Method 8155. Select and start the 385 Ammonia 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 was 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 was 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 NH_3–N were displayed. The sample wipe and placed into a cell holder and the results were recorded as in mg/L NH_3–N.

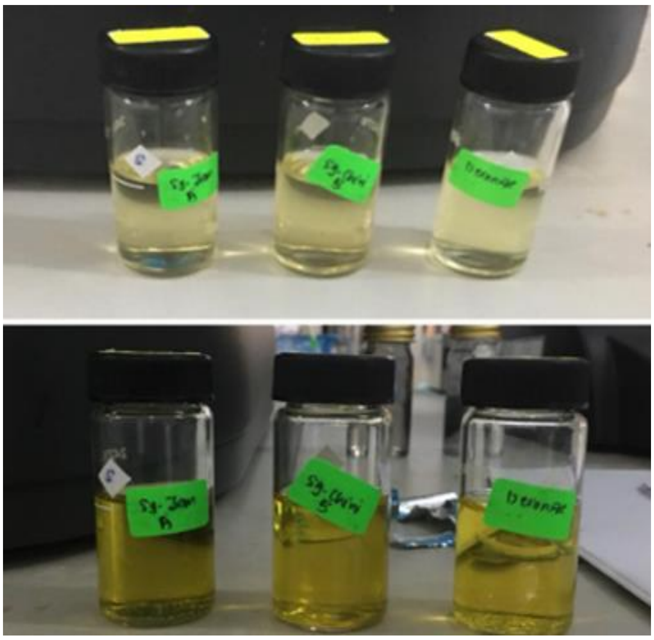


Figure 3.15   Ammoniacal Nitrogen Reading by Using DR5000

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. The 'ON/OFF' button has been pressed to start. was press to start. Then press 'CAL' button to calibrate. The display will prompt for Standard 1. Place the pH electrode in one of the buffers. Press the '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 while and hold it. After that, prepare the 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 show the 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 was 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.

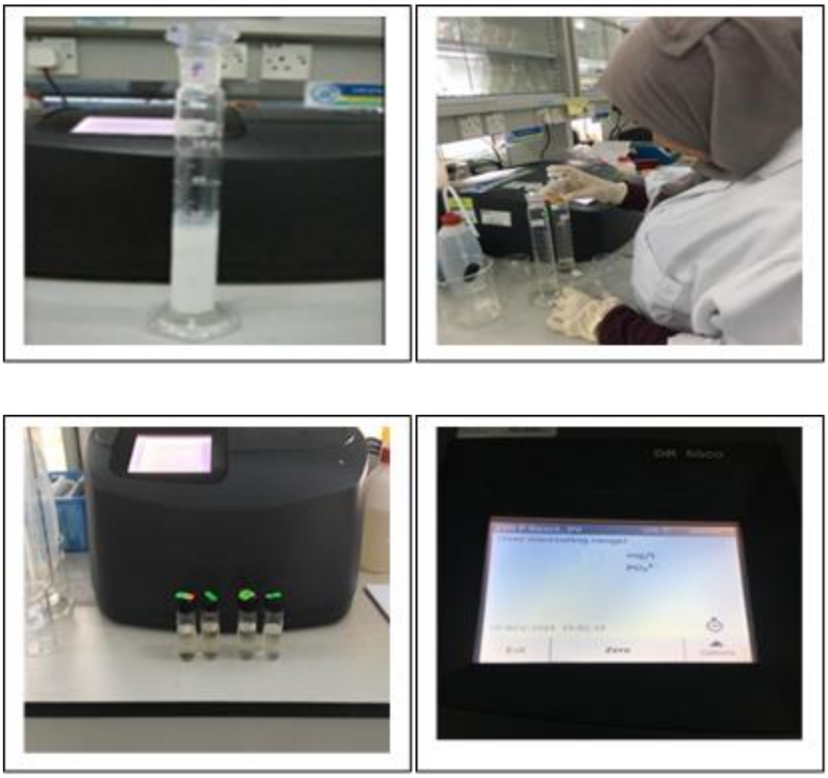


Figure 3.16 Potassium Experiment by Using DR5000

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 seven targeted heavy metals which are Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Manganese (Mn), Zinc (Zn) and Iron (Fe). 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) which is conducting by Central Laboratory in University Malaysia Pahang.

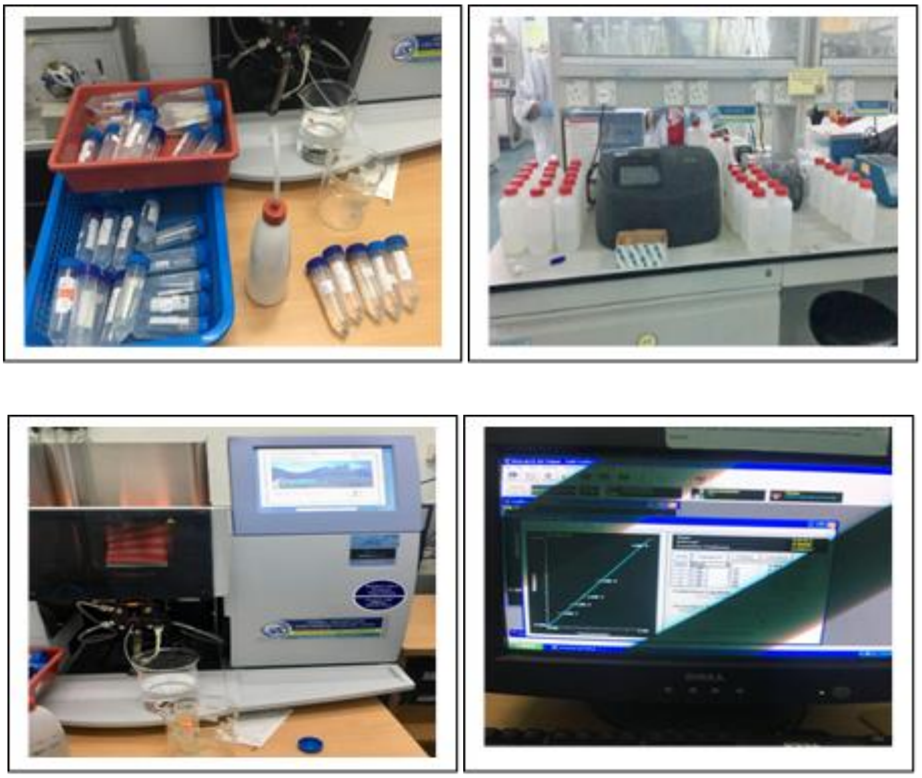


Figure 3.17 Heavy Metals Test by Using AAS Method

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter shows the results of each discovery parameter that will be analyze and discuss in 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 Chini River (Navigational Lock Gate) and Jemberau River. Another reason we carrying on this project are also to identify the current condition based on wet and dry season in Jemberau River and Chini River. All these stations are located surrounding Tasik Chini.

For this research, there are two test that had been done which are in-situ test and laboratory test. Parameters that had been tested for physical parameters are turbidity, total suspended solid (TSS), temperature and electrical conductivity (EC). While, chemical parameters tested are Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), pH, Nitrate (NO_3^-), Phosphorus (P), Potassium (K) and Ammoniacal Nitrogen (NH3-N). All data were collected and analyzed from both in-situ and laboratory test with both seasons which are rainy season and dry season. From the collected data, the graphs have been plotted using Microsoft Excel and the result for each parameter should be within the range that has been classified in Water Quality Index (WQI), so it can be concluded as safe for ecosystem in the area.

4.2 Water Quality Parameters in 2018 and 2019

4.2.1 In-Situ Test Result

4.2.1.1 pH

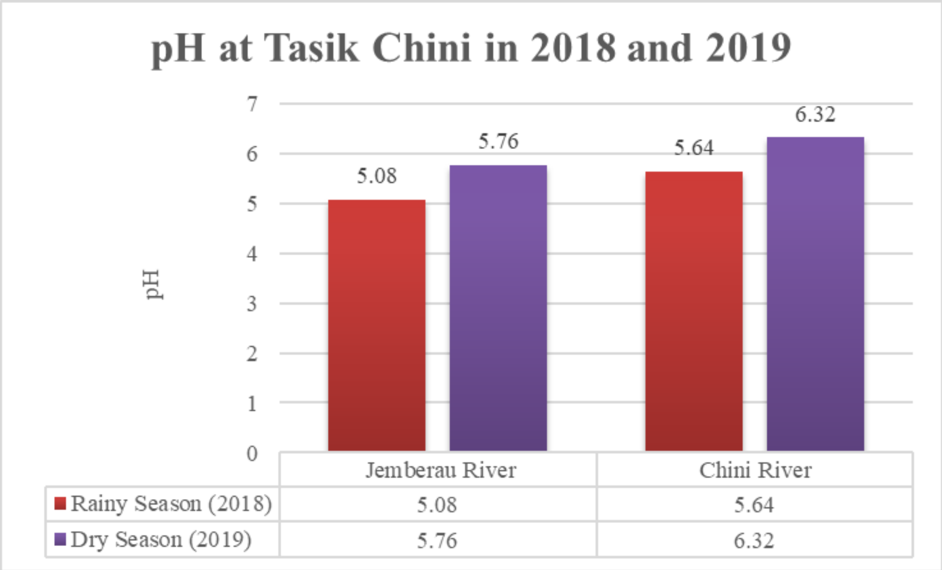


Figure 4.1 Graph for pH in 2018 and 2019

Figure 4.1 shows the pH varies from 5.08 to 6.32 during rainy and dry season in 2018 and 2019 respectively. The highest pH value was recorded at Chini River which is pH 6.32 during dry season, while the lowest value is pH 5.08 during rainy season at Jemberau River. The NWQS threshold range of pH for river in Malaysia is from 5.00-9.00. All stations are classified in Class II according to National Water Quality Standard for Malaysia. Normally, pH levels may fluctuate daily affect from photosynthesis and respiration in the water. The level of change depends on the alkalinity of the water and most common cause of acidity in the water is comes from carbon dioxide. In Malaysia, Department of Environment and Ministry of Health was used one calculation called as DOE-WQI which are consist of 6 parameters namely pH, BOD, COD, DO, suspended solids and ammoniacal nitrogen. Hence, according to DOE-Water Quality Index (WQI), pH reading during dry season at station Jemberau River was classified in Class III, while Chini River was classified in Class II.

4.2.1.2 Electrical Conductivity (EC)

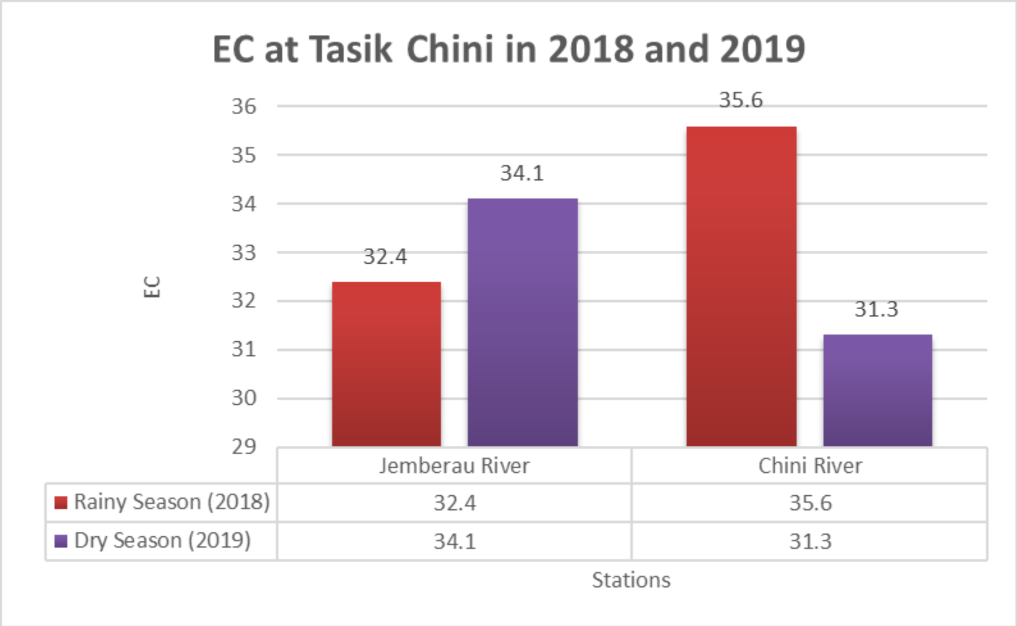


Figure 4.2 Graph for Electrical Conductivity in 2018 and 2019

Based on Figure 4.2, the electrical conductivity in 2018 and 2019 are varies from 31.30 µS/cm to 35.60 µS/cm at Jemberau River and Chini River that located around Tasik Chini. The lowest value is 31.30 µS/cm and the highest value is 35.60 µS/cm both at Chini River which is outlet to the Pahang River. According to National Water Quality Standard for Malaysia (NWQS), when value of electrical conductivity (EC) are not more than permitted threshold level which is 1000 µS/cm, thus all stations are Class I. Water conductivity can be defined as the ability to transmit electricity, heat or sound.

