



UNIVERSITI PUTRA MALAYSIA

***ASSESSMENT OF WATER QUALITY STATUS IN
UPM-SEBIEW-KEMENA RIVER SYSTEM IN
BINTULU SARAWAK***

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KEMENA RIVER SYSTEM IN BINTULU SARAWAK**



**A Project Report Submitted in Partial Fulfillment of the Requirement for
the Degree of Bachelor of Science in Aquaculture with Honours in the
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Bintulu Sarawak Campus**

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ABSTRACT

Bintulu has seen tremendous growth in the petrochemical industry, transforming it into an industrial hub for Sarawak. Rapid urbanization and population growth may contribute to the increased level of water pollution. Pollutants may be sourced from anthropogenic activities, which from industrial areas, residential areas, agricultural activities, and markets. This study was conducted to determine and compare the water quality status of UPM, Sebiew, and Kemena river. The sampling was conducted from June to September 2023. In-situ data and water samples were obtained at six sampling stations representing three sampling zones (UPM, Sebiew, Kemena). In-situ data included temperature, pH, turbidity, total dissolved solids (TDS), dissolved oxygen (DO), salinity, and conductivity. Meanwhile, laboratory analysis was conducted to determine the total suspended solids (TSS), ammoniacal nitrogen ($\text{NH}_3\text{-N}$), chemical oxygen demand (COD), and biochemical oxygen demand (BOD). According to National Water Quality Standard (NWQS), the parameters that categorized under class IIA were temperature, TDS, and conductivity, while turbidity and salinity were in class IIB and class I respectively. According to Water Quality Index (WQI) classification, TSS were classified under class I while COD and BOD were in class II. Value of pH and DO were categorized in class III while $\text{NH}_3\text{-N}$ were in class IV. Only station 1 was classified in class II, while other stations categorized in class III. The subindex for BOD were categorized as slightly polluted, while $\text{NH}_3\text{-N}$ and TSS in those three zones were classified as polluted and clean respectively. All three sampling zones were classified under class III, which was greatly influenced by DO and $\text{NH}_3\text{-N}$ and extensive treatment was required for the purpose of water supply. The presence of pollutants were the contributing factors to the lower Water Quality Index (WQI)

obtained. Based on overall data, UPM, Sebiew, and Kemena rivers were classified as slightly polluted. Further study needs to be conducted to observe the long term forecast of these three rivers.



ABSTRAK

Bintulu telah menyaksikan pertumbuhan yang pesat dalam industri petrokimia, mengubahnya menjadi hab perindustrian untuk Sarawak. Perbandaran yang pesat dan pertumbuhan penduduk boleh menyumbang kepada peningkatan tahap pencemaran air. Bahan pencemar mungkin berpunca daripada aktiviti antropogenik, iaitu dari kawasan perindustrian, kawasan perumahan, aktiviti pertanian, dan pasar. Kajian ini dijalankan untuk menentukan dan membandingkan status kualiti air sungai UPM, Sebiew, dan Kemena. Persampelan dijalankan dari Jun hingga September 2023. Data in-situ dan sampel air diperoleh di enam stesen persampelan yang mewakili tiga zon persampelan (UPM, Sebiew, Kemena). Data in-situ termasuk suhu, pH, kekeruhan, jumlah pepejal terlarut (TDS), oksigen terlarut (DO), kemasinan dan kekonduksian. Sementara itu, analisis makmal dijalankan untuk menentukan jumlah pepejal terampai (TSS), nitrogen ammonia ($\text{NH}_3\text{-N}$), permintaan oksigen kimia (COD), dan permintaan oksigen biokimia (BOD). Menurut Piawaian Kualiti Air Kebangsaan (NWQS), parameter yang dikategorikan di bawah kelas IIA ialah suhu, TDS, dan kekonduksian, manakala kekeruhan dan kemasinan masing-masing berada dalam kelas IIB dan kelas I. Mengikut klasifikasi Indeks Kualiti Air (WQI), TSS dikelaskan di bawah kelas I manakala COD dan BOD berada dalam kelas II. Nilai pH dan DO dikategorikan dalam kelas III manakala $\text{NH}_3\text{-N}$ berada dalam kelas IV. Hanya stesen 1 dikelaskan dalam kelas II, manakala stesen lain dikategorikan dalam kelas III. Subindeks bagi BOD dikategorikan sebagai tercemar sedikit, manakala $\text{NH}_3\text{-N}$ dan TSS dalam ketiga-tiga zon tersebut masing-masing dikelaskan sebagai tercemar dan bersih. Ketiga-tiga zon persampelan dikelaskan di bawah kelas III, yang banyak dipengaruhi oleh DO dan $\text{NH}_3\text{-N}$ dan rawatan yang meluas

diperlukan untuk tujuan bekalan air. Kehadiran bahan pencemar merupakan faktor penyumbang kepada penurunan Indeks Kualiti Air (WQI) yang diperolehi. Berdasarkan data keseluruhan, sungai UPM, Sebiew, dan Kemena diklasifikasikan sebagai sedikit tercemar. Kajian lanjut perlu dijalankan untuk melihat ramalan jangka panjang ketiga-tiga sungai ini.



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APPROVAL SHEET

I certify that this research project report entitled “Assessment of Water Quality Status in UPM-Sebiew-Kemena River System in Bintulu Sarawak” has been examined and approved as a partial fulfillment of the requirement for the degree of Bachelor of Science (Honors) Aquaculture in the Faculty of Agricultural Science and Forestry, Universiti Putra Malaysia Bintulu Sarawak Campus.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
SPSS	Statistical Package for the Social Sciences
NWQS	National Water Quality Standard
WQI	Water Quality Index
Temp.	Temperature
pH	Potential of hydrogen
Turb.	Turbidity
TDS	Total dissolved solids
DO	Dissolved oxygen
Sal.	Salinity
Cond.	Conductivity
TSS	Total suspended solids
BOD	Biochemical oxygen demand
COD	Chemical oxygen demand

NH₃-N Ammoniacal nitrogen

Seb. Sebiew

Kem. Kemena

°C Celsius

mg/L Milligram per liter

NTU Nephelometric turbidity units

ppm Parts per million

ppt Parts per thousand

S/m Siemens per meter

CHAPTER 1

INTRODUCTION

1.1 Background

Agricultural and industrial are the primary sectors in Sarawak, due to the larger scale provided for both sectors (Norhaziqah, 2014). Since the detection of Liquefied Natural Gas (LNG) in 1969, Bintulu has bloomed drastically from an ordinary fishing village into the advancement of petro-chemical industries, which has transformed Bintulu as an Industrial Hub of Sarawak (Pei, 2021). Samalaju Industrial Park, Kidurong O&G Industrial Park, and Nyabau Industrial Park are some examples of the industries that have the tendency to cause the degradation of water quality in the nearest river, such as Kemena and Sebiew's river.

The most important resource for sustaining life and energy in all commercial operations associated with agriculture and industry is water (Wahab et al., 2020). Hence, the water quality should be monitored properly to prevent deterioration. Water quality is defined as a state of the water in relation to the needs of one or more biotic species and/or to any need or purpose that humans may have (Nayla, 2020). Water quality monitoring equipment such as multiparameter is one of the most used as it can measure more than one electrochemical parameter such as pH, temperature, conductivity, dissolved oxygen, turbidity, total suspended solid, and salinity. There is other water quality test equipment that can be used such as pocket TDS testers, pocket pH meters, and Hach portable turbidimeter.

Deforestation, loggings, and plantations in Borneo has somehow worsened the water quality as most pollutants are flowing from factories, livestock farming, plantations, and dwellings (Leong et. al., 2018). Several basic conditions of river waters need to be met to ensure that aquatic life could thrive (Naubi et. al., 2016). Therefore, water quality analysis was implemented to measure the suitability of certain parameters, whether it is following the standard methods, and according to the standard that has been set by the Department of Environment Ministry of Environment and Water (Roy, 2018). Disastrous events, such as floods, could be one of the reasons that lead to the deterioration of clean water, where there is high level of bacteriological contamination due to the event (Hashem et. al., 2021). Water quality analysis also can be used to control the efficiency of a particular system, especially for water quality maintenance, also to determine whether it is necessary or not for an upgrade or changes in an existing system and what action should be taken to overcome it (Roy, 2018).

Water quality index (WQI) is a rating which indicates the effects of water quality parameters and one of the most effective tools as it provides information on the water quality to the citizens and policy makers (Sivaranjani et. al., 2015). It is used to determine the water quality status in a specific time and location (Naubi et al., 2016). The water quality will deteriorate due to the increment of organic pollutants and heavy metals in industrial effluents released in the water. This also will affect the water quality index of those areas.

1.2 Problem statement

The water quality index is important in ensuring the safety of rivers or ocean for variety purposes such as aquaculture, agriculture, and domestic use (Naubi et al., 2016). However, the rapid bloom of industries around Bintulu may somehow have contributed to the deterioration of water quality in those two areas, which is Sebiew-Kemena river system. These three rivers were connected to each other where UPM river is one of the rivers that flows to Sebiew and Kemena river.

The water quality index (WQI) for all rivers in Sarawak is categorized in Class II (Clean), which includes Sebiew and Kemena river (DOE, 2020). However, the status of the UPM river remains uncertain. It is important to know the status of those three rivers to ensure that it can safely be used as a water supply provided with conventional treatment and any recreational activities that involve body contact.

1.3 Objectives of the study

To determine:

- i. water quality status of UPM-Sebiew-Kemena river system.
- ii. to compare the water quality status of UPM-Sebiew-Kemena river system.

CHAPTER 2

LITERATURE REVIEW

2.1 Monitoring of water quality in Malaysia

The government of Malaysia has imposed the Environmental Quality Monitoring Program (EQMP) as an initiative to strengthen the monitoring of environmental quality. Data collection of river water quality in Malaysia is one of the programs under EQMP. The purpose of this program is to effectively monitor, preventing, and controlling pollution by reporting the current level of environmental quality in Malaysia. Beginning from 1995 to 2015, the DOE has adopted EQMP as an initiative to monitor river water quality (DOE, 2020). There are six parameters involved in the calculation of WQI; dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen ($\text{NH}_3\text{-N}$), suspended solids, and pH.

In 2018, the Department of Environment (DOE) has monitored rivers in Malaysia and there are 638 rivers in total. Out of 638, 357 (56%) were categorized as clean, 231 (36%) were slightly polluted while another 50 (8%) was polluted (DOE, 2018). According to DOE 2019, the total number of rivers monitored was 672. Out of that figure, 408 (61%) were categorized as clean, 205 (30%) were slightly polluted, and another 59 (9%) were polluted (DOE, 2019). The data obtained from DOE 2020 shows that the river water quality index (WQI) has increased in 2020, where 66% of 672 rivers categorized as clean,

while for slightly polluted and polluted rivers were 195 (29%) and 34 (5%) respectively (DOE, 2020).