4.2.1.3 Turbidity

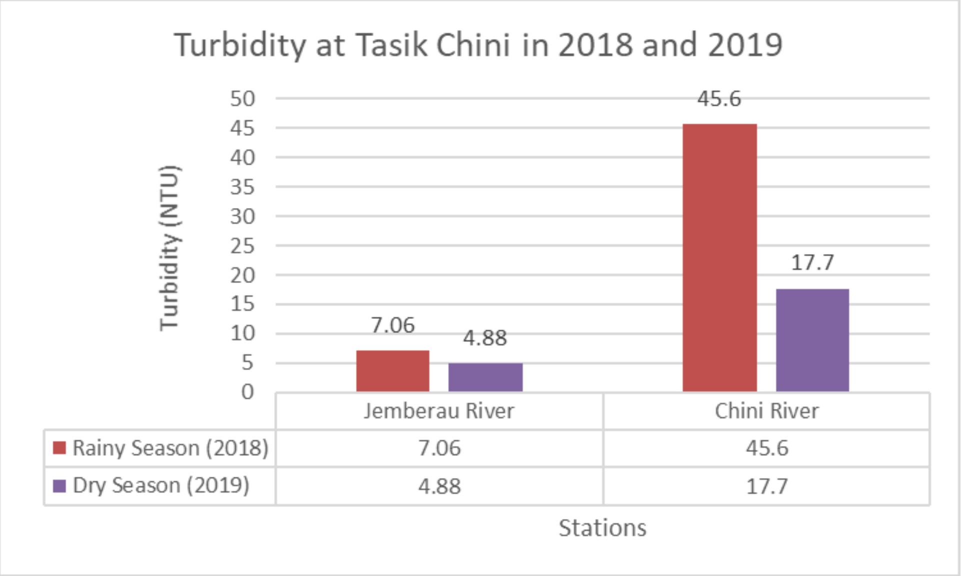


Figure 4.3 Graph for Turbidity in 2018 and 2019

Based on Figure 4.3, the value of the turbidity range at Tasik Chini from 2018 to 2019 NTU are 4.88 NTU and 45.60 respectively depends on sampling stations. The highest value for turbidity was at Chini River during rainy season in 2018, where the recorded value was 45.60 NTU. The highest value for turbidity is in Chini River because of the nearby activity which is National Service Training Programme or Program Latihan Khidmat Negara (PLKN). All samples from the sampling stations are classified in Class II based on the National Water Quality Standard for Malaysia (NWQS). According to NWQS for Class II, the water supply requires conventional treatment and the water condition is sensitive for aquatic species but it is harmless for recreational use with body contact.

4.2.1.4 Dissolved Oxygen (DO)

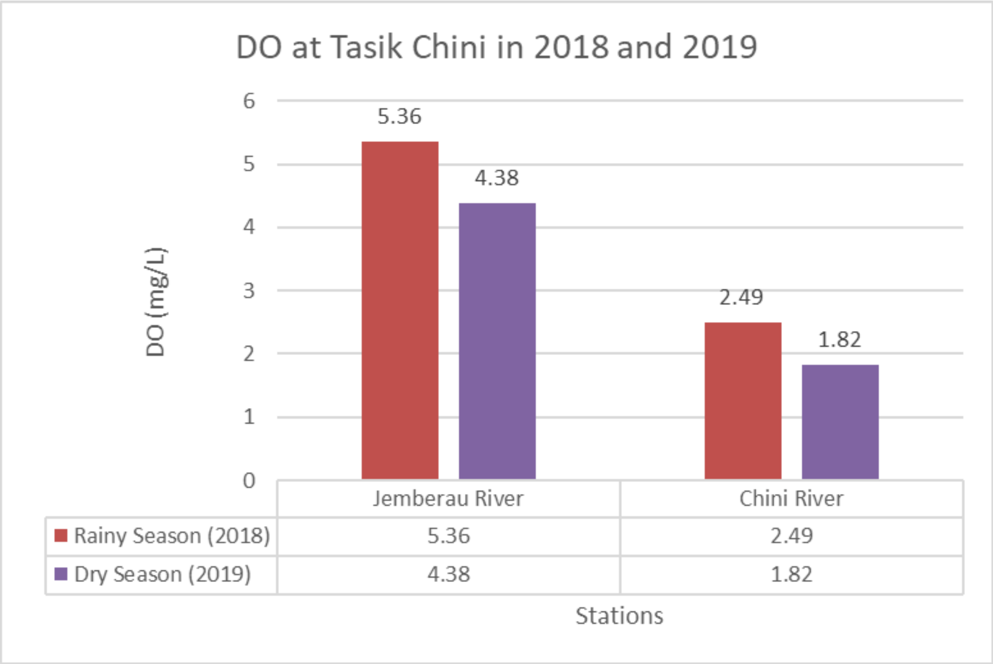


Figure 4.4 Graph for Dissolved Oxygen in 2018 and 2019

Figure 4.4 shows the concentration of dissolved oxygen at Tasik Chini in 2018 and 2019 during rainy and dry season were from 1.82 mg/L to 5.36 mg/L. The highest dissolved oxygen concentration is at Jemberau River while the lowest concentration is at Chini River. Basically, dissolved oxygen is the amount of oxygen gas (O_2) that dissolved in water. Oxygen enters into the water through direct absorption from the atmosphere, with rapid movement or as a residual product of plant photosynthesis. The temperature of the water and the amount of water moving can affect the level of dissolved oxygen. According to NWQS, station at Jemberau River during rainy season is classified as Class II, while during dry season the class is change to Class III. For Chini River, the class is fall in Class IV for both rainy and dry season. Other than that, based on DOE-Water Quality Index (WQI), the station at Jemberau River was classified in Class II during rainy season but Chini River was classified in Class IV since 2.49 mg/L value is in the range 1 mg/L to 3 mg/L.

4.2.1.5 Temperature

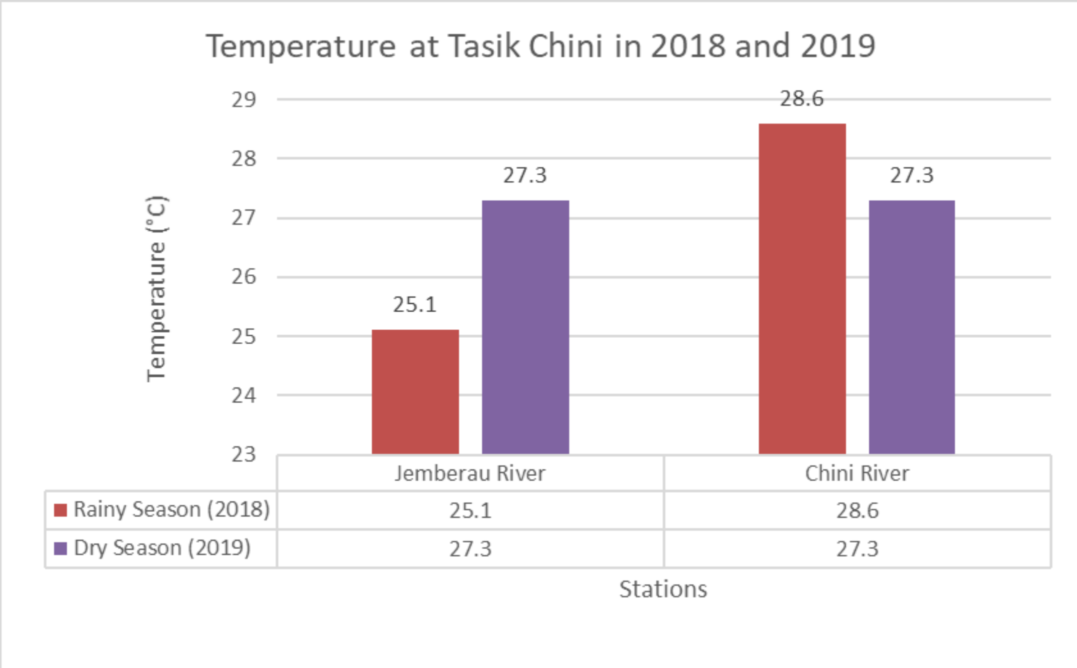


Figure 4.5 Graph for Temperature in 2018 and 2019

Based on Figure 4.5, the range of temperature for two selected rivers around Tasik Chini is around 25.10 ºC to 28.60 ºC. The highest recorded temperature is in Chini River at 28.60 ºC while the lowest reading is at Jemberau River at 25.10 °C both during rainy season. 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)

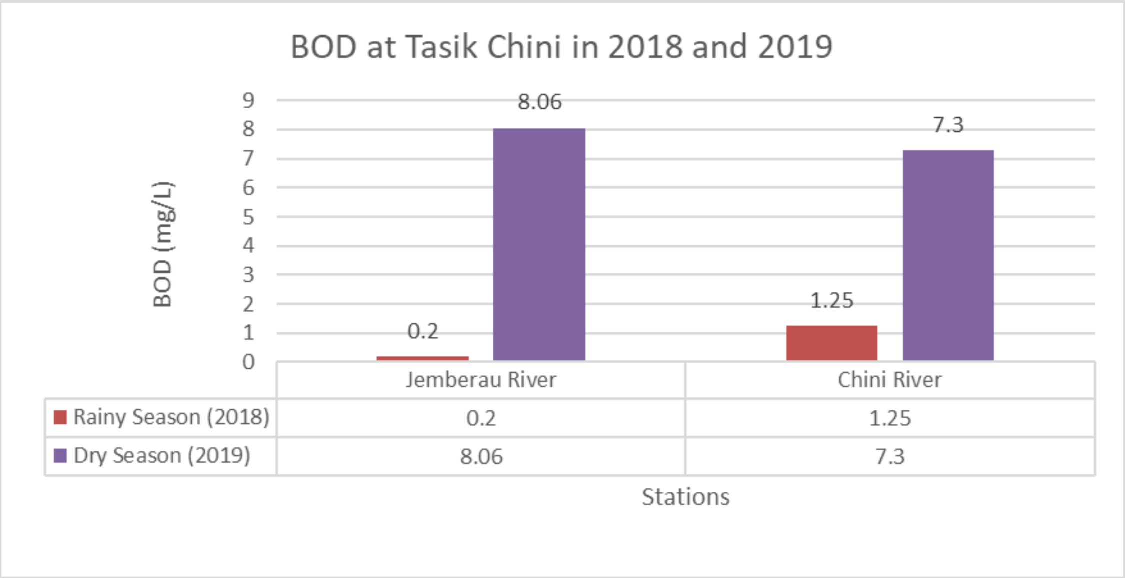


Figure 4.6 Graph for Biochemical Oxygen Demand (BOD) in 2018 and 2019

Figure 4.6 shows the various range of value for Biochemical Oxygen Demand (BOD) for Jemberau River and Chini River between 0.20 mg/L to 8.06 mg/L during rainy and dry season in 2018 and 2019. The highest value of BOD is at the Jemberau River during dry season with the value is 8.06 mg/L as it located near mining activity, but the value become the lowest during rainy season. According to National Water Quality Standard for Malaysia (NWQS), Jemberau River were classified in Class I during rainy season, while during dry season it is classified in Class IV which is the water condition is suitable to uses as irrigation. While, for the Chini River were classified in Class II and Class IV during rainy season and dry season respectively. Based on DOE-Water Quality Index (WQI), the BOD reading for both stations which are Jemberau River and Chini River was classified in Class IV during dry season in year 2019.

4.2.2.2 Chemical Oxygen Demand (COD)

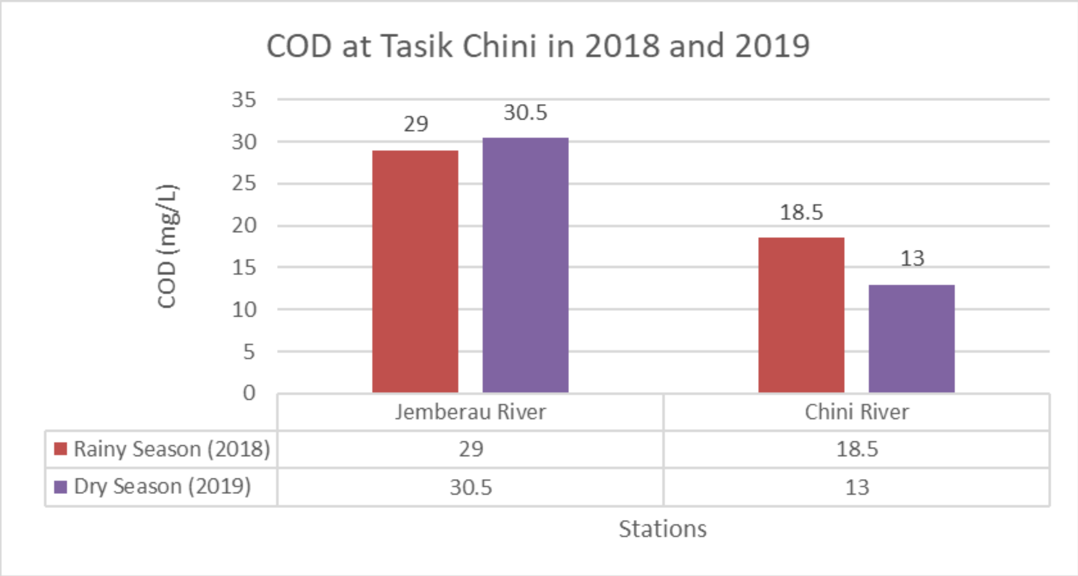


Figure 4.7 Graph for Chemical Oxygen Demand (COD) in 2018 and 2019

Figure 4.7 shows the range of Chemical Oxygen Demand (COD) at selected rivers around Tasik Chini from 13.00 mg/L to 30.50 mg/L in 2018 and 2019. The highest COD value was recorded at Jemberau River which is 30.50 mg/L while the lowest value is 13.00 mg/L at Chini River. Its value is higher in Jemberau River because it is closed to the active mining activity that had been discharge to the river and then flow to the Tasik Chini. While the lowest value is at Chini River with recorded value is 13.00 mg/L during dry season. According to National Water Quality Standard for Malaysia (NWQS) and DOE-Water Quality Index (WQI), most of the sample taken from the selected stations is classified in Class III at Jemberau River and Class II at Chini River.

4.2.2.3 Ammoniacal Nitrogen

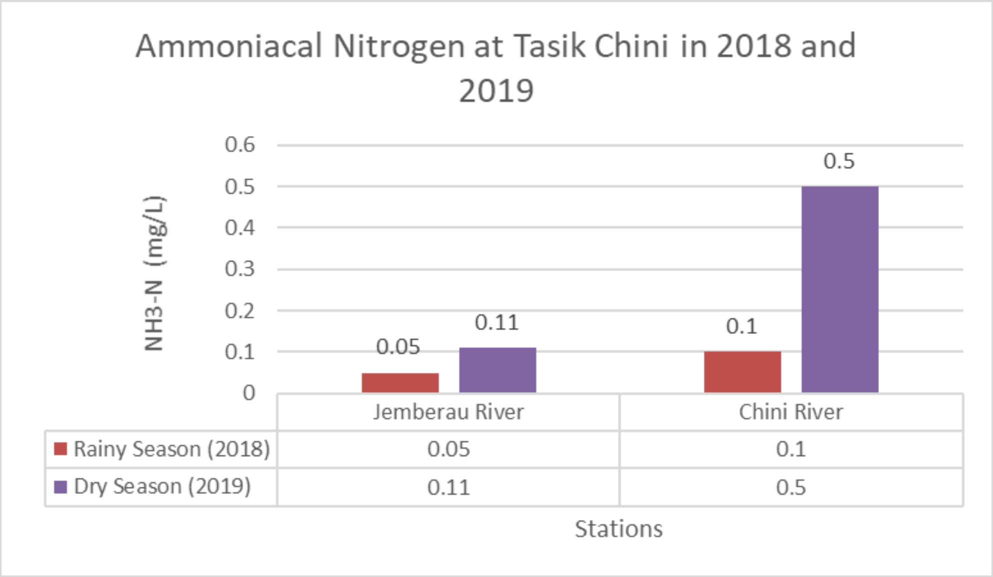


Figure 4.8 Graph for Ammoniacal Nitrogen (NH3-N) in 2018 and 2019

Figure 4.8 shows the range value of Ammoniacal Nitrogen (NH3-N) recorded were from 0.05 mg/L to 0.50 mg/L. The highest reading was recorded at Chini River which is 0.50 mg/L during dry season while the lowest reading is at Jembereau River which is 0.05 mg/L during rainy season. Based on data obtained, the highest value for NH3-N was 0.50 mg/L which is below 0.9 mg/L and hence it is classified into Class III based on NWQS and for this class, the extensive treatment is required and it is also common of economic value and tolerant species and livestock drinking. Other than that, based on DOE-Water Quality Index (WQI), the station at Jemberau River was classified in Class II during dry season. While, Chini River was classified in Class III in year 2019 during dry season since the highest reading is in the range 0.3 mg/L to 0.9 mg/L.

4.2.2.4 Nitrate

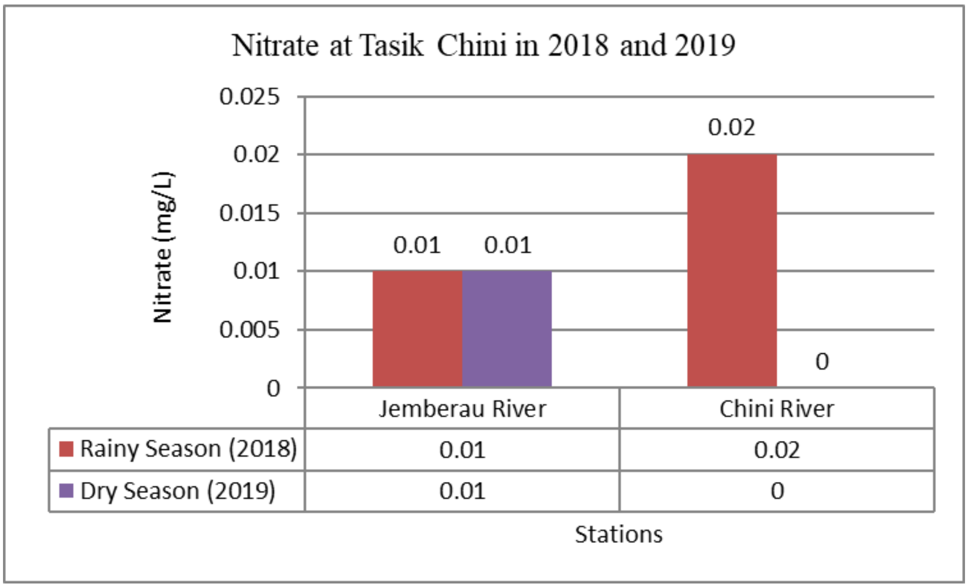


Figure 4.9 Graph for Nitrate in 2018 and 2019

From Figure 4.9, there is summarization on the range value of nitrate concentration for Jemberau River and Chini River were from 0.00 mg/L to 0.02 mg/L during rainy season and dry season. Based on the collected data, the highest concentration of nitrate was at Chini River during rainy season in 2018 which is 0.02 mg/L. Nitrate is one of the most common groundwater pollutions in the countryside. It is controlled in drinking water mainly because excessive levels can cause methemoglobinemia, or "blue baby" disease. Nitrate in groundwater is mainly derived from manure storage, fertilizers and septic systems. Fertilizer nitrogen which is not taken by plants or carried away by surface runoff leaches to the groundwater in the form of nitrate. Nitrate ion usually derived from anthropogenic sources such as 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 are in range of 0 mg/L to 7 mg/L.

4.2.2.5 Total Suspended Solid (TSS)

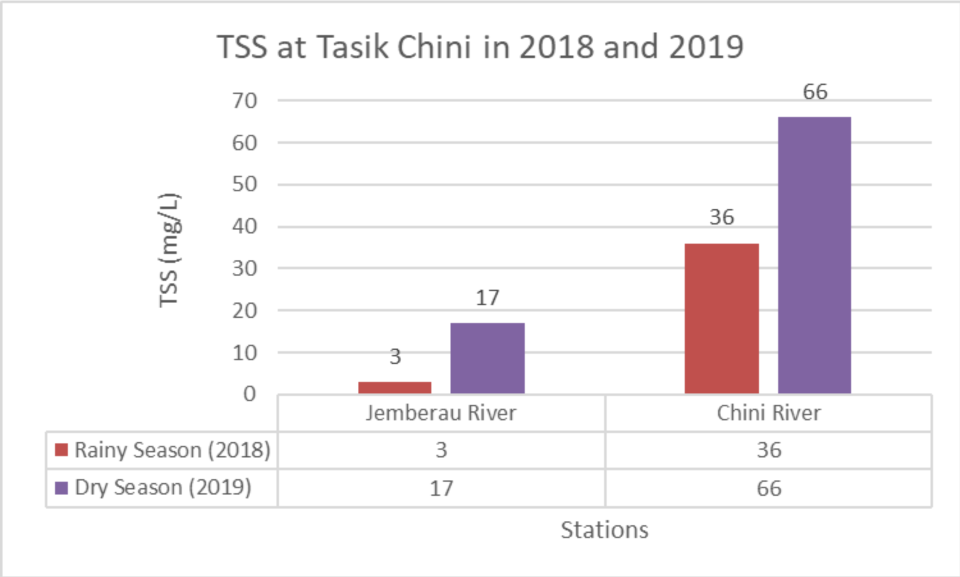


Figure 4.10 Graph for Total Suspended Solid (TSS) in 2018 and 2019

Figure 4.10 shows the Total Suspended Solid (TSS) range from 3.00 mg/L to 66.0 mg/L during the rainy season and dry season from years 2018 and 2019. The highest reading was recorded at Chini River with recorded value of 66.0 mg/L during dry season in 2019, while the lowest reading is at Jemberau River with recorded value was 3.00 mg/L during rainy season in 2018. Based on the National Water Quality Standard for Malaysia (NWQS), TSS levels to support aquatic life in freshwater ecosystem are less than 150 mg/L. According to NWQS, sample taken from stations at Jemberau River were classified as class I for both season since the value not exceed 25 mg/L, while sample from Chini River were categorized in Class II during rainy season since the value not more than 50 mg/L and Class III during dry season. Besides that, according to DOE-Water Quality Index (WQI), the station at Jemberau River is classified in Class I while Chini River is classified in Class III both during dry season in year 2019 which is slightly polluted due to surrounding land use activity.

4.2.2.6 Phosphorus

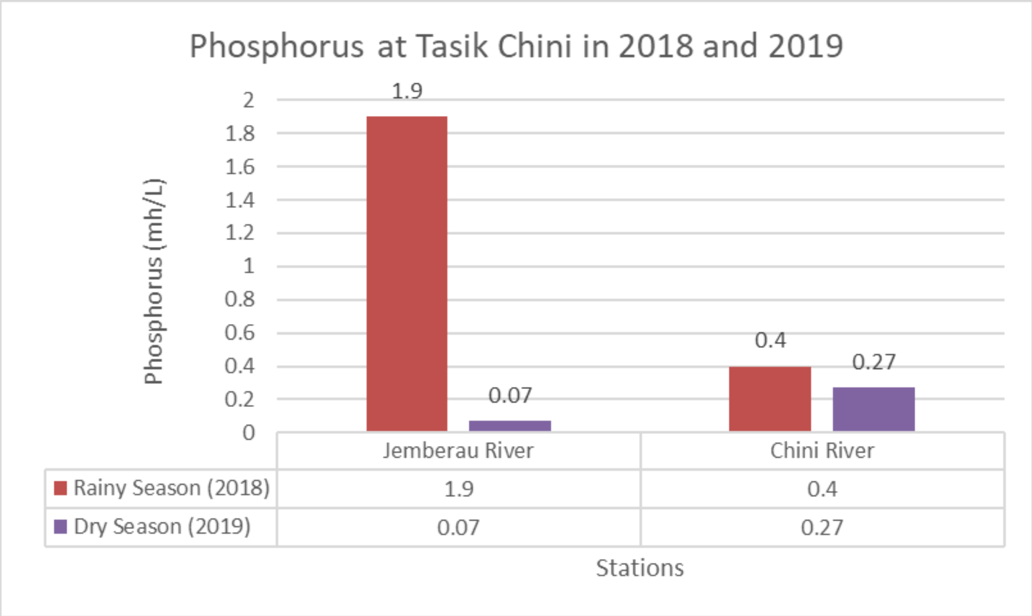


Figure 4.11 Graph for Phosphorus in 2018 and 2019

Figure 4.11 shows the average range of phosphorus concentration ranging from 0.07 mg/L to 1.90 mg/L in years 2018 and 2019. The highest concentration of Phosphorus was recorded at Jemberau River with the value 1.90 mg/L during rainy season, while the lowest value is located at Jemberau River also with the recorded data which is 0.07 mg/L during dry season. Concentration of phosphorus at Jemberau River becomes higher due to the river location is near with palm oil plantation. As we know, the quantity of phosphorus in the soil is generally small, and this often prevents plant growth and hence that is why people often use phosphate fertilizers on their farmland. As a result, the agricultural activities near Jemberau River will cause agricultural runoff into Tasik Chini and finally will pollute the lake. In addition, agricultural runoff consists of pesticides, fertilizers and domestic emissions that will affect the water quality and aquatic life. According to NWQS, for Jemberau River is classified in Class I during dry season while during rainy season it is classified in Class II. Other than that, for Chini River is classified in Class II for both rainy season and dry season in year 2018 and 2019.

4.2.2.7 Potassium

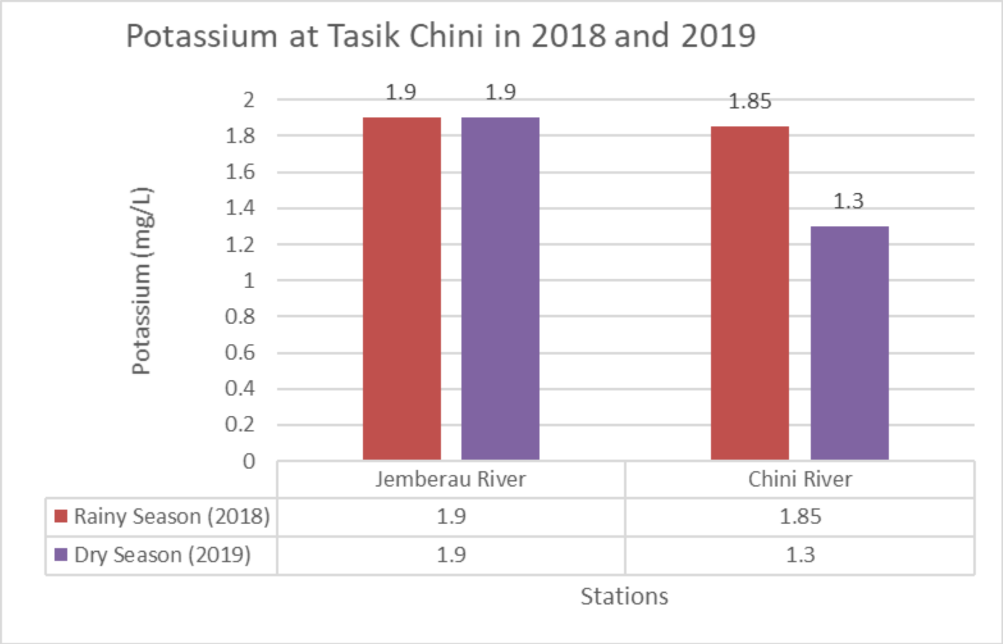


Figure 4.12 Graph for Potassium in 2018 and 2019

Based on Figure 4.12, the average potassium concentration of each sample taken in 2018 and 2019 are varies from 1.30 mg/L to 1.90 mg/L. The highest potassium concentration was recorded in Jemberau River is 1.90 mg/L for both rainy season and dry season while the lowest value is 1.30 mg/L at Chini River during dry season in 2019. High concentration is affected by iron production from mining activities near the Tasik Chini. Increased exposure to potassium can cause significant health effects in people with kidney disease, coronary artery disease, heart disease, diabetes, hypertension while older individuals who have reduced the physiological reserves in their kidney function and individuals who are taking medications that interfere with normal control potassium in the body. All of this disease can easily give the bad impact to the villager's health if the potassium concentration is too high in their drinking water.