The biochemical oxygen demand (BOD), ammoniacal nitrogen ($\text{NH}_3\text{-N}$), and suspended solids (SS) continued to be important in terms of river pollution, according to observations made the previous year. A high level of BOD may result from improper sewage treatment or wastewater from industry and agricultural sectors. While SS are linked to inappropriate earthworks and land clearing activities, $\text{NH}_3\text{-N}$ sources may come from home waste and livestock farms. (DOE, 2018)

2.2 River water quality status in Malaysia

The demand for water consumption in Malaysia has increased due to the rapid urbanization and population growth. This has unfortunately contributed to the increased level of water pollution. Based on the data obtained from the Department of Environment (DOE), there were a total of 579 rivers detected in Malaysia during 2008, but the number is declining in 2019, where only 477 remained (NSTP, 2019).

Table 2.1: Data on the number of rivers in Malaysia based on their status as in 2008 to 2017 (Goi, 2020).

States	Number of rivers based on their status (2008-2017)		
	Clean	Slightly polluted	Polluted
Sabah	54	9	0
Sarawak	14	40	0
Kedah	8	7	0
Perlis	4	2	0
Penang	1	8	3
Perak	23	13	4
Selangor	4	4	1
Melaka	2	5	2
Johor	14	37	27
Pahang	13	12	0
Terengganu	10	14	0
Kelantan	16	6	2

The number of clean rivers in Malaysia are declining during 2017, where 219 out of 477 rivers are classified as clean, 207 are slightly polluted and the remaining are polluted. These polluted rivers were caused by anthropogenic activities, which came from industrial areas, residential areas, agricultural activities, markets, and others. (Goi, 2020). These activities will contribute to the increment in the concentration of heavy metals, mercury, coliforms, and nutrient loads. However, during 2020 the rivers show a good improvement where they are cleaner and clearer compared to 2017. This has been proven where Sungai Kim Kim that is popular for having chemical waste pollution, has started to recover, followed by Sungai Melaka, rivers in Klang Valley, and others (Goi, 2020).

The highest number of clean rivers was detected in Sabah, which includes 54 rivers (Goi, 2020). Based on the data from DOE 2019, Sungai Apas, Sungai Kalabakan, Sungai Kimanis, Sungai Kinabatangan, and Sungai Moyog are some of the rivers that have been

classified as clean in class II according to water quality index (DOE, 2019). Sungai Kinabatangan was nominated as the largest river in Sabah (WWF, 2004). However, the water quality of the river has deteriorated due to the logging activities, and it is reported that cocoa and oil palm plantations have been developed, which took more than 60000 ha of the land (Harun et al., 2015). Effluents that come from palm oil areas, fertilizers, pesticides, sediments from plantation activities, logging, and sewage from nearby villages have contributed to the pollution of Sungai Kinabatangan (WWF, 2004). Since the development of Sungai Kinabatangan into Ramsar site, there are few problems that have been detected like logging, soil erosion, impacts of agricultural activities include deterioration of water quality, habitat loss, oil palm plantations and oil palm mills (Sahana, 2013). The wide use of pesticides and fertilizers along Sungai Kinabatangan led to tributary pollution, where it has caused floating dead fish in that river, also there is no proper sanitation system in most villages along Sungai Kinabatangan (WWF, 2004). This affects the cleanliness of the river and at the same time has caused deterioration of water quality. This practice could also influence the consumers' health as the river was a source for bathing, washing, also as a drinking source especially for the villagers (WWF, 2004).

The most significant slightly polluted rivers in Malaysia are detected in Sarawak. Some locations observed were Batang Rajang, Sungai Merit, and Sungai Angkaya. However, most parts of Batang Rajang were categorized as slightly polluted in Class II and/or Class III due to some factors such as elimination of domestic waste, agricultural runoff, and logging activities (Ling et al, 2017). One of the main problems that contributes to the deterioration of water quality along Sungai Rajang is the lack of a proper domestic sewage effluent treatment system. The discharge from this area flowed directly into the

river, which then led to pollution as an effect from untreated or partially treated waste (Ling et al, 2017).

The number of polluted rivers in Malaysia was majorly identified in Johor. The polluted rivers were mainly detected in industrial areas such as Sungai Kopok, Sungai Kim Kim, Sungai Tukang Batu, Sungai Laloh, Sungai Buluh, Sungai Perembi, Sungai Masai, Sungai Rekoh, Sungai Plentong, Sungai Tebrau, Sungai Stulang, Sungai Skudai, Sungai Danga, Sungai Melayu, Sungai Perepat, and Sungai Pentas (Loheswar, 2019). Taking an example from Sungai Buluh, there are numerous industries near the basin, also small industries, and several wet markets along the river (Rowshon et al., 2014). As a result, there will be a numerous amount of suspended trash which leads to the formation of mini islands of rubbish (Loheswar, 2019). When exposed to sunlight, this mini island will be releasing a toxic smell that is not just harmful to humans, but also might kill underwater organisms as well. Sungai Perembi in Johor consists of industrial discharge on the baseflow, where the upstream water flow is linked to the nearest drainage system (Zainudin & Mohamed, 2006). This is potentially one of the factors that lead to the pollution of Sungai Perembi as the effluents discharge could increase the amount of ammonia and COD in the water bodies. Despite that, the development of commercial industries, small and medium business, and effluent treatment plants were also some of the factors that influenced the safeness and cleanliness of the rivers (Loheswar, 2019).

2.3 River water quality index in Bintulu

The water quality index is defined as a summary of water quality data for reporting purposes to the public in a consistent manner (Sivaranjani et al., 2015). A water quality index (WQI) is very helpful in detecting the current water status of an area by interpreting all the measurements into a single term, which will later guide the researcher to choose the most suitable treatment technique for those problems in selected areas. Water quality index (WQI) for all rivers in Sarawak are categorized in Class II (Clean), which includes Sebiew and Kemena river (DOE, 2020). The data below shows the water quality index for Sebiew and Kemena river from 2016 until 2020.

Table 2.2: Data on water quality index (WQI) of Sebiew and Kemena river based on DOE.

River	Year	WQI	Category	Class
Sg. Kemena	2016	77	Slightly polluted	II
	2017	77	Slightly polluted	II
	2018	85	Clean	II
	2019	85	Clean	II
	2020	82	Clean	II
Sg. Sebiew	2016	76	Slightly polluted	III
	2017	76	Slightly polluted	III
	2018	86	Clean	II
	2019	83	Clean	II
	2020	81	Clean	II

The data on water quality index of Sungai Kemena and Sungai Sebiew have shown a good improvement starting from 2018 to 2019, where the WQI value for both rivers has increased gradually. However, the data obtained from 2019 to 2020 have recorded a slight change in WQI but remain in class II. This means that these two rivers can still be safely used for water supply provided with conventional treatment and any recreational activities that involve body contact.

2.4 Characteristics of water quality parameters

There are six water quality parameters that are used in WQI calculations: pH, dissolved oxygen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen, and total suspended solids (TSS). Table 3 shows some parameters that are used to compare some rivers in Malaysia.

Table 2.3: Concentration of water quality parameters obtained in some rivers in Malaysia.

Location	Parameter class					
	pH	DO (mg/L)	BOD (mg/L)	COD (g/L)	TSS (mg/L)	NH3-N (mg/L)
Sungai Petani river (SP)	6.6365 - 7.615	7.228 - 10.095	5 - 26.77	26 - 74.5	20 - 258	1.04 - 3.58
Kuantan river (KR)	5.29 - 6.75	4.59 - 5.98	N/A	5.75 - 17.5	N/A	N/A
Liwagu river, Tambunan Sabah. (LR)	6 - 8.5	6.19 - 7.79	0.38 - 0.59	0.67 - 4.8	0.6 - 4.0	0.05 - 0.3
Sungai Pelan, Bintulu (PB)	5.85 ± 0.10	4.48 ± 0.10	0.99 ± 0.17	5.47 ± 2.59	0.004 ± 0.001	0.20 ± 0.05

SP: (Hashem et al., 2021); **KR:** (Kozaki et al., 2016); **LR:** (Cleophas et al., 2013); **PB:** (Leong et al., 2018).

The pH range for every location stated above is still in the suitable range that has been set by the DOE. Example taken from Sungai Petani, where the pH value for Sungai Petani varies according to the wet and dry season. During the wet season, pH values of some stations in Sungai Petani are categorized in class II and class I, while all stations are categorized in class I (Hashem et al., 2021). According to the value of pH obtained on this river, it is said that the river is suitable for aquatic life. While for Liwagu river, most of the stations have a value of pH almost 7.0 even though there is a waste discharge and this caused Liwagu river can be categorized under class I as the water pH is not affected due to the waste discharge (Cleophas et al., 2013).

While for the DO concentration, it shows that Sungai Petani has the most suitable value as been set by the DOE. The DO concentration during wet and dry season was categorized under class I, which shows that the river is within the WQI range and is very suitable for aquatic life sustainability (Hashem et al., 2021). While for Sungai Pelan, it shows that the values are not within the standard limit. This is caused by the location of the river itself, where it is nearer the schools and housing where human activities and waste disposal that are exposed to the river could affect the water quality (Leong et al., 2018). Furthermore, the water samples are said to have a higher mean of bacterial counts, and this could contribute to the low level of DO in Sungai Pelan (Leong et al., 2018).

Liwagu river has shown the lowest value of BOD among all the rivers stated in Table 3. The value is within the standard range, where it means that the water is safely available for human consumption (Cleophas et al., 2013). As for Sungai Petani, the BOD recorded has the highest value. This is caused by the exposure to the organic waste that

comes from industrial areas and household waste, also due to the lower water flow during the sampling, where a small amount of waste could rapidly increase the value of BOD (Hashem et al., 2021).

For COD concentration, Sungai Petani has recorded the highest value among all rivers in Table 3. This is due to the greatest number of pollutants from the river. It includes the highest amount of organic matter, which unfortunately increased the growth of bacteria that causes high COD concentration in the river (Hashem et al., 2021). Fertilizers, unsuccessful septic systems, disposal from wastewater treatment plants, and discharge from pets and animal farm also contribute to the rise of COD concentration in Sungai Petani (Hashem et al., 2021).

The concentration of total suspended solid (TSS) of Sungai Petani is leading other rivers stated in Table 3. This is caused by a shortage of rain during the dry season (Hashem et al., 2021). On the other hand, TSS concentration in Sungai Pelan is quite low compared to other rivers. This specifies that there is no occurrence of organic pollution on the surface water (Leong et al., 2018). High TSS in Sungai Petani is also due to the nearby activities of industrial institutions and factories that dispose of their solid waste into the river, which contributes to the high concentration (Hashem et al., 2021). $\text{NH}_3\text{-N}$ obtained in Sungai Petani is the highest among all, while Liwagu river obtained the lowest concentration. $\text{NH}_3\text{-N}$ has been detected in Liwagu rivers as an impact of application of fertilizer for the development of land and agriculture (Cleophas et al., 2013).