4.2.2.8 Heavy Metal (AAS Method)

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

Jemberau River	Chromium, Cr (mg/L)	Lead, Pb (mg/L)	Copper, Cu (mg/L)	Cadmium, Cd (mg/L)	Iron, Fe (mg/L)	Zinc, Zn (mg/L)	Manganese, Mn (mg/L)
October	-0.080	0.013	0.032	-0.021	0.492	0.005	0.069
February	-0.139	0.304	-0.031	0.454	-	-	-
Chini River	**Chromium, Cr (mg/L)**	**Lead, Pb (mg/L)**	**Copper, Cu (mg/L)**	**Cadmium, Cd (mg/L)**	**Iron, Fe (mg/L)**	**Zinc, Zn (mg/L)**	**Manganese, Mn (mg/L)**
October	-0.087	0.004	0.035	-0.023	1.57	0.00	0.080
February	-0.131	0.211	-0.036	0.454	-	-	-

Table 4.1 shows the concentration in unit mg/L for seven parameters of heavy metals in sample obtained at Jemberau River and Chini River during rainy season and dry season in 2018 and 2019. These heavy metal levels are determined by Atomic Absorption Spectroscopy (AAS) which are seven parameters carried out in laboratory by using AAS method are Chromium (Cr), Lead (Pb), Copper (Cu), Manganese (Mn), Iron (Fe), Cadmium (Cd) and Zinc (Zn). Based on the data recorded that has been tabulated above, the concentration of heavy metals in water samples is slightly higher according to permissible range of NWQS. This situation occur indicates that it is due to land use activities surrounding the rivers such as agricultural, mining, palm oil plantation, logging, rubber plantation and also emission of waste from residential area. All of this activity can lead to increasing water pollution at Jemberau River and Chini River.

Moreover, the increasing velocity of the river flow also can affect the increment of heavy metals concentration during rainy season. Heavy metals showed an increase in dissolved phase as the velocity increased due to their desorption from the suspended particulate matters (Jianzhi et al., 2012). The impervious surfaces created by buildings and pavement significantly alter the way water flows through watersheds, conveying additional pollutants with runoff. Meaning that, the frequency and amount of rainfalls also contributes to the increasing concentration of heavy metals as there are more surface runoff flows into the nearby river. From Figure 4.13 and Figure 4.14, we can see that the difference of total amount precipitation between October 2018 and February 2019. During rainy season in October 2018, the total amount of precipitation is 387 mm while during dry season in February 2019, the amount of precipitation is only 38 mm. That value indicates that, when there is higher amount of precipitation so that the velocity of the river increase, thus the concentration of heavy metals also might be increase. In fact, the samples for rainy season were taken on 26 October 2018 while dry season were taken on 20 February 2019 for both Jemberau River and Chini River.

Table 4.2 Weather forecast for October 2018 (rainy season) at Pekan, Pahang

Date	Hi/Lo	Precipitation (mm)
Mon 10/1	34°/25°	0
Tue 10/2	34°/24°	0
Wed 10/3	34°/23°	5
Thu 10/4	34°/24°	0
Fri 10/5	33°/23°	27
Sat 10/6	31°/25°	15
Sun 10/7	31°/25°	4
Mon 10/8	32°/24°	0
Tue 10/9	29°/24°	4
Wed 10/10	30°/24°	6
Thu 10/11	31°/23°	5
Fri 10/12	32°/23°	3
Sat 10/13	31°/23°	55
Sun 10/14	32°/23°	33
Mon 10/15	33°/23°	66
Tue 10/16	32°/23°	0
Wed 10/17	34°/24°	14
Thu 10/18	33°/23°	33
Fri 10/19	33°/22°	22
Sat 10/20	34°/23°	0
Sun 10/21	32°/24°	0
Mon 10/22	33°/24°	1
Tue 10/23	32°/24°	32
Wed 10/24	33°/24°	2
Thu 10/25	33°/24°	0
Fri 10/26	33°/24°	0
Sat 10/27	34°/25°	0
Sun 10/28	34°/24°	0
Mon 10/29	33°/24°	0
Tue 10/30	30°/25°	53
Wed 10/31	32°/25°	7

Table 4.3 Weather forecast for February 2019 (dry season) at Pekan, Pahang

Date	Hi/Lo	Precipitation (mm)
Fri 2/1	32°/23°	0
Sat 2/2	31°/23°	2
Sun 2/3	29°/24°	4
Mon 2/4	32°/23°	0
Tue 2/5	32°/23°	0
Wed 2/6	32°/22°	0
Thu 2/7	32°/22°	0
Fri 2/8	32°/23°	0
Sat 2/9	32°/23°	0
Sun 2/10	32°/21°	0
Mon 2/11	33°/21°	0
Tue 2/12	31°/22°	0
Wed 2/13	30°/23°	2
Thu 2/14	32°/22°	0
Fri 2/15	32°/23°	0
Sat 2/16	32°/23°	0
Sun 2/17	31°/23°	10
Mon 2/18	31°/24°	19
Tue 2/19	32°/23°	0
Wed 2/20	32°/23°	1
Thu 2/21	32°/23°	0
Fri 2/22	33°/23°	0
Sat 2/23	32°/23°	0
Sun 2/24	32°/22°	0
Mon 2/25	33°/22°	0
Tue 2/26	32°/23°	0
Wed 2/27	30°/23°	0
Thu 2/28	33°/23°	0

4.3 Comparison of Water Quality during years 2016, 2017, 2018 and 2019

4.3.1 In-Situ Test Result

4.3.1.1 pH

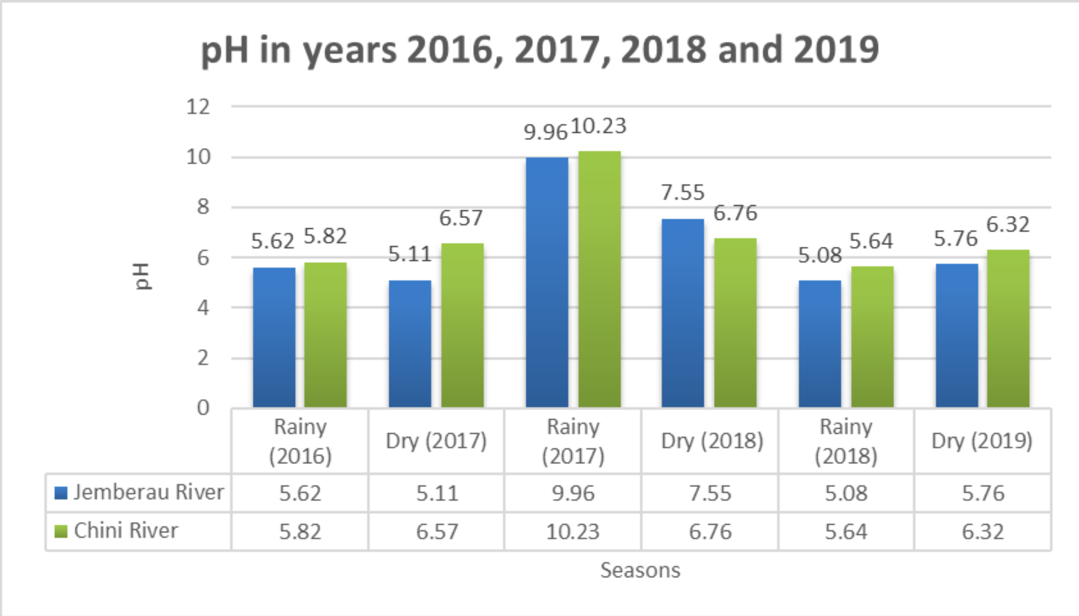
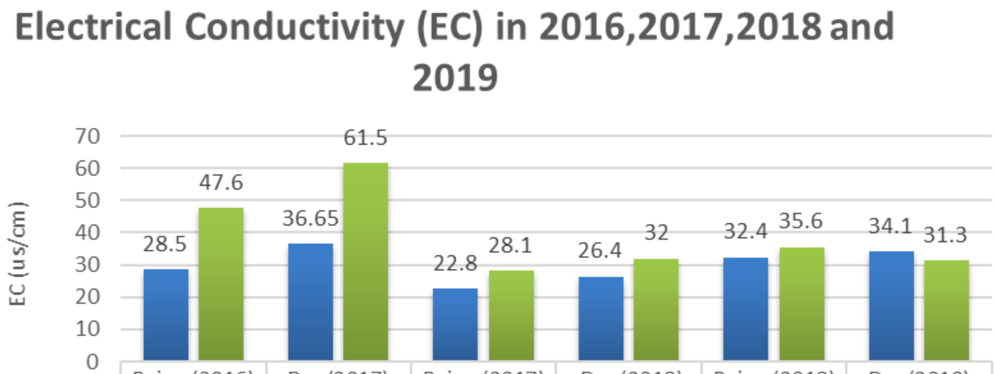


Figure 4.13 Graph for pH in 2016, 2017, 2018 and 2019

Based on Figure 4.13, there are varies in range for pH at Jemberau River which are 5.11 to 9.96 while Chini River are from 5.64 to 10.23 that varies from 2016 to 2019 with different seasons including rainy and dry season. The highest pH value at Jemberau River which is pH 9.96 in rainy seasons 2017 while the lowest value is pH 5.11 during dry season 2017. According NWQS, threshold range of pH for river in Malaysia is from 5.00-9.00. The pH value was fluctuating from 2016 until 2019 for both Jemberau River and Chini River in rainy season and dry season. According to National Water Quality Standard for Malaysia, all station is classified in Class III.

4.3.1.2 Electrical Conductivity (EC)

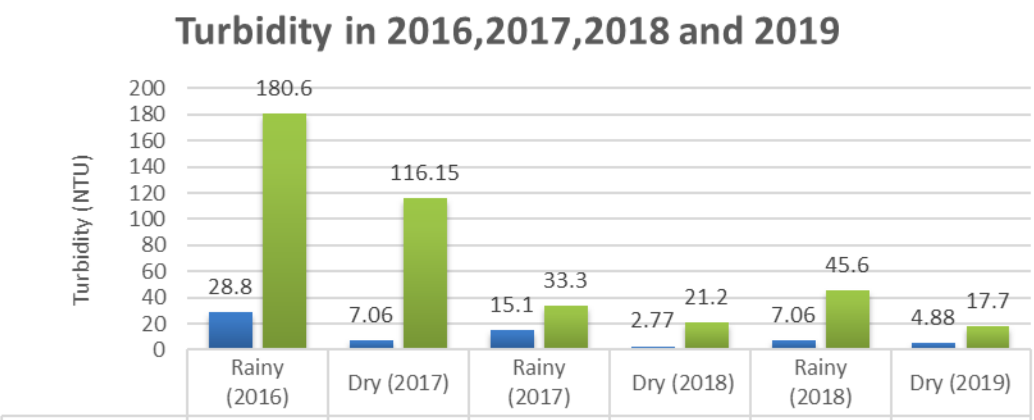


	Rainy (2016)	Dry (2017)	Rainy (2017)	Dry (2018)	Rainy (2018)	Dry (2019)
Jemberau River	28.5	36.65	22.8	26.4	32.4	34.1
Chini River	47.6	61.5	28.1	32	35.6	31.3

Figure 4.14 Graph for Electrical Conductivity in 2016, 2017, 2018 and 2019

Figure 4.14 shows the variation value of electrical conductivity for years 2016 until 2019 from 22.8 µS/cm to 61.5 µS/cm at Jemberau River and Chini River. The lowest and the highest value recorded were 22.8 µS/cm in rainy season at Jemberau River and 61.5 µS/cm in dry season at Chini River respectively. The value for electrical conductivity was higher at Chini River because the station is near to the National Service Training Programme or Program Latihan Khidmat Negara which is the runoff occur and hence flow into the river. Based on National Water Quality Standard for Malaysia (NWQS), all stations are Class I because the recorded data as shown in the table above for electrical conductivity (EC) are not more than permitted threshold level which is 1000 µS/cm.

4.3.1.3 Turbidity



	Rainy (2016)	Dry (2017)	Rainy (2017)	Dry (2018)	Rainy (2018)	Dry (2019)
Jemberau River	28.8	7.06	15.1	2.77	7.06	4.88
Chini River	180.6	116.15	33.3	21.2	45.6	17.7

Figure 4.15 Graph for Turbidity in 2016, 2017, 2018 and 2019

According to Figure 4.15, the variation for turbidity value at Jemberau River was between 2.77 NTU to 28.28 NTU. While, the range value Chini River were from 17.7 NTU to 180.6 NTU. Based on the recorded value, the turbidity reading is decreasing from 2018 to 2019 for both Jemberau River and Chini River which is from rainy season to dry season. The highest value for turbidity was Chini River during rainy season in year 2016 with recorded value was 180.6 NTU. While the lowest turbidity value was at Jemberau River in year 2018 during dry season with recorded value 2.77 NTU.