2.5 Water Quality Standards in Malaysia

The water quality status for these rivers could be determined using the Water Quality Index (WQI). There are six main parameters involved in the calculation, which are dissolved oxygen (DO), Biological Oxygen Demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen, total suspended solids (TSS) and pH. All these parameters value will later then being transferred into the Water Quality Index (WQI) formula based on DOE, 2020. The WQI could be used to determine suitability in terms of water uses according to NWQS.

$$WQI = 0.22(\text{siDO}) + 0.19(\text{siBOD}) + 0.16(\text{siCOD}) + 0.15(\text{siAN}) + 0.16(\text{siTSS}) + 0.12(\text{siPH})$$

Where,

siDO = Subindex DO (% saturation)

siBOD = Subindex BOD

siCOD = Subindex COD

siAN = Subindex NH₃N

siTSS = Subindex TSS

siPH = Subindex pH

Subindex for DO (in % saturation)

$$SIDO = 0$$

$$\text{for } x \leq 8$$

$$SIDO = 100$$

$$\text{for } x \geq 92$$

$$SIDO = -0.395 + 0.030x^2 - 0.00020x^3$$

$$\text{for } 8 < x < 92$$

Subindex for BOD

$$SIBOD = 100.4 - 4.23x$$

$$\text{for } x \leq 5$$

$$SIBOD = 108 * \exp(-0.055x) - 0.1x$$

$$\text{for } x > 5$$

Subindex for COD

$$SICOD = -1.33x + 99.1$$

$$\text{for } x \leq 20$$

$$SICOD = 103 * \exp(-0.0157x) - 0.04x$$

$$\text{for } x > 20$$

Subindex for NH₃-N

$$SIAN = 100.5 - 105x$$

$$\text{for } x \leq 0.3$$

$$SIAN = 94 * \exp(-0.573x) - 5 * |x - 2|$$

$$\text{for } 0.3 < x < 4$$

$$SIAN = 0$$

$$\text{for } x \geq 4$$

Subindex for SS

$$\begin{aligned} \text{SISS} &= 97.5 * \exp(-0.00676x) + 0.05x \\ \text{SISS} &= 71 * \exp(-0.0016x) - 0.015x \\ \text{SISS} &= 0 \end{aligned}$$

$$\begin{aligned} &\text{for } x \leq 100 \\ &\text{for } 100 < x < 1000 \\ &\text{for } x \geq 1000 \end{aligned}$$

Subindex for pH

$$\begin{aligned} \text{SpH} &= 17.2 - 17.2x + 5.02x \\ \text{SpH} &= -242 + 95.5x - 6.67x \\ \text{SpH} &= -181 + 82.4x - 6.05x \\ \text{SpH} &= 536 - 77.0x + 2.76x \end{aligned}$$

$$\begin{aligned} &\text{for } x < 5.5 \\ &\text{for } 5.5 \leq x < 7 \\ &\text{for } 7 \leq x < 8.75 \\ &\text{for } x \geq 8.75 \end{aligned}$$

Note:

* means multiply with

Table 2.4: National Water Quality Standards for Malaysia (After DOE, 2020)

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

Table 2.5: Water classes and uses (water supply)

Class	Uses (Water supply)
Class I	Practically no treatment necessary.
Class IIA	Conventional treatment required.
Class IIB	Recreational use with body contact.
Class III	Extensive treatment required.
Class IV	Irrigation
Class V	None of the above.

Table 2.6: DOE water quality classification based on water quality index (After DOE, 2020).

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

Table 2.7: DOE water quality index classification (After DOE, 2020).

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	-	> 7.0	6.0 - 7.0	5.0 - 6.0	< 5.0	> 5.0
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

CHAPTER 3

METHODOLOGY







3.1 Study area

A cross-sectional study design was selected to observe the water quality status in UPM-Sebiew-Kemena river system. The study will be conducted in six river points, where two points in UPM river (station 1 and 2), two points in Sebiew river (station 3 and 4), and another two points in Kemena river (station 5 and 6). The sampling station is shown in *Figure 1* below.



Figure 3.1: Maps showing sampling stations in UPM, Sebiew, and Kemena rivers.

Table 3.1: Sampling stations in UPM, Sebiew, and Kemena rivers

Zone A: UPM	
 <p>Station 1 Shared farm 1 3°12'27.5"N 113°05'31.6"E</p>	 <p>Station 2 Sri Rajang College 3°12'27.5"N 113°05'31.6"E</p>
Zone B: Sebiew	
 <p>Station 3 <i>Taman Sutera 5</i> 3°12'24.1"N 113°05'04.9"E</p>	 <p>Station 4 <i>Kg. Sebiew</i> 3°10'03.3"N 113°03'06.3"E</p>
Zone C: Kemena	
 <p>Station 5 Bintulu wharf 3°10'04.46"N 113°02'41.266"E</p>	 <p>Station 6 Bintulu waterfront 3°10'23.672"N 113°02'09.743"E</p>

3.2 Water Sampling and storage

The water samples will be collected once a month from every station point, which will take 4 months in total, beginning from June until September 2023. There are 18 samples that will be collected for lab analysis. Portable Multiparameter WQC-24 will be used to measure the pH, dissolved oxygen, electrical conductivity, turbidity, temperature, salinity, and total dissolved solids (TDS). The water samples will be collected at each station by using 2 units of 500mL and one unit of 1000mL plastic bottles. It will then be transferred to the laboratory for chemical analysis purposes and be kept in the freezer to maintain the samples.

3.3 Lab Analysis

3.3.1 Biochemical Oxygen Demand (BOD)

BOD will be analyzed using Standard Method 5210-B 5-day BOD test (APHA, 2012). A volume of 300mL of water samples will be taken from each sampling station. It will be aerated for 10 to 15 minutes. The initial reading will be recorded using the DO meter. Then, the samples will be left incubated with temperature 30°C for 5 days. After 5 days, the latest reading of DO will be taken. The calculation below shows the formula for obtaining BOD (mg/L):

$$\text{BOD (mg/L)} = \text{Initial DO} - \text{Final DO}$$

3.3.2 Chemical Oxygen Demand (COD)

COD will be analyzed using standard method APHA 5220B: Open Reflux Method (APHA, 2012). A volume of 50mL of water sample and blank sample will be prepared using the reflux flask. To the samples, a spoon of anti-bumping will be added. Next, 1g of mercuric sulphate, HgSO_4 were added to both samples and blank. Then, 5mL of sulfuric acid reagent will be added into both samples and shake. After that, both samples and blank will be filled up with 25mL of Kalium Dichromate $\text{K}_2\text{Cr}_2\text{O}_7$ and 70mL of sulfuric acid reagent. The samples will be heated for two hours with the aid of reflux condenser, retort stand, and hotplate. While waiting for the samples, prepare conical flasks that fill up with 300L distilled water for each replicate and blank sample. Once the heating is done, turn off the hotplate and fill the content of heated samples into conical flasks prepared before. Add 2mL of Ferroin indicator into the samples. Place the flasks on a hotplate and turn on the stir button. Using a digital burette, titrate the contents against standard Ferrous Ammonium Sulfate to brownish green.

3.3.3 Ammoniacal Nitrogen ($\text{NH}_3\text{-N}$)

Ammoniacal Nitrogen will be analyzed using standard methods 4500- NH_3 F. Phenate Method (APHA, 2012). Standard ammonium, fenol, natrium nitroprusside, and alkaline reagent will be prepared. For standard ammonium solution (SS1), 3.670g of $(\text{NH}_4)_2\text{SO}_4$ will be added into 1 L of deionized water. For fenol, 10g of Fenol $\text{C}_6\text{H}_6\text{O}$ will be mixed with 100 ml ethanol, $\text{C}_2\text{H}_5\text{OH}$. Natrium Nitroprusside will be prepared by mixing 0.5 g of $\text{Na}_2[\text{Fe}(\text{CN})_5\text{NO}]\cdot 2\text{H}_2\text{O}$ with 100 ml deionized water. As for

alkaline reagent (B), 20g $C_6H_5Na_3O_7$ will be mixed with 1 g of NaOH in 100ml of deionized water.

For the procedure, 10mL from SS1 will be pipetted and mixed with 990mL of deionized water into another flask. From the standard solutions, 0.5mL, 1mL, 5mL, and 10mL will be distributed respectively into another different flask. Deionized water will be added into all samples until it reaches 100mL. The flask is labelled with 0.05, 0.10, 0.50, and 1.00 ppm respectively. Then, 5.0 mL from every solution above will be poured into the test tubes including distilled water as a blank solution.

As for the samples, three replicates of every sample will be added with 5.0mL of water samples. Next, add 0.2 mL Fenol solution, Natrium Nitroprusside solution, and oxidation reagent respectively. After adding each of the solutions, it needs to be shaken before being left for 60 minutes. After 60 minutes, the samples will be poured into cuvettes and put into a spectrophotometer. The absorbance value will be observed.

3.3.4 Total Suspended Solid (TSS)

TSS will be analyzed using standard method 2540 D. Total Suspended Solids Dried at 103-105°C (APHA, 2012). Prepare aluminium foil as a holder for filter paper. Then, prewash the filter paper with 50mL distilled water. Dry the sample in oven 103 to 105°C for 15 minutes. After that, cool in the dessicator for 10 minutes. Weighed the sample using digital balance. Next, filter 100ml of water sample and dry it in oven 103 to 105°C for 60 minutes. Cool in the desiccator for 20 minutes and weigh it. Total suspended solids (TSS) are calculated as follows:

$$\text{TSS} = [(\text{weight of filter} + \text{residue (mg)} - \text{weight of filter (mg)}) \times 1000] / \text{volume of sample filtered (mL)}$$

3.4 Statistical analysis

This study will be carried out by using SPSS version 25, while one-way Analysis of Variance (ANOVA) will be used to compare the mean between months, zones, and stations of sampling. There will be three different stations, which is UPM, Sebiew, and Kemena. The water quality index in these three stations will be calculated by measuring the dissolved oxygen, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), pH, ammoniacal nitrogen, and total suspended solids (TSS). The mean in these three locations will be calculated and compared using Tukey alpha.

CHAPTER 4

RESULTS

4.1 Water quality parameters

There are 11 parameters that have been used to conduct this study. They are temperature ($^{\circ}\text{C}$), pH, turbidity (NTU), total dissolved solid (ppm), dissolved oxygen (mg/L), salinity (ppt), conductivity (S/m), total suspended solid (mg/L), ammoniacal nitrogen (mg/L), chemical oxygen demand (mg/L), and biochemical oxygen demand (mg/L). The statistical analyzed data of physicochemical parameters are shown in Table 4.1 and Table 4.2. Table 4.1 shows that there are no significant differences in temperature, turbidity, COD, and BOD for all three zones (UPM, Seb., Kem.). While turbidity is the only parameter that has no significant difference for sampling months. Table 4.2 on the other hand shows three parameters that have no significant difference, which is turbidity, COD, and BOD.

Table 4.1: Water quality parameters (mean \pm standard error) at different months and zones of sampling

Parameters	Month					Zone	
	June	July	Aug	Sept	UPM	Seb.	Kem.
Temp. (°C)	28.23 \pm 0.17 ^a	28.97 \pm 0.14 ^b	30.76 \pm 0.15 ^c	28.10 \pm 0.14 ^a	28.58 \pm 0.25	29.34 \pm 0.26	29.12 \pm 0.24
pH	5.27 \pm 0.25 ^a	5.57 \pm 0.28 ^{ab}	5.78 \pm 0.23 ^{ab}	6.30 \pm 0.08 ^b	5.26 \pm 0.26 ^a	5.86 \pm 0.17 ^{ab}	6.07 \pm 0.14 ^b
Turb. (NTU)	67.69 \pm 3.06	111.46 \pm 41.55	77.96 \pm 6.46	64.44 \pm 10.61	50.66 \pm 5.78	96.57 \pm 31.11	93.94 \pm 5.82
TDS (ppm)	1118 \pm 216 ^{ab}	1625 \pm 498 ^b	1062 \pm 387 ^{ab}	39 \pm 3.14 ^a	33 \pm 3.81 ^a	1121 \pm 240 ^b	1728 \pm 410 ^b
DO (mg/L)	2.74 \pm 0.23 ^a	3.81 \pm 0.38 ^b	3.50 \pm 0.19 ^{ab}	3.26 \pm 0.20 ^{ab}	3.75 \pm 0.30	2.98 \pm 0.17	3.25 \pm 0.19
Sal. (ppt)	1.58 \pm 0.32 ^{ab}	5.25 \pm 1.46 ^c	3.81 \pm 1.01 ^{bc}	0.02 \pm 0.003 ^a	0.02 \pm 0.003 ^a	1.54 \pm 0.36 ^a	6.45 \pm 1.10 ^b
Cond (S/m)	0.30 \pm 0.06 ^a	n.a.	0.68 \pm 0.17 ^b	0.01 \pm 0.001 ^a	0.01 \pm 0.001 ^a	0.23 \pm 0.06 ^a	0.74 \pm 0.16 ^b
TSS (mg/L)	11.53 \pm 2.00 ^a	29.53 \pm 4.62 ^b	29.40 \pm 6.15 ^b	19.72 \pm 4.58 ^{ab}	9.09 \pm 2.52 ^a	19.13 \pm 3.09 ^a	39.42 \pm 4.16 ^b
NH ₃ -N (mg/L)	0.82 \pm 0.14 ^a	1.07 \pm 0.28 ^a	1.95 \pm 0.31 ^b	0.69 \pm 0.12 ^a	1.21 \pm 0.20 ^{ab}	1.55 \pm 0.27 ^b	0.64 \pm 0.11 ^a
COD (mg/L)	21.69 \pm 0.64 ^a	23.32 \pm 1.10 ^a	20.47 \pm 0.88 ^a	27.38 \pm 1.32 ^b	21.15 \pm 0.94	24.32 \pm 0.95	24.19 \pm 1.05
BOD (mg/L)	n.a.	1.00 \pm 0.20 ^a	5.82 \pm 0.49 ^c	3.18 \pm 0.30 ^b	2.78 \pm 0.47	4.49 \pm 0.74	2.72 \pm 0.41

Means with similar or no superscripts were not significantly different ($P < 0.05$) between zones. n.a. = data not available

Table 4.2: Water quality parameters (mean \pm standard error) at different stations of sampling

Parameters	Station					
	1	2	3	4	5	6
Temp.(°C)	28.03 \pm 0.4 ^a	29.13 \pm 0.20 ^{ab}	29.72 \pm 0.35 ^b	28.97 \pm 0.37 ^{ab}	29.28 \pm 0.36 ^{ab}	28.97 \pm 0.31 ^{ab}
pH	5.89 \pm 0.29 ^{bc}	4.63 \pm 0.34 ^a	6.44 \pm 0.06 ^c	5.28 \pm 0.24 ^{ab}	5.66 \pm 0.14 ^{bc}	6.47 \pm 0.16 ^c
Turb. (NTU)	35.76 \pm 6.78	65.56 \pm 7.29	130.46 \pm 61.86	62.68 \pm 3.53	87.91 \pm 9.85	99.98 \pm 6.16
TDS (ppm)	17 \pm 1.57 ^a	50 \pm 3.05 ^a	578 \pm 187 ^{ab}	1665 \pm 389 ^b	2051 \pm 600 ^b	1405 \pm 570 ^{ab}
DO (mg/L)	4.80 \pm 0.20 ^b	2.71 \pm 0.38 ^a	2.80 \pm 0.27 ^a	3.16 \pm 0.21 ^a	3.34 \pm 0.18 ^a	3.17 \pm 0.34 ^a
Sal. (ppt)	0.007 \pm 0.002 ^a	0.03 \pm 0.004 ^a	0.77 \pm 0.3 ^a	2.31 \pm 0.6 ^a	5.66 \pm 1.3 ^b	7.23 \pm 1.8 ^b
Cond. (S/m)	0.004 \pm 0.001 ^a	0.01 \pm 0.002 ^a	0.19 \pm 0.06 ^{ab}	0.28 \pm 0.10 ^{abc}	0.69 \pm 0.22 ^{bc}	0.79 \pm 0.25 ^c
TSS (mg/L)	4.75 \pm 0.84 ^a	13.43 \pm 4.73 ^a	18.29 \pm 3.71 ^a	19.96 \pm 5.10 ^a	40.38 \pm 4.43 ^b	38.46 \pm 7.26 ^b
NH ₃ -N (mg/L)	0.65 \pm 0.22 ^a	1.78 \pm 0.25 ^b	2.25 \pm 0.42 ^b	0.85 \pm 0.21 ^a	0.75 \pm 0.20 ^a	0.53 \pm 0.11 ^a
COD (mg/L)	20.35 \pm 1.42	21.94 \pm 1.26	23.55 \pm 1.57	25.08 \pm 1.10	25.44 \pm 1.24	22.93 \pm 1.66
BOD (mg/L)	2.40 \pm 0.51	3.16 \pm 0.79	4.79 \pm 0.99	4.20 \pm 1.15	2.31 \pm 0.58	3.13 \pm 0.57

Means with similar or no superscripts were not significantly different (P<0.05) between stations.

4.1.1 Temperature

Based on the result obtained (Figure 4.1), the mean temperature was 29.01°C. The highest temperature between months was in August 30.76°C, while the lowest was in September 28.1°C. While between zones, the highest temperature was recorded in Sebiew, 29.34°C, while the lowest was in UPM, 28.58°C. Between six sampling stations, the highest temperature recorded was in station 3, 29.13°C and the lowest was in station 1, 28.03°C. Based on ANOVA statistical analysis, there were significant differences in temperature ($P < 0.05$) on different months and sampling stations (Table 4.1).

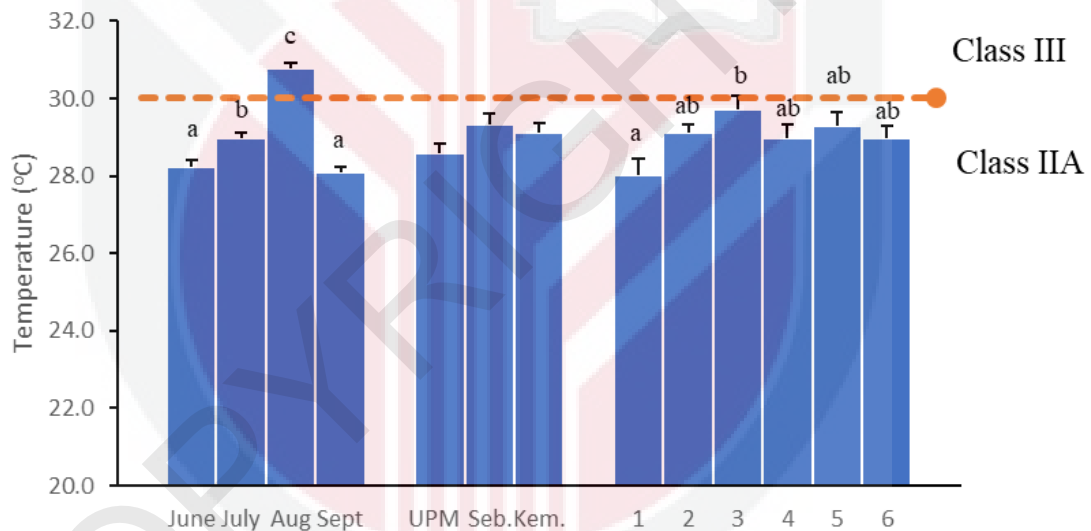


Figure 4.1: Mean levels of temperature and water classification based on National Water Quality Standard (NWQS) according to month, zone, and stations.

Note: Missing superscript means there are not significantly different at 5% level.

4.1.2 pH

Figure 4.2 shows the mean for pH was 5.73. The highest pH was obtained during September, 6.3, while June recorded the lowest pH, 5.27. Between the three zones, Kemena has the highest pH among all, 6.07 and the lowest was 5.26 in UPM. While between all six stations, station 6 has the highest pH, 6.47, while the lowest was 4.63 in station 2. According to ANOVA statistical analysis (Table 4.1), there were significant differences in pH ($P < 0.05$) on different months, zones, and sampling stations (Table 4.1 and Table 4.2).

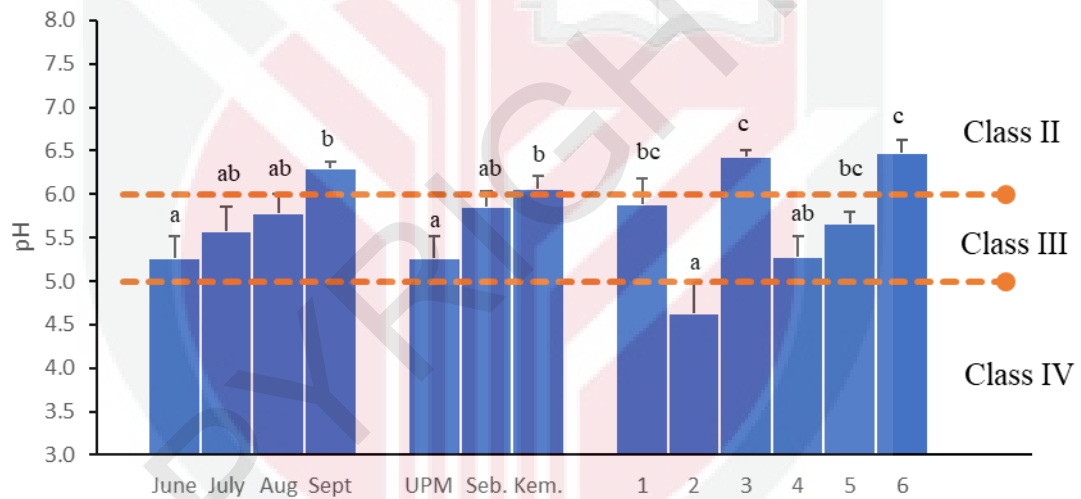


Figure 4.2: Mean levels of pH and water classification based on water quality index (WQI) according to month, zone, and stations.