4.3.1.4 Dissolved Oxygen (DO)

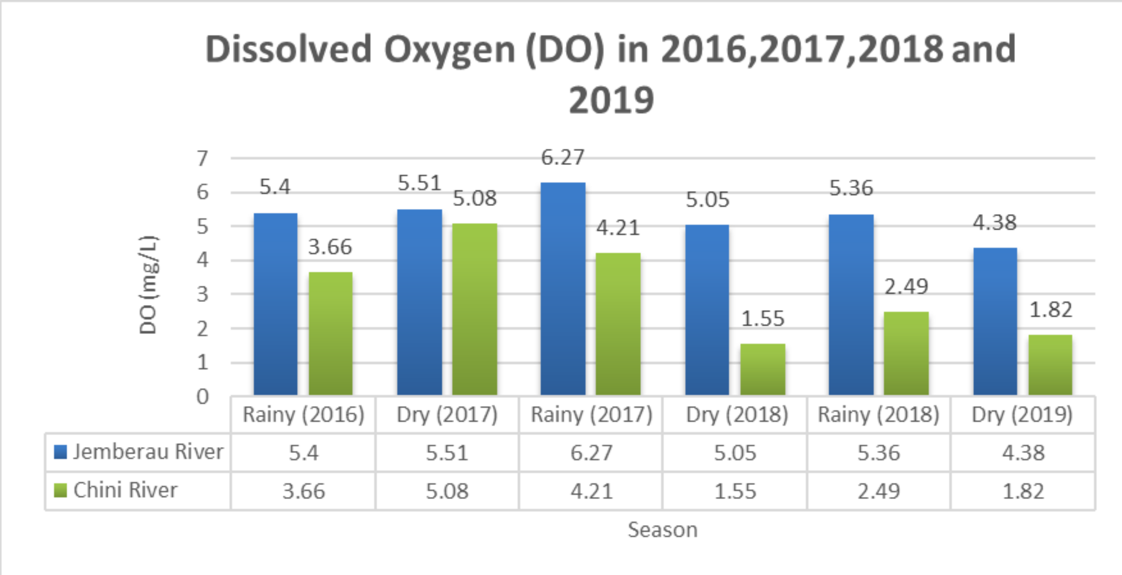
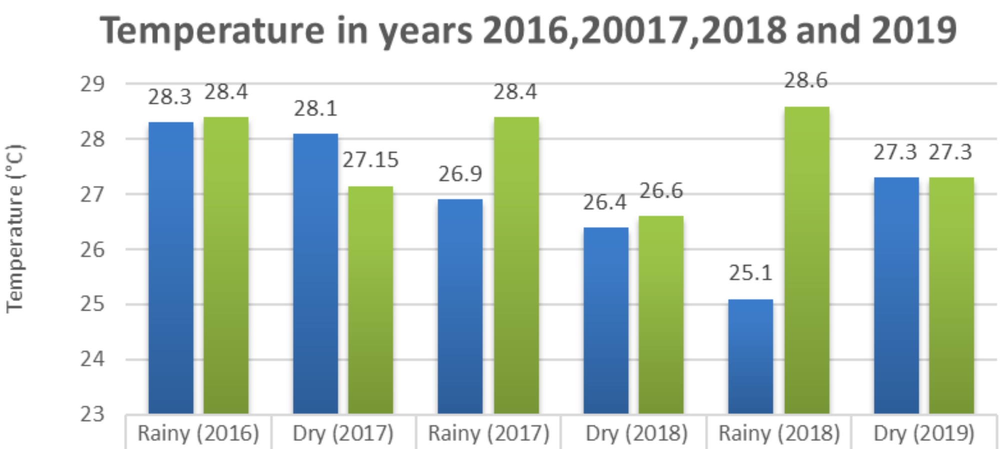


Figure 4.16 Graph for Dissolved Oxygen in 2016, 2017, 2018 and 2019

Figure 4.16 above show that the dissolved oxygen concentration at Jemberau River were in range from 4.38 mg/L to 6.27 mg/L while the dissolved oxygen concentration at Chini River were in range from 1.55 mg/L to 5.08 mg/L. The highest dissolved oxygen value was recorded at Jemberau River with reading 6.27 mg/L during rainy season in 2017 which is effect from mining activity near the river. While the lowest value was during dry season in year 2018 at Chini River which is 1.55 mg/L. Basically dissolved oxygen affected by photosynthetic activities. Based on NWQS, most of the station was classified as Class II with the range value is from 5 mg/L to 7 mg/L.

4.3.1.5 Temperature



	Rainy (2016)	Dry (2017)	Rainy (2017)	Dry (2018)	Rainy (2018)	Dry (2019)
Jemberau River	28.3	28.1	26.9	26.4	25.1	27.3
Chini River	28.4	27.15	28.4	26.6	28.6	27.3

Figure 4.17 Graph for Temperature in 2016, 2017, 2018 and 2019

Figure 4.17 show that, the variation reading for temperature which was tabulated from 25.1 ºC to 28.6 ºC. The highest reading was recorded at Chini River during rainy season in year 2018 which is 28.6 ºC while the lowest reading is at Jemberau River during rainy season also in year 2018 with value 25.1 °C. Based on National Water Quality Standard for Malaysia (NWQS), the temperature is considered normal for all station surrounding Tasik Chini.

4.3.2 Laboratory Test Result

4.3.2.1 Biochemical Oxygen Demand (BOD)

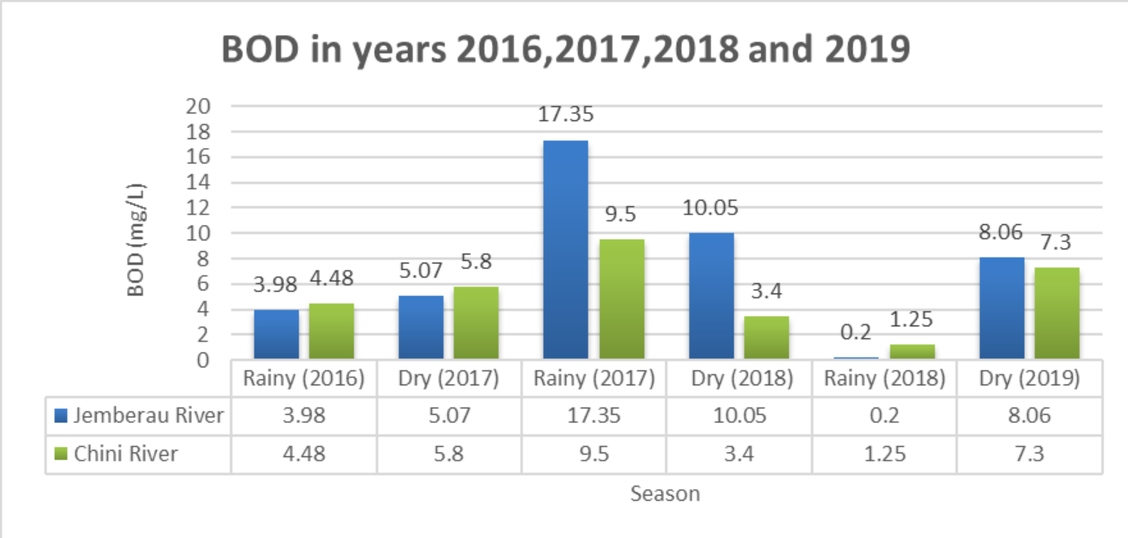


Figure 4.18 Graph for Biochemical Oxygen Demand (BOD) in 2016, 2017, 2018 and 2019

According to Figure 4.18, the variation reading for Biochemical Oxygen Demand (BOD) was between 0.2 mg/L to 17.35 mg/L. The highest value for BOD was at Jemberau River during rainy season in year 2017 with recorded value is 17.35 mg/L. While, the lowest reading for BOD also at Jemberau River but in different year which is in 2018 during rainy season with recorded value 0.2 mg/L. Based on the value tabulated above, the value of BOD was increased drastically from year 2016 to 2017 because of organic waste from living in nearby forest. Based on the National Water Quality Standard for Malaysia (NWQS), most of the samples tested were classified into Class III.

4.3.2.2 Chemical Oxygen Demand (COD)

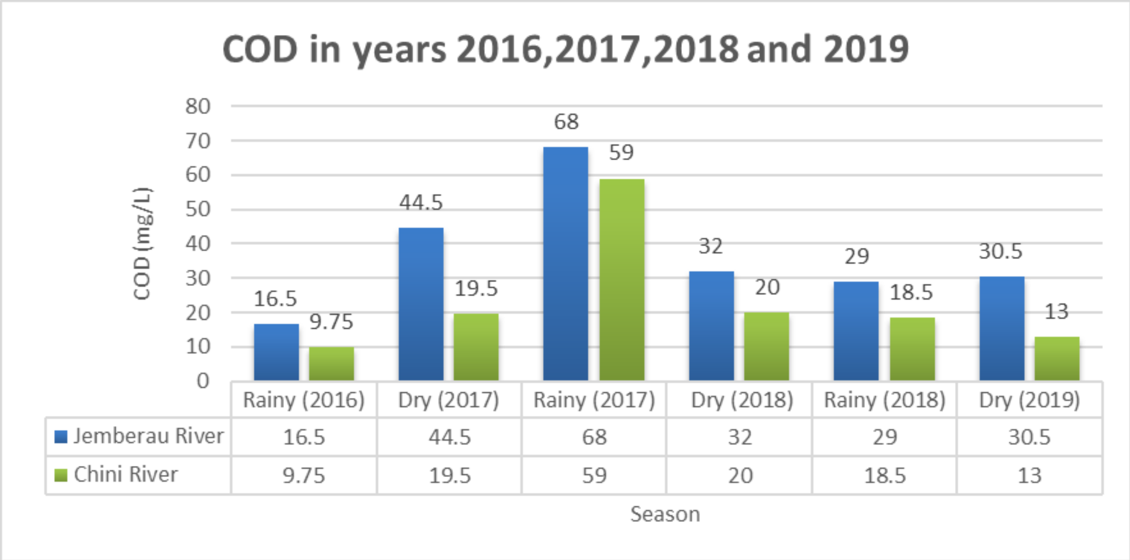


Figure 4.19 Graph for Chemical Oxygen Demand (COD) in 2016, 2017, 2018 and 2019

Based on Figure 4.19, the range of data for Chemical Oxygen Demand (COD) are from 9.75 mg/L to 68.0 mg/L. Based on the recorded data above, the highest COD value was recorded at Jemberau River which is 68.0 mg/L during rainy season in year 2017 while the lowest value is 9.75 mg/L at Chini River during rainy season in 2016. Furthermore, nearby area with the activation of mining activity and logging activity has been contributing the major effect to the highest COD value at Jemberau River. The reactivation of iron-mining activity near the Jemberau River was believed discharge effluent from mining area into the lake. According to National Water Quality Standard for Malaysia (NWQS), during wet and dry season for year 2016 until 2019, COD reading at all sampling station are classify in Class III, except for Jemberau River in year 2017 during rainy season is classified in Class IV because the value is 68.0 mg/L.

4.3.2.3 Ammoniacal Nitrogen

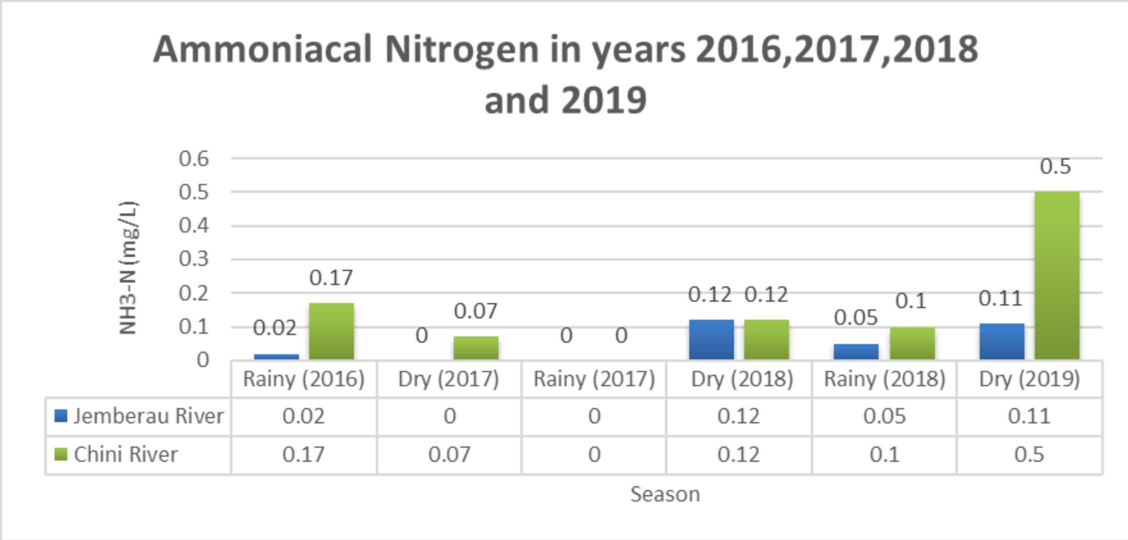


Figure 4.20 Graph for Ammoniacal Nitrogen (NH3-N) in 2016, 2017, 2018 and 2019

Figure 4.20 above show that, the variation range value of Ammoniacal Nitrogen (NH3-N) were recorded from 0 mg/L to 0.17mg/L. from the data that has been recorded, the highest concentration value was recorded at Chini River during rainy season in year 2016 with value 0.17mg/L, while the lowest reading is at Jemberau River which is 0 mg/L during dry season and rainy season in year 2017. However, Chini River also got value 0 mg/L in 2017 during rainy season. From the observation, all the samples collected during rainy and dry season contained small number of concentrations for ammoniacal nitrogen which is less than the maximum limit set by the World Health Organization (WHO). According the tabulated data above which is based on NWQS, all value for NH3-N were below 0.3 mg/L are classified into Class II which means that for this class need conventional treatment for water supply and also sensitive to aquatic species.