Note: Superscripts means there are significantly different at 5% level.

4.1.3 Turbidity

The mean for turbidity is 80.39 NTU. Figure 4.3 shows that between those four months observation, July has recorded the highest turbidity with 111.46 NTU, while the lowest one is in September, 64.44 NTU. For the three zones, Sebiew recorded the highest turbidity, 96.57 NTU while the lowest is 50.66 NTU in zone. Besides that, station 3 has the highest turbidity among all six stations, which is 130.46 NTU, while the lowest turbidity observed in station 1, 35.76 NTU. There were no significant differences in turbidity.

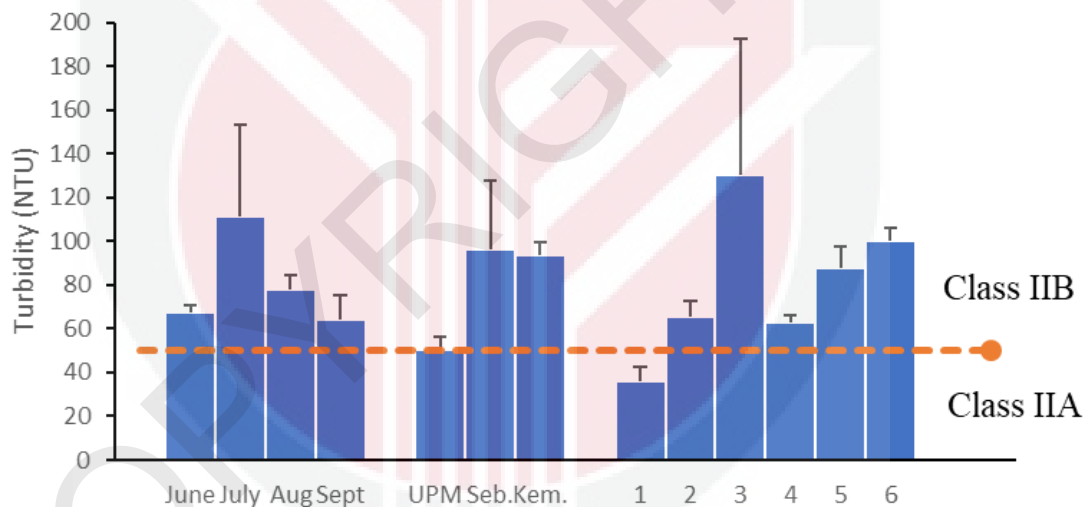


Figure 4.3: Mean levels of turbidity and water classification based on National Water Quality Standard (NWQS) according to month, zone, and stations.

Note: Missing superscript means there are not significantly different at 5% level.

4.1.4 Total dissolved solid (TDS)

The mean for TDS is 961 ppm. Based on Figure 4.4, the highest TDS was recorded in July with 1625.22 ppm, while the lowest is 38.89 ppm during September. Kemena has the highest TDS that is 1728.17 ppm, while the lowest recorded in UPM with 33.42 ppm. As for the stations, station 5 recorded the highest TDS, 2051.33 ppm, and station 1 has the lowest TDS among all stations, 17 ppm. Table 4.1 shows the significant differences in TDS ($P < 0.05$) on different months, zones, and sampling stations (Table 4.1 and Table 4.2).

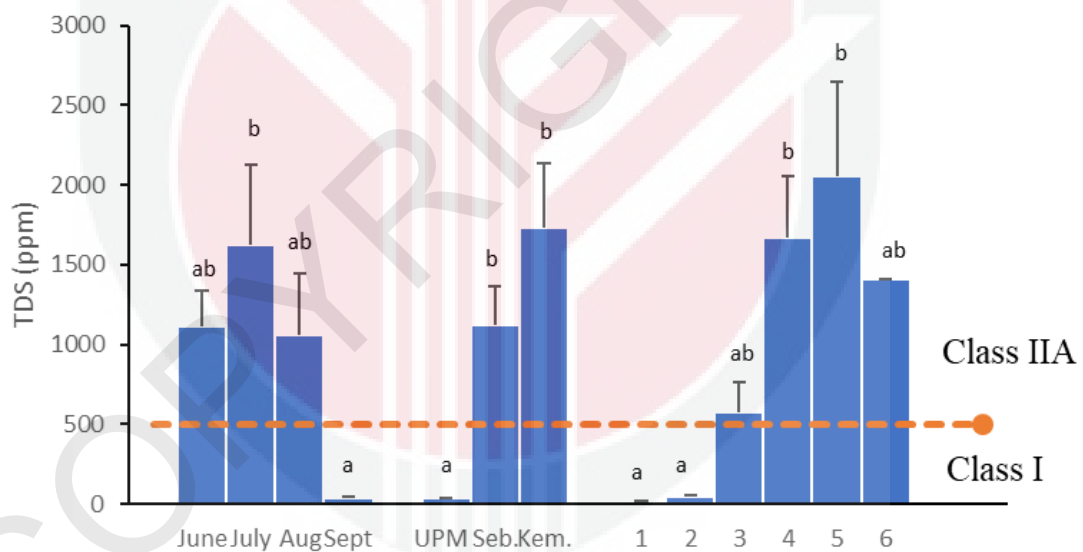


Figure 4.4: Mean levels of TDS and water classification based on National Water Quality Standard (NWQS) according to month, zone, and stations.

Note: Superscripts means there are significantly different at 5% level.

4.1.5 Dissolved oxygen (DO)

The mean for DO is 3.33 mg/L. Figure 4.5 shows that between those four months of study, July has the highest DO that is 3.81 mg/L, and the lowest was in June, 2.74 mg/L. For the three zones, the highest DO recorded in UPM, 3.75 mg/L while the lowest was 2.98 mg/L in Sebiew. Among all the stations, station 1 has the highest DO compared to other stations with 4.8 mg/L, while the lowest is 2.71 mg/L in station 2. Table 4.1 shows that there are significant differences in DO ($P < 0.05$) on different months and sampling stations (Table 4.1 and Table 4.2).

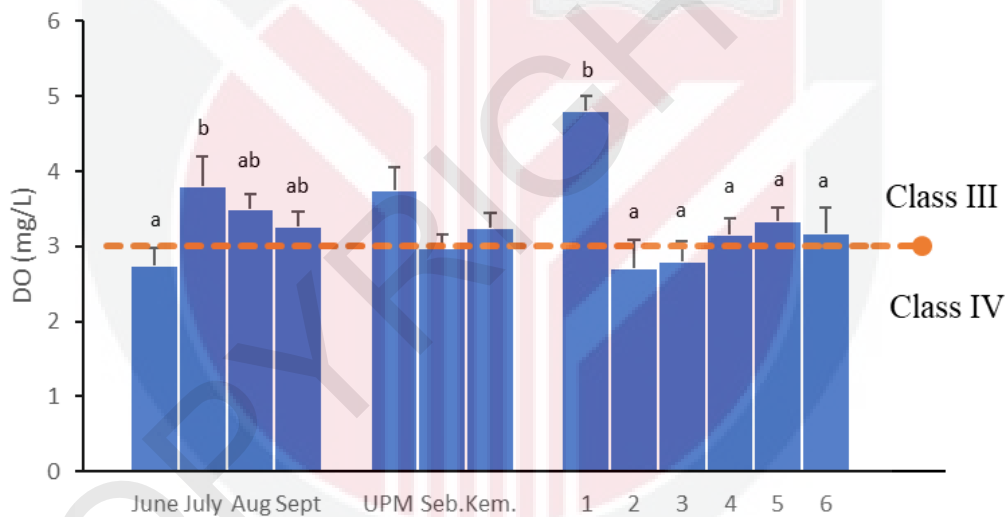


Figure 4.5: Mean levels of DO and water classification based on water quality index (WQI) according to month, zone, and stations.

Note: Superscripts means there are significantly different at 5% level.

4.1.6 Salinity

The mean for salinity is 2.67 ppt. Figure 4.6 shows that July has recorded the highest salinity, 5.25 ppt, while the lowest is during September, which only 0.02 ppt. Among the three zones, the highest salinity is 6.45 ppt in Kemena, while the lowest is 0.02 ppt in UPM. While the highest salinity is 7.23 ppt in station 6, and the lowest is 0.007 ppt in station 1. There were significant differences in salinity ($P < 0.05$) on different months, zones, and sampling stations (Table 4.1 and Table 4.2).

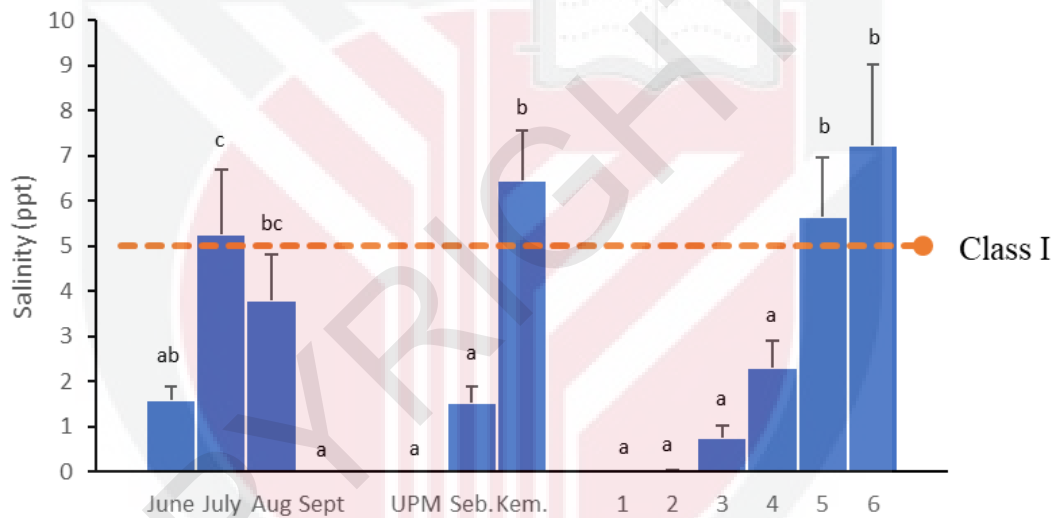


Figure 4.6: Mean levels of salinity and water classification based on National Water Quality Standard (NWQS) according to month, zone, and stations.

Note: Superscripts means there are significantly different at 5% level.

4.1.7 Conductivity

The mean for conductivity is 2.1 S/m. The highest conductivity was recorded on July with 7.4 S/m, while the lowest is 0.007 S/m during September as been shown in Figure 4.7. Sebieuw has the highest conductivity that is 5.22 S/m, while the lowest recorded is in UPM with 0.005 S/m. As for the stations, station 3 recorded the highest conductivity, 10.01 S/m, and station 1 has the lowest conductivity among all stations, 0.004 S/m. There were significant differences in conductivity ($P < 0.05$) on different months, zones, and sampling stations (Table 4.1 and Table 4.2).

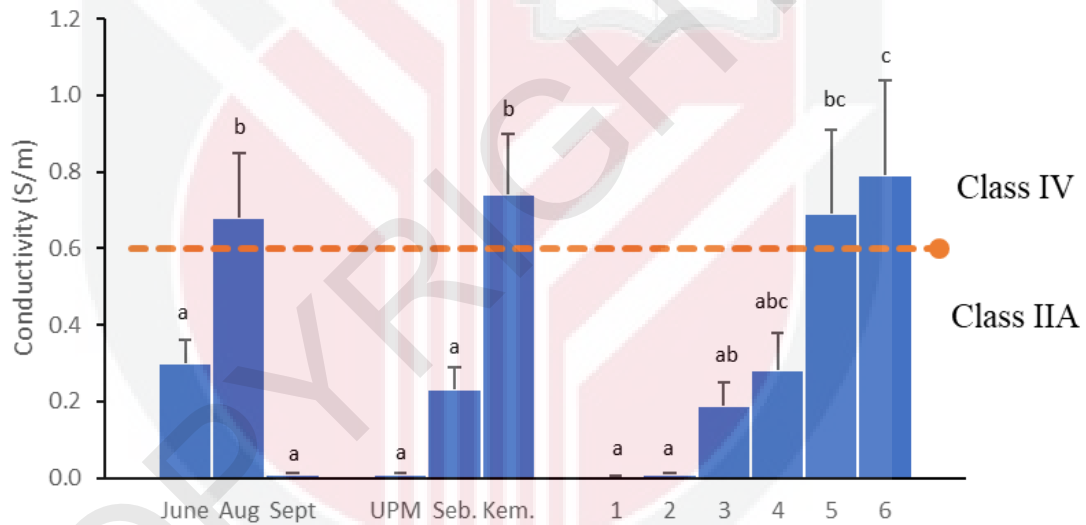


Figure 4.7: Mean levels of conductivity and water classification based on National Water Quality Standard (NWQS) according to month, zone, and stations.

Note: Superscripts means there are significantly different at 5% level.

4.1.8 Total suspended solid (TSS)

The mean for TSS is 22.54 mg/L. Figure 4.8 shows that July has the highest TSS, that is 29.53 mg/L, and the lowest was in June, 11.53 mg/L. For the three zones, the highest TSS recorded in Kemena, 39.42 mg/L while the lowest was 9.09 mg/L in UPM. Among all the stations, station 5 has the highest TSS compared to other stations with 40.38 mg/L, while the lowest is 4.75 mg/L in station 1. There were significant differences in TSS ($P < 0.05$) on different months, zones, and sampling stations (Table 4.1 and Table 4.2).

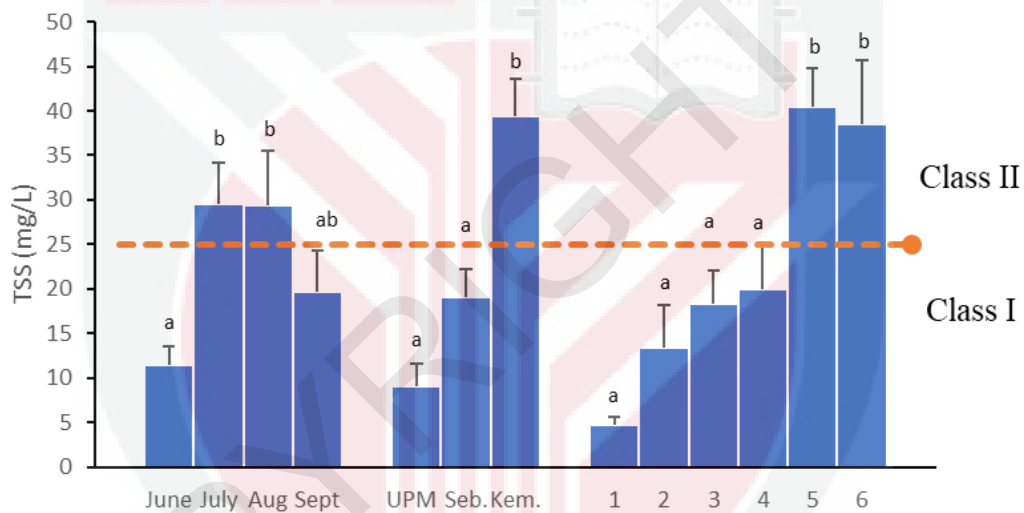


Figure 4.8: Mean levels of TSS and water classification based on water quality index (WQI) according to month, zone, and stations.

Note: Superscripts means there are significantly different at 5% level.

4.1.9 Ammoniacal nitrogen (NH₃-N)

The mean for NH₃-N is 1.53 mg/L. Figure 4.9 shows that August has recorded the highest NH₃-N with 1.95 mg/L, while the lowest one is in September, 0.69 mg/L. For the three zones, Sebiew recorded the highest NH₃-N, 1.55 mg/L while the lowest is 0.64 mg/L in Kemena. Besides that, station 3 has the highest NH₃-N among all six stations, which is 2.25 mg/L, while the lowest NH₃-N observed in station 6, 0.53 mg/L. There were significant differences in NH₃-N ($P < 0.05$) on different month, zones, and sampling stations (Table 4.1 and Table 4.2).

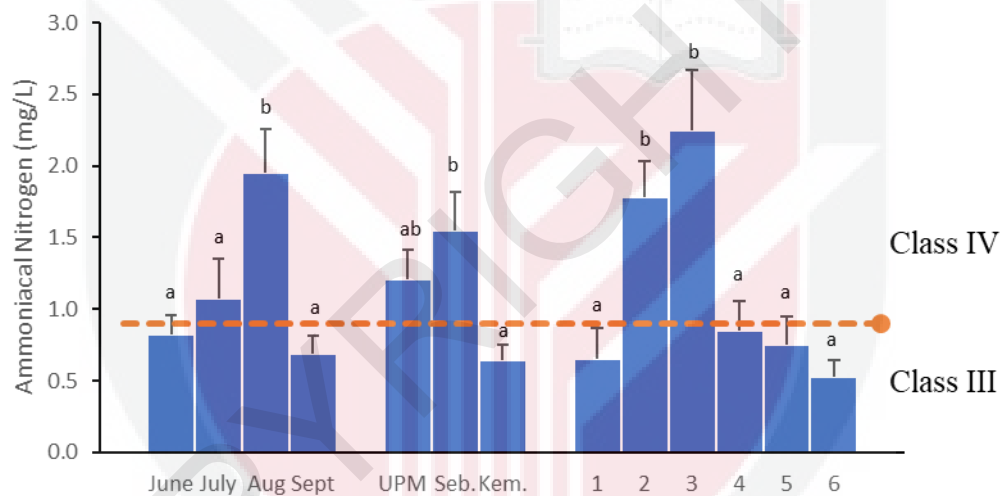


Figure 4.9: Mean levels of NH₃-N and water classification based on water quality index (WQI) according to month, zone, and stations.

Note: Superscripts means there are significantly different at 5% level.

4.1.10 Chemical oxygen demand (COD)

The mean for COD was 23.22 mg/L. Figure 4.10 shows the highest COD was obtained during September, 27.38 mg/L, while August has recorded the lowest COD, 20.47 mg/L. Between the three zones, Sebiew has a highest COD among all, 24.32 mg/L and the lowest was 21.15 mg/L in UPM. While between all six stations, station 5 has the highest COD, 25.44 mg/L, while the lowest was 20.35 mg/L in station 1. There are significant differences in COD ($P < 0.05$) on different months of sampling (Table 4.1).

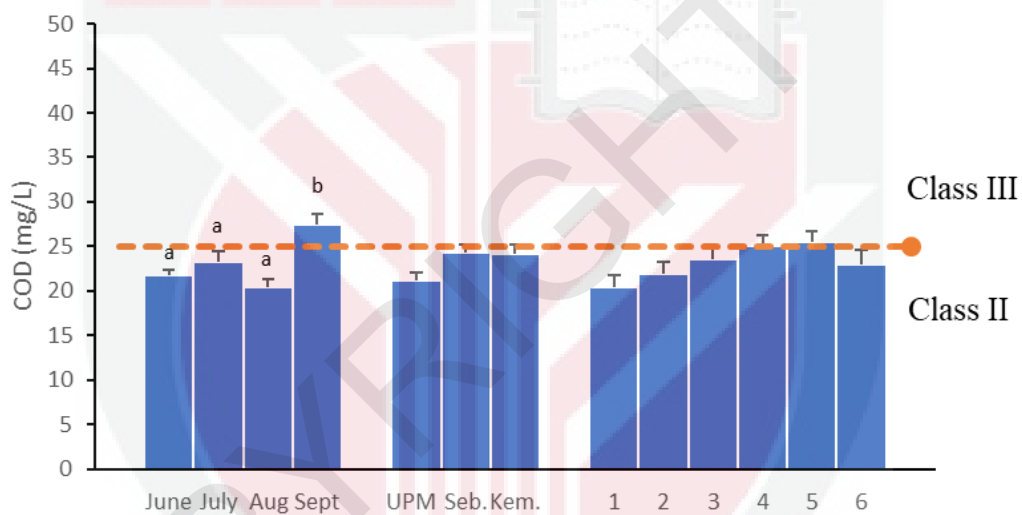


Figure 4.10: Mean levels of COD and water classification based on water quality index (WQI) according to month, zone, and stations.

Note: Superscripts means there are significantly different at 5% level.

4.1.11 Biochemical oxygen demand (BOD)

The mean for BOD is 3.33 mg/L. August has recorded the highest BOD, 5.82 mg/L, while the lowest is during July, which only 1.00 mg/L been shown in Figure 4.11. Among the three zones, the highest BOD is 4.49 mg/L in Sebiew, while the lowest is 2.72 mg/L in Kemena. While the highest BOD is 4.79 mg/L in station 3, and the lowest is 2.31 mg/L in station 5. There are significant differences in BOD ($P < 0.05$) on different months of sampling (Table 4.1).