4.3.2.4 Nitrate

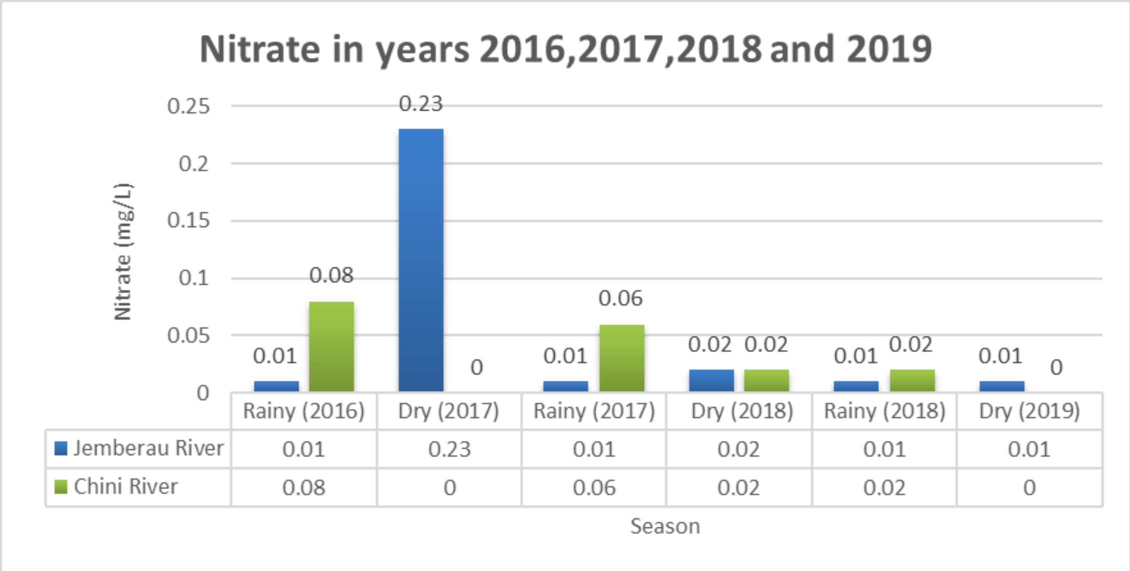


Figure 4.21 Graph for Nitrate in 2016, 2017, 2018 and 2019

Figure 4.21 above shows that the variation range value of nitrate concentration readings for both rainy and dry season was from 0.0 mg/L to 0.23 mg/L. From the tabulated data, the lowest reading was recorded with 0 mg/L in year 2017 and 2019 which is both in dry season at station Chini River. The highest reading of nitrate was recorded at Jemberau River during dry season in 2017 with value 0.23 mg/L. For additional information, nitrate nitrogen is product from organic matter which is decomposition process has been done by bacteria. Moreover, nitrate ion is derived from anthropogenic sources such as agricultural activity and domestic sewage. From the graph, it is shown that there has drastically increasing concentration from year 2016 to 2017 at Jemberau River, this is the worse effect by discharge from palm oil plantation, logging activity and rubber plantation at the nearby area. Based on National Water Quality Standard for Malaysia (NWQS), all stations were classified into Class II since the values of nitrate concentration in ranged 0 to 7 mg/L.

4.3.2.5 Total Suspended Solid (TSS)

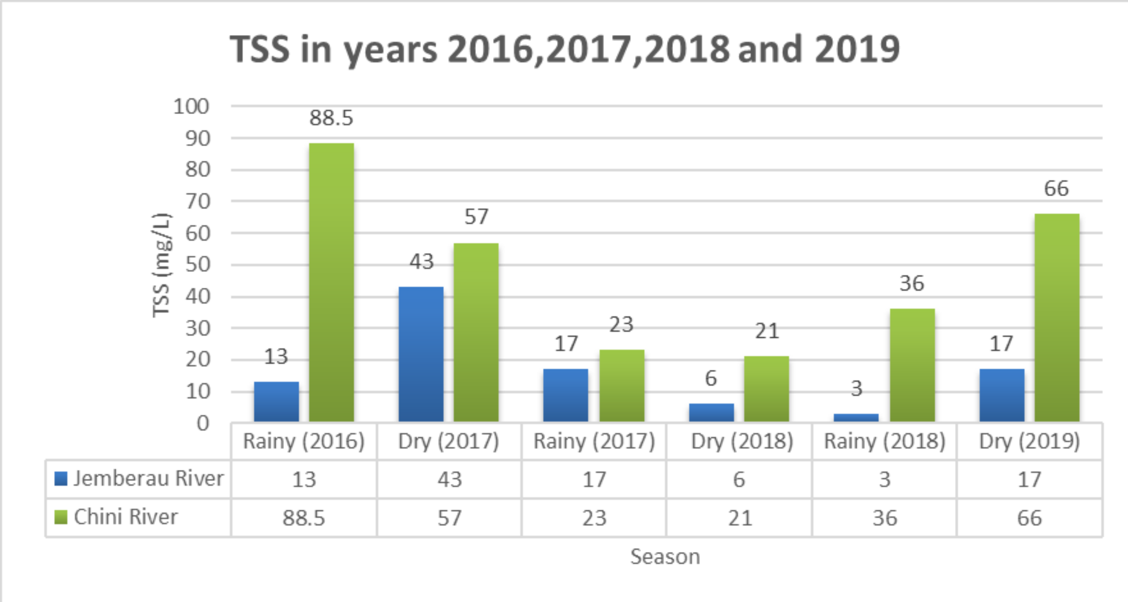


Figure 4.22 Graph for Total Suspended Solid (TSS) in 2016, 2017, 2018 and 2019

Figure 4.22 above shows that the concentration range of Total Suspended Solid (TSS) is from 3.0 mg/L to 88.5 mg/L. The highest reading was recorded at Chini River in year 2016 during rainy season with reading value is 88.5 mg/L, while the lowest reading is at Jemberau River during rainy season in year 2018 with reading value is 3 mg/L. Total suspended solids (TSS) are considered to be one of the major pollutants that contributes to the deterioration of water quality, contributing to higher costs for water treatment, decreases in fish resources, and the general aesthetics of the water(Verma, Wei and Kusiak, 2013). TSS is an important parameter, as the excessive TSS decline is dissolved oxygen (DO) in effluent water. According to National Water Quality Standard for Malaysia (NWQS), all stations were classified into Class II except for Chini River in years 2016, 2017 and 2019 was classified in Class III because the concentration reading for that years was exceeded more than 50 mg/L.

4.3.2.6 Phosphorus

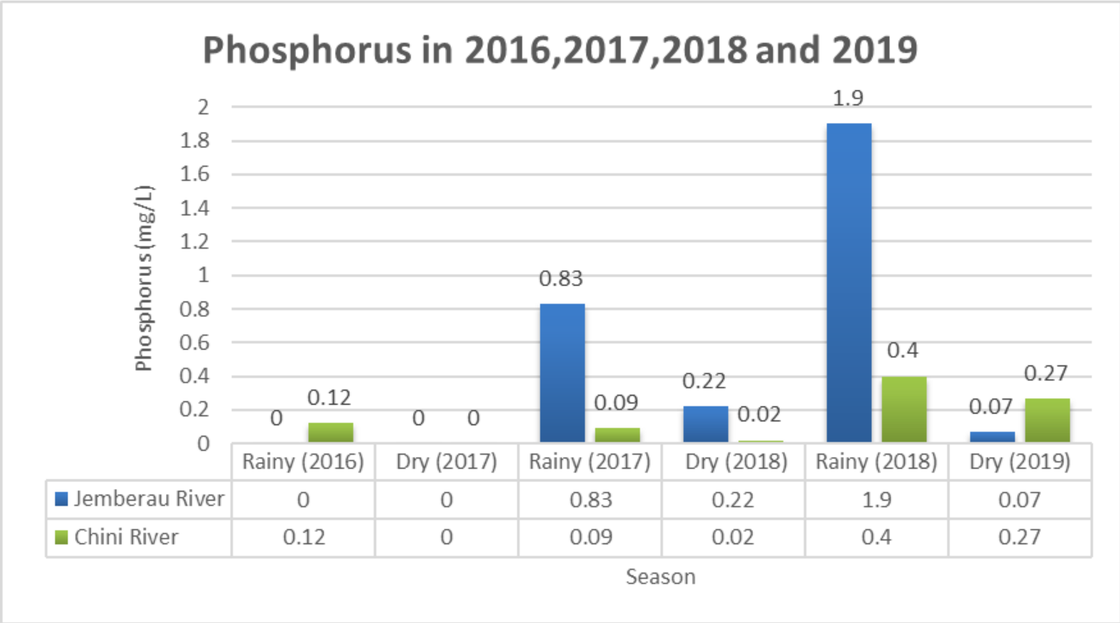


Figure 4.23 Graph for Phosphorus in 2016, 2017, 2018 and 2019

Based on Figure 4.23, there are variation reading of range for Phosphorus concentration for dry season and rainy season was begins from 0 mg/L to 1.90 mg/L. The highest Phosphorus concentration reading was recorded at Jemberau River with 1.90 mg/L during rainy season while the lowest value is 0 mg/L for Jemberau River in years 2016 and 2017 and Chini River in year 2017 during dry season. The highest amount of phosphorus concentration at Jemberau River is because the mining activity located near to the river and runoff might be occurring during rainy season. In addition, other land use activity nearby the river such as palm oil plantation which used fertilizers and pesticides can contribute to the highest level of phosphorus at Jemberau River. Other than that, the agriculture runoff also will flow into the Chini River and then will spread off to the whole Tasik Chini. Based on NWQS classification, all samples are classified in Class I.

4.3.2.7 Potassium

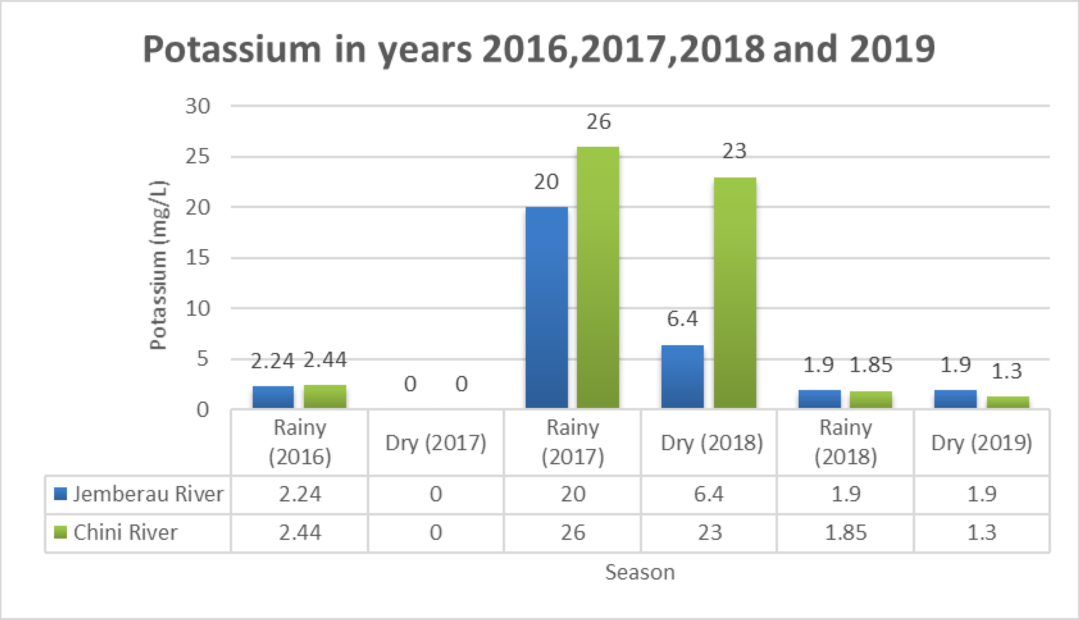


Figure 4.24 Graph for Potassium in 2016, 2017, 2018 and 2019

Figure 4.24 show variation reading of the range for potassium concentration for dry season and rainy season in years 2016, 2017, 2018 and 2019 are from 0 mg/L to 26.0 mg/L. According to the recorded data as shown in table above, the highest potassium concentration value was recorded at Chini River which is 26.0 mg/L during rainy season in year 2017 while the lowest value is 0 mg/L at Jemberau River and Chini River both in the same year in 2017 during dry season. In addition, the concentration of potassium becomes higher was because the discharge from palm oil plantation, logging activity and rubber plantation nearby the river. Based on NWQS classification, all the stations are classified in Class I since the value is at natural levels.

4.3.2.8 Heavy Metals

RESULTS FOR SOIL SAMPLES IN 2018 (ICP-MS METHOD)

Table 4.4 Heavy Metal Results for soil sample at Jemberau River (outside river)

No	Parameter	Results (26/10/18)	Unit
1	Beryllium (Be)	Not Detected (Less than 0.5)	ppb
2	Sodium (Na)	809.8	ppm
3	Magnesium (Mg)	Not Detected (Less than 0.1)	ppm
4	Aluminium (Al)	62555.80	ppm
5	Potassium (K)	27647.7	ppm
6	Calcium (Ca)	Not Detected (Less than 0.1)	ppm
7	Vanadium (V)	102.14	ppm
8	Chromium (Cr)	54.95	ppm
9	Manganese (Mn)	23292.86	ppm
10	Iron (Fe)	106980.3	ppm
11	Cobalt (Co)	437.6	ppb
12	Nickel (Ni)	Not Detected (Less than 0.5)	ppb
13	Copper (Cu)	226.26	ppm
14	Zinc (Zn)	181.97	ppm
15	Arsenic (As)	226.26	ppm
16	Selenium (Se)	1.13	ppm
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)	5073.37	ppm
22	Lead (Pb)	180.68	ppm

Table 4.5 Heavy Metal Results for soil sample at Jemberau River (inside river)

No	Parameter	Results	Unit
1	Beryllium (Be)	Not Detected (Less than 0.5)	ppb
2	Sodium (Na)	644.6	ppm
3	Magnesium (Mg)	Not Detected (Less than 0.1)	ppm
4	Aluminium (Al)	367.61	ppm
5	Potassium (K)	14490.2	ppm
6	Calcium (Ca)	Not Detected (Less than 0.1)	ppm
7	Vanadium (V)	117.70	ppm
8	Chromium (Cr)	634.97	ppm
9	Manganese (Mn)	170732.69	ppm
10	Iron (Fe)	150415.8	ppm
11	Cobalt (Co)	1.97	ppm
12	Nickel (Ni)	Not Detected (Less than 0.5)	ppb
13	Copper (Cu)	15.97	ppm
14	Zinc (Zn)	958.64	ppm
15	Arsenic (As)	360.83	ppm
16	Selenium (Se)	Not Detected (Less than 0.5)	ppb
17	Molybdenum (Mo)	4.19	ppm
18	Silver (Ag)	218.8	ppb
19	Cadmium (Cd)	Not Detected (Less than 0.5)	ppb
20	Antimony (Sb)	6.86	ppm
21	Barium (Ba)	3152.14	ppm
22	Lead (Pb)	958.89	ppm

Based on the result obtained from Table 4.4 to Table 4.5, the heavy metals concentration in soil sample are higher for Aluminium (Al), Manganese (Mn) and Iron (Fe) for outside river at Jemberau River. While, for soil sample inside Jemberau River, the higher concentration is Potassium (K), Manganese (Mn) and Iron (Fe). All of the tabulated data for heavy metals were recorded based on the soil sample that taken at 26^th October 2018. The data that has been recorded indicated that the higher concentration for these heavy metals element was resulted from the land use activity near the Jemberau River which is specifically known as mining activity that contribute the worse effect for water quality.