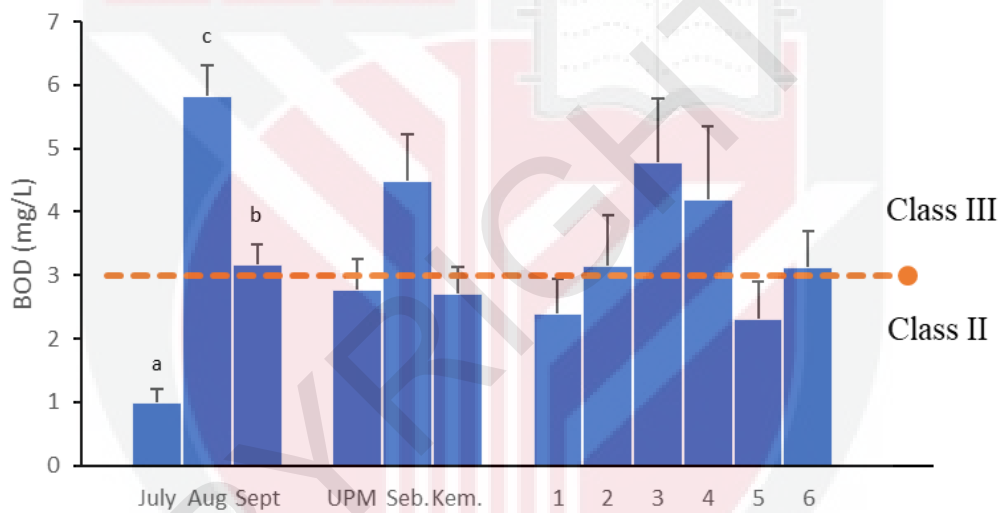


Figure 4.11: Mean levels of BOD and water classification based on water quality index (WQI) according to month, zone, and stations.

Note: Superscripts means there are significantly different at 5% level.

4.2 Water quality Index (WQI)

There are three parameters tested for the determination of WQI. They are BOD, $\text{NH}_3\text{-N}$, and TSS. The sub index value for BOD in UPM, Sebiew, and Kemena river was 89, 82, and 89. According to WQI, the index range is classified as slightly polluted. For $\text{NH}_3\text{-N}$, all three rivers have recorded a lower value which is 49 in UPM, 42 in Sebiew, and 62 in Kemena river. According to WQI, the sub index could be classified as polluted. While for the TSS, UPM river recorded a sub-index of 93, while sub index for both Sebiew and Kemena river were 87 and 78 respectively. All three rivers are categorized as clean according to the WQI.

From June until September, the WQI are ranged from 64 to 70. The highest WQI is 70, which was obtained in July while the lowest was 64, as recorded in August. WQI for all months was classified as Class III. For the three zones, WQI are ranging from 64 to 69. The highest was 69, which was obtained in Kemena and the lowest is 64 that was recorded in Sebiew. The WQI for these three zones was classified as Class III. While for the sampling stations, the range for WQI is from 60 to 77. The highest WQI obtained is 77 in station 1, while the lowest was 60 in station 2. The WQI for these stations was classified as Class III, except for station 1 which is in class II.

Table 4.3: Water quality classification in three zones (UPM, Seb., Kem.) based on the water quality index.

Sub Index WQI	Zone					
	UPM	Status	Sebiew	Status	Kemena	Status
BOD	89	Slightly polluted	82	Slightly polluted	89	Slightly polluted
NH ₃ -N	49	Polluted	42	Polluted	62	Polluted
TSS	93	Clean	87	Clean	78	Clean
WQI	69	Slightly polluted	64	Slightly polluted	68	Slightly polluted

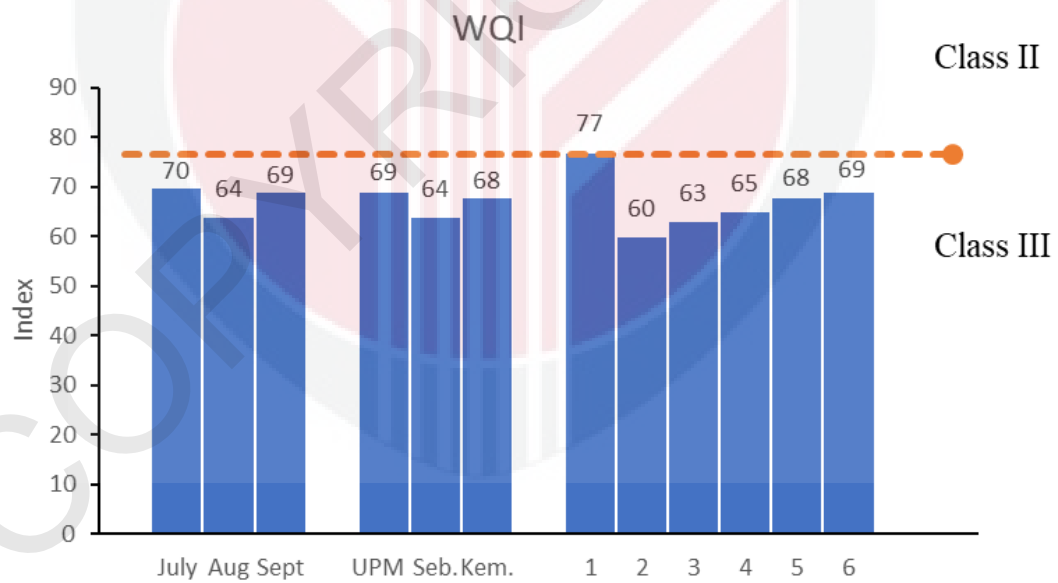


Figure 4.12: Mean levels of WQI according to month, zone, and stations.

CHAPTER 5

DISCUSSION

5.1 Water Quality Parameters

Increment in water temperature leads to the decrement of oxygen content in water, which caused stress to many organisms (Kasan et al., 2023). The highest temperature obtained from this study is in August. According to the weather forecast, the maximum temperature hits during August is 34°C. The highest temperature on station 3 could be mainly due to the sampling timing, where it took approximately four hours, which is from 9.30 am to 1.30 pm, to obtain samples from every stations. However, the location of station 3 was near to the construction area. The construction works which might involve the process of cutting down trees will somehow lead to the rising of water temperature as there is lack of transpiration (Fahad, 2022). This caused light to penetrate directly to the water and unfortunately increased the temperature. The construction work also could lead to soil erosion, where the sediment will slowly flow into the river and cause high turbidity. The turbid the water, the warmer the river could be as turbid water absorbs more heat compared to clear water (Norhaziqah, 2014). Unlike station 3, station 1 on the other side has recorded the lowest temperature along four months of sampling. Station 1 which is in UPM are surrounded by trees and forests. It provides shade to the river and which caused the river to be cooler on daytime, also the occurrence of evaporation and transpiration process which reduce sensible heat (Ellison et al., 2017).

For aquatic life, pH that ranges from 6.5 to 8 are considered safe and appropriate (Hashem et al., 2021). One of the factors that contributes to the low value of pH is the occurrence of ammonium. This ammonium will somehow increase the soil acidity where H^+ was released especially during the nitrification process (Ling et al., 2017). For this study, the mean pH obtained was 5.73 which is lower than the standard set by National Water Quality Standard (NWQS). The lowest pH was obtained at Station 2, that is 4.63. The pH was low could be due to the agricultural activities which involved the use of fertilizers majorly. A study that has been conducted in Batang Rajang also indicates that lower pH is due to the existence of nitrogen pollution that originates from domestic wastewater and the use of nitrogen fertilizer (Ling et al., 2017). The result shows that pH beginning from June until August remained low compared to September, which is a bit higher, 6.3. The low pH obtained during the first three months of sampling might be caused by the weather itself. Because of warmer temperatures during June until August, it is decreasing the value of pH in station 2. Temperature also could be one of the reasons that leads to lower pH, which turns the river into acidic (Sujaul et al., 2015). The system's equilibrium shifts when there is increment in temperature, absorbing excess heat and resulting in the creation of H^+ ions that lowers the value of pH (Westlab, 2023).

The water from Sebiew river is more turbid compared to UPM and Kemena river, which can be clearly seen in station 3. One of the factors that contributes to the high level of turbidity is sand dredging activities, where sediments are suspended due to storing and disposing of excess mining materials (Aris et al., 2014). At station 3, the river was located nearer to the construction site and residential area. The sand that accumulated especially at the riverbank, due to the construction activity was slowly entering the water contributes

to the high turbidity in water. Besides that, the sand that was brought to the river especially during rainy days is also one of the factors that leads to the high level of turbidity. Kelantan river has been turbid due to the numerous amounts of suspended solids and siltation, which are origins from the logging activities in Lojing Highlands (Peck Yen & Rohasliney, 2013). Based on a study that has been conducted regarding Sungai Langat, it was reported that the turbidity changes frequently due to few factors such as flash floods and pollution from agricultural and industrial area (Ahmed et al., 2022). It indicates that one of those factors might be the reason for the high level of turbidity in station 3.

TDS is defined as the total amount of organic and inorganic materials that exist in the water (Azmizah et al., 2017). Higher amount of TDS together with the rising salinity has increased the concentrations of heavy metals in the water (Ahmed et al., 2022). High TDS that recorded in station 5 could possibly be due to its location that are influenced by tides. The movement of tides from seawater have greatly affect the amount of TDS in river as the concentration of dissolved salts are mainly higher, which also at the same time enables the water to conduct electricity (Muhammad et al., 2015). However, the mean amount of TDS for those 6 locations are 961 ppm, which is in the range that has been set by the National Water Quality Standard (NWQS). This could possibly be affected by the weather, where during the first three months of sampling, the weather was quite hot and warmer. This high temperature caused evaporation of water and minerals that contained in water were concentrated faster (Shoukat et al., 2020). Apart from that, the location of station 5 where there is tidal interference also could be another factor that leads to the high reading of TDS. A study conducted in Tunggak has recorded high amount of TDS in

certain sampling stations, which caused by few factors such as tidal disturbance and agricultural activities (Hossain et al., 2013).

Similar to other parameters, dissolved oxygen (DO) also plays a very important role in ensuring that all aquatic organisms survive. Dissolved oxygen indicates the amount of oxygen present in water bodies. Water temperature, sediments, and the amount of oxygen used by organisms for anaerobic activities such as respiration and decomposition, have somehow affected the amount of DO in water (Cleophas et al., 2013). Among all stations, station 1 has the highest amount of DO, which is 4.8 mg/L., which contributes to the increasing amount of DO in UPM. Station 1, which are in UPMKB are surrounded by trees and bushes, and the river body are majorly shades by the trees around. The level of DO is also affected by temperature. As the water temperature in station 1 was lowest than other stations, then the dissolved oxygen also greatly higher than other stations. While station 2 has the lowest DO, which is 2.71 mg/L. This is due to the surface of the river that is mostly directly exposed to sunlight, also there are trees and some aquatic plants which contribute to the lowest DO in station 2. The DO concentration and temperature are inter-related to each other. This is caused by the photosynthetic activities of aquatic lives such as plants and algae which actively generate oxygen at high temperature (Wahab et al., 2020). A study conducted in Perlis River mentioned that lower concentration of DO was caused by factors such as the flow of river, occurrence of organic pollution, water temperature, and assimilative capacity of river (Amneera et al., 2019).