RESULTS FOR WATER SAMPLES IN 2019 (ICP-OES METHOD)

Table 4.6 Heavy Metal Results for water sample at Jemberau River

No	Parameter	Results	Unit
1	Argentum (Ag)	Not Detected (Less than 0.1)	ppm
2	Aluminium (Al)	0.28	ppm
3	Boron (B)	0.24	ppm
4	Barium (Ba)	Not Detected (Less than 0.1)	ppm
5	Bismuth (Bi)	Not Detected (Less than 0.1)	ppm
6	Calcium (Ca)	1.70	ppm
7	Cadmium (Cd)	Not Detected (Less than 0.1)	ppm
8	Cobalt (Co)	Not Detected (Less than 0.1)	ppm
9	Chromium (Cr)	Not Detected (Less than 0.1)	ppm
10	Copper (Cu)	Not Detected (Less than 0.1)	ppm
11	Iron (Fe)	2.97	ppm
12	Galium (Ga)	Not Detected (Less than 0.1)	ppm
13	Indium (In)	Not Detected (Less than 0.1)	ppm
14	Potassium (K)	1.33	ppm
15	Lithium (Li)	Not Detected (Less than 0.1)	ppm
16	Magnesium (Mg)	0.57	ppm
17	Manganese (Mn)	0.71	ppm
18	Sodium (Na)	1.71	ppm
19	Nickel (Ni)	Not Detected (Less than 0.1)	ppm
20	Lead (Pb)	Not Detected (Less than 0.1)	ppm
21	Strontium (St)	Not Detected (Less than 0.1)	ppm
22	Thallium (TI)	Not Detected (Less than 0.1)	ppm
23	Zinc (Zn)	Not Detected (Less than 0.1)	ppm

Table 4.7 Heavy Metal Results for water sample at Chini River

No	Parameter	Results	Unit
1	Argentum (Ag)	Not Detected (Less than 0.1)	ppm
2	Aluminium (Al)	0.52	ppm
3	Boron (B)	Not Detected (Less than 0.1)	ppm
4	Barium (Ba)	Not Detected (Less than 0.1)	ppm
5	Bismuth (Bi)	Not Detected (Less than 0.1)	ppm
6	Calcium (Ca)	1.78	ppm
7	Cadmium (Cd)	Not Detected (Less than 0.1)	ppm
8	Cobalt (Co)	Not Detected (Less than 0.1)	ppm
9	Chromium (Cr)	Not Detected (Less than 0.1)	ppm
10	Copper (Cu)	Not Detected (Less than 0.1)	ppm
11	Iron (Fe)	1.58	ppm
12	Galium (Ga)	Not Detected (Less than 0.1)	ppm
13	Indium (In)	Not Detected (Less than 0.1)	ppm
14	Potassium (K)	0.82	ppm
15	Lithium (Li)	Not Detected (Less than 0.1)	ppm
16	Magnesium (Mg)	0.69	ppm
17	Manganese (Mn)	Not Detected (Less than 0.1)	ppm
18	Sodium (Na)	1.72	ppm
19	Nickel (Ni)	Not Detected (Less than 0.1)	ppm
20	Lead (Pb)	Not Detected (Less than 0.1)	ppm
21	Strontium (St)	Not Detected (Less than 0.1)	ppm
22	Thallium (TI)	Not Detected (Less than 0.1)	ppm
23	Zinc (Zn)	Not Detected (Less than 0.1)	ppm

Based on the result obtained from Table 4.6 to Table 4.7, the highest heavy metals concentration in water sample at Jemberau River are Aluminium (Al), Boron (B), Calcium (Ca), Iron (Fe), Magnesium (Mg), Manganese (Mn), Sodium (Na) and Potassium (K). While, the highest heavy metals concentration in water sample at Chini River are Aluminium (Al), Calcium (Ca), Iron (Fe), Potassium (K), Magnesium (Mg) and Sodium (Na). All of the tabulated data for heavy metals were recorded based on the water sample that taken at 20^{th} February 2019. The data that has been recorded indicated that the higher concentration for these heavy metals element was resulted from the land use activity near the Jemberau River which is specifically known as mining activity that contribute the worse effect for water quality. While for the Chini River, the water quality may affect from nearby activity such as the National Service Training Programme or Program Latihan Khidmat Negara.

4.4 Water Quality Index (WQI)

There are six parameters that are selected for WQI which are Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solid (SS), Ammoniacal Nitrogen (AN) and pH. In addition, the calculations are not done on their own parameters but on their sub-index which are known as SIDO, SIBOD, SICOD, SIAN, SISS and SIpH.

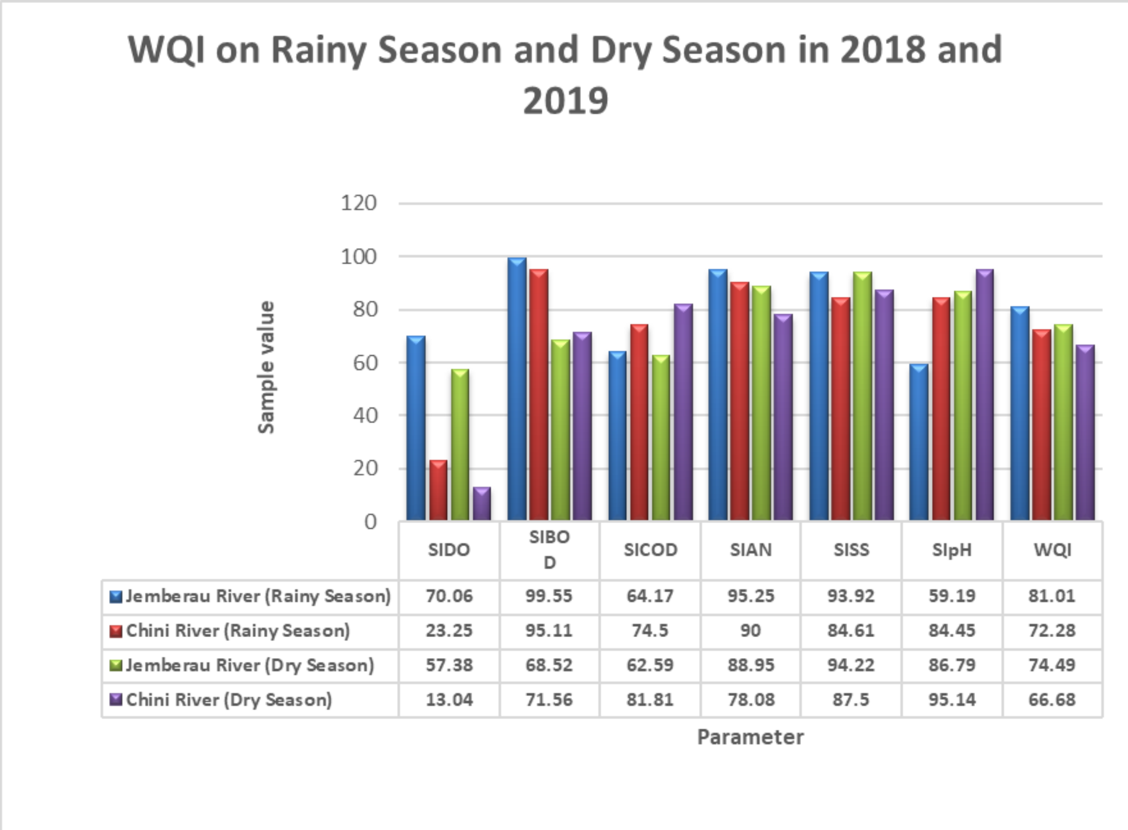


Figure 4.25 Graph for Water Quality Index at Jemberau River and Chini River during rainy season in 2018 and dry season in 2019

Figure 4.25 shows the Water Quality Index (WQI) for Jemberau River and Chini River. Based on DOE-WQI, the selected station at Jemberau River during rainy season in 2018 is classified in Class II, while Jemberau River during dry season in 2019 and Chini River during both rainy and dry season are classified in Class III. From above data, it is means that the water quality of Jemberau River and Chini River is different from the location of the sampling station.

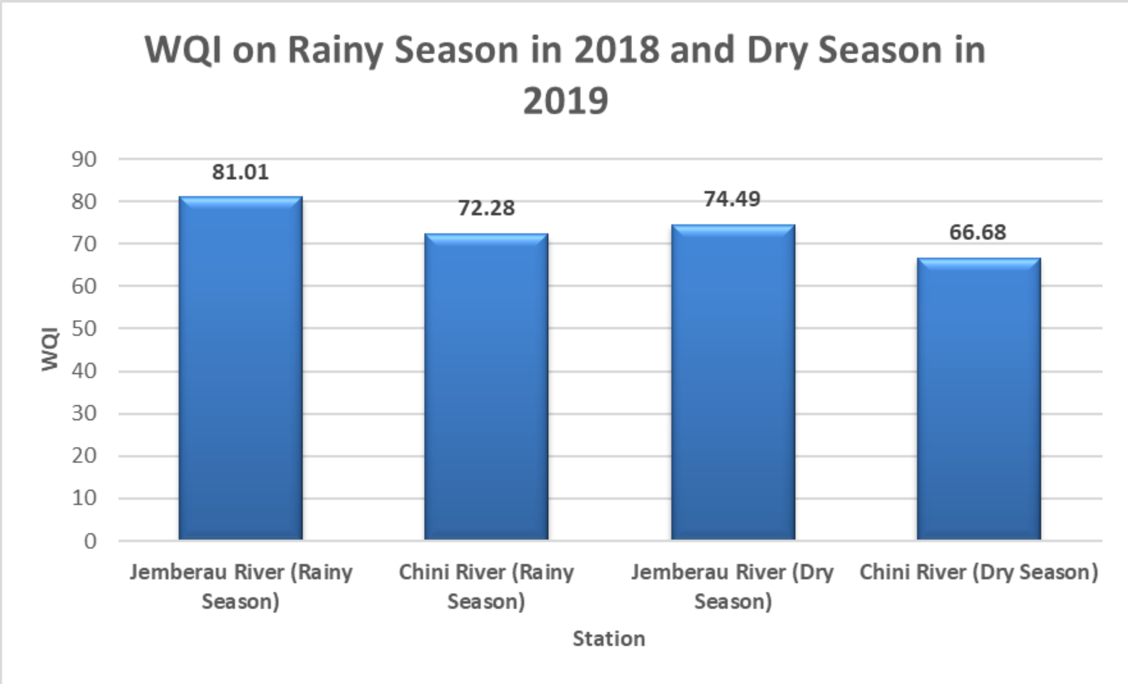


Figure 4.26 Graph for Water Quality Standard based on WQI at Jemberau River and Chini River during rainy season in 2018 and dry season in 2019

From Figure 4.26, it is shows that the water quality for all sampling stations at Tasik Chini during rainy season and dry season. According to DOE-WQI, station at Jemberau River during rainy season in 2018 is classified in Class II because the WQI value is 81.01 which is in the range 76.50-92.70, so that the water quality at this station is consider clean. While the other stations at Jemberau River during dry season in 2019 and Chini River during both rainy and dry season are classified in Class III. It is classified in Class III because of the WQI value for that rivers are in the range 51.90-76.50 which is the index range is classified as slightly polluted. The water pollution might be coming from the land use activities surrounding Tasik Chini such as mining activity, residential area and agricultural activity which generated by local people.

CHAPTER 5

CONCLUSION

5.1 Introduction

In this research, the current water quality status and classification for Jemberau River and Chini River was determined based on National Water Quality Standards (NWQS) for Malaysia and Water Quality Index (WQI) from Department of Environment Malaysia. Based on the analysis that has been made, station at Jemberau River and Chini River are classified as Class III which is according to index range of WQI, the station at Jemberau River and Chini River was classified as slightly polluted and polluted respectively. In addition, the water sample collected from station Jemberau River is classified in Class III due to land use activity nearby the river such as mining activity that can cause surface runoff and hence contributes to heavy metals pollution in the river. While, Chini River is classified in Class III which is slightly polluted because there have the National Service Training Programme or Program Latihan Khidmat Negara (PLKN) near the river and the effluent or sewage discharge from that activity flowing into the Chini River and cause the water pollution. In addition, Chini River also act as outlet to Pahang River, so that it will give worse effect in the future if the river is not treating well from now.

From the study area, the environment of Tasik Chini changes since 1984 or earlier because of the development in surrounding areas through human activities such as mining, logging, oil palm plantation, and also building infrastructure for the National Service Centre (Mohd Jaafar, S., 2013). Based on the collected data for two different stations of water samples that has been analyzed, we can conclude that the main sources of water pollution in Tasik Chini is comes from nearby mining activity. From the in-situ analysis and laboratory experiment that has been conducted, there are varied reading of parameter concentration based on different location and seasons. Other than that, the land use activity at certain location give the most impact to the reading taken especially for heavy metals concentration. According to NWQS and DOE-WQI, since most stations surrounding Tasik Chini is classified as Class III, hence the water supply need an extensive treatment and it is not suitable for drinking uses. Besides that, for fishery activities it is act as livestock drinking, common of economic value and tolerant species.

5.2 Recommendations

Based on the analyzed results and conclusion that has been made, the land use activities surrounding Tasik Chini such as mining, residential area and agricultural are the main source that contributes to water pollution. Some of the concentration of heavy metals become higher from year to year is probably because the water samples are taken from nearest mining activity. There are several recommendations in order to get more accurate reading when doing the research in future studies about water quality in Tasik Chini which are:

i. Do the correct preservation technique when doing the laboratory test.

ii. The reading for turbidity must be taken at the collected samples location as soon as the samples are taking.

iii. The water samples must be collected near the land use activity area and ensure that the flow of water is not disturbing before the sample is taking.

iv. Samples analysis that conducted in the laboratory should be taking two reading for each test in order to get average value.

v. Ensure that the water samples collected in each station are label correctly and the water samples must pour inside the clean bottles in order to avoid impurities.

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APPENDIX A1
IN-SITU TEST RESULTS

Table A1: Result of pH at Tasik Chini during rainy and dry season in 2018 and 2019

Station / Season	Jemberau River	Chini River
October 2018 (Rainy)	5.08	5.64
February 2019 (Dry)	5.76	6.32

Table A2: Electrical Conductivity (EC) in µS/cm at Tasik Chini during rainy and dry season in 2018 and 2019

Station / Season	Jemberau River	Chini River
October 2018 (Rainy)	32.40	35.60
February 2019 (Dry)	34.10	31.30

Table A3: Turbidity in NTU at Tasik Chini during rainy and dry season in 2018 and 2019

Station / Season	Jemberau River	Chini River
October 2018 (Rainy)	7.06	45.60
February 2019 (Dry)	4.88	17.70

Table A4: Dissolved Oxygen in mg/L at Tasik Chini during rainy and dry season in 2018 and 2019

Station / Season	Jemberau River	Chini River
October 2018 (Rainy)	5.36	2.49
February 2019 (Dry)	4.38	1.82

Table A5: Temperature in °C at Tasik Chini during rainy and dry season in 2018 and 2019

Station / Season	Jemberau River	Chini River
October 2018 (Rainy)	25.10	28.60
February 2019 (Dry)	27.30	27.30

APPENDIX A2
LABORATORY TEST RESULTS

Table A6: Biochemical Oxygen Demand (BOD) in mg/L during rainy and dry season in 2018 and 2019

Station / Season	Jemberau River	Chini River
October 2018 (Rainy)	0.20	1.25
February 2019 (Dry)	8.06	7.30

Table A7: Chemical Oxygen Demand (COD) in mg/L during rainy and dry season in 2018 and 2019

Station / Season	Jemberau River	Chini River
October 2018 (Rainy)	29.00	18.50
February 2019 (Dry)	30.5	13.00

Table A8: Ammoniacal Nitrogen (NH3-N) in mg/L during rainy and dry season in 2018 and 2019

Station / Season	Jemberau River	Chini River
October 2018 (Rainy)	0.05	0.10
February 2019 (Dry)	0.11	0.50

Table A9: Nitrate (NO3-) in mg/L during rainy and dry season in 2018 and 2019

Station / Season	Jemberau River	Chini River
October 2018 (Rainy)	0.01	0.02
February 2019 (Dry)	0.01	0.00

APPENDIX A3
LABORATORY TEST RESULTS

Table A10: Total Suspended Solid (TSS) in mg/L during rainy and dry season in 2018 and 2019

Station / Season	Jemberau River	Chini River
October 2018 (Rainy)	3.00	36.00
February 2019 (Dry)	17.00	66.00

Table A11: Suspended Solid (SS) in mg/L during rainy and dry season in 2018 and 2019

Station / Season	Jemberau River	Chini River
October 2018 (Rainy)	6.00	23.00
February 2019 (Dry)	5.50	17.50

Table A12: Phosphorus (P) in mg/L during rainy and dry season in 2018 and 2019

Station / Season	Jemberau River	Chini River
October 2018 (Rainy)	1.90	0.40
February 2019 (Dry)	0.07	0.27

Table A13: Potassium (K) in mg/L during rainy and dry season in 2018 and 2019

Station / Season	Jemberau River	Chini River
October 2018 (Rainy)	1.90	1.85
February 2019 (Dry)	1.90	1.30

APPENDIX A4
LABORATORY TEST RESULTS

Table A14: Heavy Metal (AAS Method) in mg/L during rainy and dry season in 2018 and 2019

Jemberau River	Chromium, Cr (mg/L)	Lead, Pb (mg/L)	Copper, Cu (mg/L)	Cadmium, Cd (mg/L)	Iron, Fe (mg/L)	Zinc, Zn (mg/L)	Manganese, Mn (mg/L)
October	-0.080	0.013	0.032	-0.021	0.492	0.005	0.069
February	-0.139	0.304	-0.031	0.454	-	-	-
Chini River	**Chromium, Cr (mg/L)**	**Lead, Pb (mg/L)**	**Copper, Cu (mg/L)**	**Cadmium, Cd (mg/L)**	**Iron, Fe (mg/L)**	**Zinc, Zn (mg/L)**	**Manganese, Mn (mg/L)**
October	-0.087	0.004	0.035	-0.023	1.57	0.00	0.080
February	-0.131	0.211	-0.036	0.454	-	-	-

APPENDIX A5
WATER QUALITY INDEX (WQI)

Table A16: Water Quality Index (WQI) during rainy and dry season in 2018 and 2019

26 October 2018 (Rainy Season)																
STATION	**DO (%)**	**DO**	**SIDO**	**BOD**	**SIBOD**	**COD**	**SICOD**	**AN**	**SIAN**	**SS**	**SISS**	**pH**	**SIpH**	**WQI**	**Class**	**Category**
Jemberau River	64.00	5.36	70.06	0.20	99.55	29.00	64.17	0.05	95.25	6.00	93.92	5.08	59.19	81.01	II	Clean
Chini River	31.60	2.49	23.25	1.25	95.11	18.50	74.50	0.10	90.00	23.00	84.61	5.64	84.45	72.28	III	Slightly Polluted
20 February 2019 (Dry Season)																
Jemberau River	55.20	4.38	57.38	8.06	68.52	30.50	62.59	0.11	88.95	5.50	94.22	5.76	86.79	74.49	III	Slightly Polluted
Chini River	23.00	1.82	13.04	7.30	71.56	13.00	81.81	0.50	78.08	17.50	87.50	6.32	95.14	66.68	III	Slightly Polluted

APPENDIX A6
ANALYSIS PARAMETER BY STATIONS

Table A16: Analysis parameter by stations from 2016 to 2019

Station / Parameter	Jemberau River										Chini River									
Researcher	Munirah						Hafiz		Nadia		Munirah						Hafiz		Nadia	
Date	29/9/16	24/11/16	Average	5/3/17	17/5/17	Average	November	January	26/10/18	20/2/19	29/9/16	24/11/16	Average	5/3/17	17/5/17	Average	November	January	26/10/18	20/2/19
pH	5.90	5.34	5.62	4.91	5.31	5.11	9.96	7.55	5.08	5.76	5.50	6.13	5.82	6.18	6.95	6.57	10.23	6.76	5.64	6.32
Electrical Conductivity (EC)	27.00	30.00	28.50	57.30	16.00	36.65	22.80	26.40	32.40	34.1	33.30	61.90	47.60	99.0	24.0	61.50	28.10	32.00	35.60	31.3
Turbidity (NTU)	4.96	51.60	28.28	11.40	2.72	7.06	15.10	2.77	7.06	4.88	32.20	329.00	180.60	204.00	28.30	116.15	33.30	21.20	45.60	17.7
Dissolved Oxygen (DO) (mg/L)	5.80	4.99	5.40	5.05	5.97	5.51	6.27	5.05	5.36	4.38	3.06	4.25	3.66	4.82	5.33	5.08	4.21	1.55	2.49	1.82
Temperature(°C)	29.30	27.30	28.30	29.00	27.20	28.10	26.90	26.40	25.10	27.3	29.20	27.60	28.40	26.0	28.3	27.15	28.40	26.60	28.60	27.3
Biochemical Oxygen Demand (BOD) (mg/L)	3.55	4.40	3.98	6.40	3.73	5.07	17.35	10.05	0.2	8.06	4.55	4.30	4.48	6.50	5.10	5.80	9.50	3.40	1.25	7.30
Chemical Oxygen Demand (COD) (mg/L)	9.00	24.00	16.50	45.00	44.00	44.50	68.00	32.00	29.00	30.5	6.00	13.50	9.75	10.00	29.00	19.50	59.00	20.00	18.50	13.00
Ammoniacal Nitrogen (mg/L)	0.00	0.04	0.02	0.00	0.00	0.00	0.00	0.12	0.05	0.11	0.04	0.29	0.17	0.11	0.07	0.07	0.00	0.12	0.10	0.50
Nitrate (mg/L)	0.02	0.00	0.01	0.01	0.45	0.23	0.01	0.02	0.01	0.01	0.00	0.06	0.08	0.00	0.00	0.00	0.06	0.02	0.02	0.00
Total Suspended Solids (TSS) (mg/L)	9.00	17.00	13.0	6.00	80.00	43.00	17.00	6.00	3.00	17.00	3.00	174.00	88.50	113.00	1.00	57.00	23.00	21.00	36.00	66.00
Suspended Solids (SS) (mg/L)	7.00	38.00	22.50	14.00	1.00	7.50	1.00	3.00	6.00	5.50	33.50	267.50	150.50	158.00	90.50	124.25	20.00	17.00	23.00	17.50
Phosphorus (mg/L)	0.00	0.00	0.00	N/A	N/A	N/A	0.83	0.22	1.90	0.07	0.11	0.12	0.12	N/A	N/A	N/A	0.09	0.02	0.40	0.27
Potassium (mg/L)	2.42	2.06	2.24	N/A	N/A	N/A	20.00	6.40	1.90	1.9	2.87	2.01	2.44	N/A	N/A	N/A	26.00	23.00	1.85	1.3
Hardness (Mg/Ca) (mg/L)	-	-	-	-	-	-	1.19/1.95	1.32/2.28	-	-	-	-	-	-	-	-	2.28/1.95	1.90/0.81	-	-
Heavy Metal (mg/L) Cadmium, Cd	-	-	-	-	-	-	0.00	0.004	-0.021	0.454	-	-	-	-	-	-	0	0.001	-0.023	0.454
Lead, Pb	-	-	-	-	-	-	1.107	0.000	0.013	0.304	-	-	-	-	-	-	0.958	0.00	0.004	0.211
Chromium, Cr	-	-	-	-	-	-	0.452	0.016	-0.080	-0.139	-	-	-	-	-	-	0.426	0.00	-0.087	-0.131
Copper, Cu	-	-	-	-	-	-	0.078	0.041	0.032	-0.031	-	-	-	-	-	-	0.081	0.040	0.035	-0.036
Nickel, Ni	-	-	-	-	-	-	0.015	-	-	-	-	-	-	-	-	-	0.023	-	-	-
Iron, Fe	-	-	-	-	-	-	-	-	0.492	-	-	-	-	-	-	-	-	-	1.57	-
Zinc, Zn	-	-	-	-	-	-	-	-	0.005	-	-	-	-	-	-	-	-	-	0.00	-
Manganese, Mn	-	-	-	-	-	-	-	-	0.069	-	-	-	-	-	-	-	-	-	0.08	-

APPENDIX A7
WATER CLASSIFICATION BASED ON WQI AND NWQS

LOCATION: Station 1 (Jemberau River)

COORDINATE: N 03º41.952” E 102º93.122”

WEATHER: Rainy season (26 October 2018)

PARAMETER	UNIT	SAMPLE VALUE	WQI CLASS	NWQS CLASS
Temperature	˚C	25.10	-	II
DO	mg/L	5.36	II	II
pH	-	5.08	III	III
EC	µS/cm	32.40	-	I
Turbidity	NTU	7.06	-	II
BOD	mg/L	0.20	I	I
COD	mg/L	29.00	III	III
NH3-N	mg/L	0.05	I	I
TSS	mg/L	3.00	I	I

APPENDIX A8
WATER CLASSIFICATION BASED ON WQI AND NWQS

LOCATION: Station 2 (Chini River)

COORDINATE: N 03º45.091” E 102º89.194”

WEATHER: Rainy season (26 October 2018)

PARAMETER	UNIT	SAMPLE VALUE	WQI CLASS	NWQS CLASS
Temperature	˚C	28.60	-	II
DO	mg/L	2.49	IV	IV
pH	-	5.64	III	III
EC	µS/cm	35.60	-	I
Turbidity	NTU	45.60	-	II
BOD	mg/L	1.25	II	II
COD	mg/L	18.50	II	II
NH3-N	mg/L	0.10	II	I
TSS	mg/L	36.00	II	II

APPENDIX A9
WATER CLASSIFICATION BASED ON WQI AND NWQS

LOCATION: Station 3 (Jemberau River)

COORDINATE: N 03o41.959” E 102o93.105”

WEATHER: Dry season (20 February 2019)

PARAMETER	UNIT	SAMPLE VALUE	WQI CLASS	NWQS CLASS
Temperature	˚C	27.30	-	II
DO	mg/L	4.38	III	III
pH	-	5.76	III	III
EC	µS/cm	34.10	-	I
Turbidity	NTU	4.88	-	I
BOD	mg/L	8.06	IV	IV
COD	mg/L	30.50	III	III
NH3-N	mg/L	0.11	II	II
TSS	mg/L	17.00	I	I

APPENDIX A10
WATER CLASSIFICATION BASED ON WQI AND NWQS

LOCATION: Station 4 (Chini River)

COORDINATE: N 03o45.036’’ E 102o89.182’’

WEATHER: Dry season (20 February 2019)

PARAMETER	UNIT	SAMPLE VALUE	WQI CLASS	NWQS CLASS
Temperature	˚C	27.30	-	II
DO	mg/L	1.82	IV	IV
pH	-	6.32	II	II
EC	µS/cm	31.30	-	I
Turbidity	NTU	17.70	-	II
BOD	mg/L	7.30	IV	IV
COD	mg/L	13.00	II	II
NH3-N	mg/L	0.50	III	III
TSS	mg/L	66.00	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	Water Supply II – Conventional treatment required. Fishery II – Sensitive aquatic species.
Class IIB	Recreational use with body contact.
Class III	Water Supply III – Extensive treatment required. Fishery III – Common, of economic value and tolerant species; livestock drinking.
Class IV	Irrigation
Class V	None of the above.

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