Salinity is one of the most important parameters which affects the consumption of organisms (Kazemi et al., 2013). Station 6 has recorded the highest salinity among all other stations due to its location that is near to the estuary. In addition, during the first three months of sampling, there was a small amount of rainfall compared to September. This somehow leads to salt built-up which are unable to flushed out. Plus, high temperature during that time was also one of the factors lead to the rising amount of salinity as the evaporation rates are higher, which later caused the salt left behind and increase the concentration. Apart from that, tidal is also one of the factors for the high amount of salinity in station 6. Seawater that flows from the sea reaching the sampling zone, which resulting in the high amount of salinity (Muhammad et al., 2015). However, the level of salinity drastically drops in September. This is due to the rainy season, where during the sampling process, all six locations have recorded lower salinity compared to the previous sampling. A study made in Thailand regarding the climate change effects of seawater quality and green mussel production has stated that monthly rainfall resulted in lower salinity (Srisunont et al., 2022). The existence of rainfall has flushed the salt built-up which also lowers the concentration of salt in water.

Conductivity in water is commonly affected by three factors, which is inorganic dissolved solids, organic compound, and temperature (Al-Badaii et al., 2013). Increment in conductivity of streams indicates the existence of source of dissolved ions in that zone (Cleophas et al., 2013). Conductivity in Kemena, which consists of station 5 and station 6 have recorded the highest value for conductivity among all other stations. High temperature collaborating with high amount of salinity in station 5 and 6 have somehow

increased the value for conductivity as well. This is because when the temperature is high, water becomes warmer. This caused the salt content in water to break into ions and enhanced the ability of water to conduct electricity. A study that has been conducted in Paka River Terengganu is conducted during dry season on their second sampling. It has proven that climate change affects the salinity which later increase conductivity of that zone (Muhammad et al., 2015). Since the location of station 5 are located near to the fish market and restaurants near the riverbank, while station 6 are located near to the shopping mall and construction work on the other side of the river, these factors might probably become few reasons to the higher conductivity value in these two stations. A study conducted in Perak has stated that agricultural, land use, and industrial activities have impacts on the mineral contents in the water, which somehow affects the value for conductivity (Rahmanian et al., 2015).

Total suspended solids (TSS) are solids in water that can be obtained through filtration process. TSS is one of a good indicator for the existence of pollutants, mainly nutrients and metals, and it consists of materials such as silt, decayed animals and plants matter, sewage, and industrial waste (Wahab et al., 2018). Among the three zones, Kemena has recorded the highest TSS in both stations, which is station 5 and station 6, but the highest was in station 5. High TSS may cause increment in the water temperature as a result of suspended particles activities, which absorbed heat from sunlight (Hanisah et al., 2013). The location of station 5, which is located near to the fish market with some development around that area, could possibly be one of the major factors that lead to high TSS. A study that has been conducted in Perlis River also shown a high value of TSS in Kangar market, which is due to the wet market discharged that are coming from the market

itself (Amneera et al., 2019). However, the level of TSS is depends on the level of runoff, where the rainfall for example, has caused dilution of river water. Hence, the level of TSS in the river was decreasing.

Ammoniacal nitrogen ($\text{NH}_3\text{-N}$) is one of the important parameters as the presence of it could be toxic for aquatic lives. With the aid of oxygen, $\text{NH}_3\text{-N}$ could oxidize into nitrate nitrogen ($\text{NO}_3\text{-N}$), which at the same time results in the changes of dissolved oxygen and nitrate nitrogen ($\text{NO}_3\text{-N}$) concentration (Nuruzzaman et al., 2018). Among all stations, station 3 which is in Sebiew has recorded the highest amount of $\text{NH}_3\text{-N}$, which is 2.25 mg/L. The value has exceeded the standard that has been set. According to the National Water Quality Standard (NWQS), the standard value for $\text{NH}_3\text{-N}$ is 0.9 mg/L. Due to this, $\text{NH}_3\text{-N}$ for station 3 has been classified as Class III. There is another study that has been conducted in Sungai Petani which recorded the highest amount of $\text{NH}_3\text{-N}$ obtained, 3.58 mg/L. This is due to the location of sampling stations, which are surrounded by factories, farms, and restaurants (Hashem et. al., 2021). For this study, high $\text{NH}_3\text{-N}$ in station 3 could possibly be caused by the tributaries that are mostly surrounded by residential areas and construction works near to the river. Effluent discharged from nearby houses directly into the river and this caused increasing amount of $\text{NH}_3\text{-N}$ indirectly. High amount of $\text{NH}_3\text{-N}$ also indicates pollution which can affect the health of aquatic life especially (Wardani et al., 2021).

Chemical oxygen demand (COD) tests indicate the amount of oxygen required to decompose organic matter and oxidize inorganic chemicals and usually high concentration

of COD indicates that the water is polluted (Amneera et al., 2019). High value of COD indicates that the water quality is deteriorate (Hanisah et al., 2013). According to the result obtained, the value of COD for all stations is still in permissible range that has been set by National Water Quality Standard (NWQS). There are few factors that could affect the changes in COD such as the rapid movement of water together with organic matter content, and the diluted organic substances due to the high volume of water (Hanisah et al., 2013). The standard range according to NWQS is 25 mg/L and most stations recorded a lower reading except for station 4 and station 5, which have slightly exceeded the limit but are still considered in a good range. Compared to a study in Perlis River, the highest COD recorded was 68.5 mg/L which categorized as class IV under NWQS. This higher number of COD is caused by a numerous decomposition of organic and inorganic contaminants, also dissolved and suspended substances in the water bodies which flow from the wet market (Amneera et al., 2019). Another study conducted in Terengganu River basin also has recorded higher value of COD that is 2.24 to 39.00 mg/L during wet season, and 1.90 to 20.48 mg/L on dry season. The high value of COD was stated due to the improper sanitation by local villages. As a result, biological loadings are flowing into the river which are also affected by the locations of sampling that have high population (Wahab et al., 2020).

Biochemical oxygen demand (BOD) indicates the amount of oxygen that been absorbed by microorganisms because of decaying organic substances through aerobic conditions (Wahab et al., 2020). It means that the aquatic life needs to compete for oxygen to survive and those who did not manage to do so will exposed to negative effects such as stressed and death. Among the three zones, Sebiew river has the highest BOD compared

to the other two zones. The highest reading for BOD could be seen at station 3, where it is possibly affected by the dead trees and plants around the area. The process of decaying also involved the use of oxygen by the microorganisms, mixed up with other contributors such as fertilizer, animal farm, septic system, and construction discharge (Al-Badaii et al., 2013). This will contribute to the depletion of oxygen in the river which later leads to a greater value of BOD. A study that was conducted in coastal region Miri has recorded a high value for BOD, 10.36 mg/L, which is located at *Kolam MGP*. However, there are other locations within the study area which recorded high BOD such as Taman Bulatan Lake, Jalan Airport, and Jalan Maigold. High BOD concentrations in these stations are due to the domestic sewage and the dead plants that float on the surface of water (Nyambar & Mohan, 2023).

5.2 Water Quality Index

The sub index for BOD is mainly high in UPM, Sebiew, and Kemena river which ranged from 82 to 89. This resulted in the three rivers being categorized as slightly polluted. While the sub index for $\text{NH}_3\text{-N}$ ranged from 42 to 62, which classified as polluted. Station 3 is one of the contributing factors that lead to the status of UPM, Sebiew, and Kemena river. However, the sub index for TSS in those three rivers are ranged from 78 to 93, which classified as clean.

The status of Sebiew and Kemena river are declining compared to 2020, when Movement Control Order (MCO) was implemented by the government. During this period, most of the rivers have been reported more clean and clearer. This is due to the discontinuation of operating industries, and it contributes to the declining number of effluents in the river especially from the industries (Goi, 2020). However, it is a big challenge to maintain the quality of rivers as most of the industries have maximizing their production to cover losses, they endured during MCO (Nor Ain, 2020).

The WQI obtained for UPM is 69. According to the WQI classification, the river was categorized as class III and there is no previous study made regarding these rivers yet. Discharges from agricultural activities could be the major factors that lead to this value. According to the data obtained from DOE, since 2016 Sebiew river has been categorized in class III. However, beginning from 2018, the river has slightly improved to class II. From this study, Sebiew river has been categorized in class III. The previous WQI recorded from Sebiew river was 81, this study has obtained 64 (class III). While for

Kemena river, DOE has categorized it in class II. While from this study, Kemena river was categorized in class III. The previous data for Kemena river was 82 and this study has obtained 68. The WQI obtained in Sebiew and Kemena river shows slightly different from previous studies because it is a cumulative data for four months only and not for overall 12 months. Plus, the differences are due to the lower sub index of DO and $\text{NH}_3\text{-N}$ in all three zones obtained during this study. The lower subindex has affected the WQI of the rivers.

The UPM river is said to be one of the contributing factors that lead to the status of Sebiew and Kemena river, as they are connected. This could be due to agricultural land use in UPM, and external factors such as poor water quality from other rivers in Bintulu that are connected to Sebiew and Kemena river as well. Most researchers have addressed this issue as one of the most contributing factors that lead to the declining of water quality in Malaysia, majorly in 2015 to 2017 (Camara et al., 2019). Furthermore, the river status in UPM, Sebiew, and Kemena in this study also could be affected by the MCO in 2020. Most industries have maximized the production to cover losses, and this might result in poor status of water quality especially rivers that are nearer to factories (Goi, 2020).

CHAPTER 6

CONCLUSION

UPM, Sebiew, and Kemena rivers are categorized as class III in terms of WQI with the mean index 67, 64, and 68. These three rivers are slightly polluted. The subindex for BOD indicates that the water was slightly polluted, while $\text{NH}_3\text{-N}$ and TSS in those three zones were classified as polluted and clean, respectively. From the mean obtained, it clearly shows that all three zones have very tiny gaps among each other which indicates that changes in UPM water quality could be one of the factors that contribute to the changes in Sebiew and Kemena rivers. The low value of WQI is usually associated with the higher level of water pollution.

According to NWQS, the parameters that categorized under class IIA are temperature, TDS, and conductivity, while turbidity and salinity are in class IIB and class I respectively. According to WQI, TSS falls under class I while COD and BOD are in class II. The values of pH and DO were in class III while $\text{NH}_3\text{-N}$ are in class IV. Based on WQI classification, only station one are classified in class II, while other stations categorized in class III. All three sampling zones were under class III, which is influenced by DO and $\text{NH}_3\text{-N}$. This indicates that the rivers require more comprehensive water treatment. Agricultural sewage and the location which is nearer to the industrial sites and residential area are the probable contributing factors to the lower WQI obtained. Also, the effects of post-MCO have been one of the factors that lead to the declining status of those

three rivers. Based on overall data obtained in this study, UPM, Sebiew, and Kemena rivers were found to be slightly polluted (Class III).



References

- Ahmed, M. F., Mokhtar, M. Bin, Lim, C. K., & Majid, N. A. (2022). *Identification of Water Pollution Sources for Better Langat River Basin Management in Malaysia*.
- Al-Badaii, F., Shuhaimi-Othman, M., & Gasim, M. B. (2013). Water quality assessment of the Semenyih river, Selangor, Malaysia. *Journal of Chemistry*.
<https://doi.org/10.1155/2013/871056>
- Amneera, W. A., Wahidatul, N., Zainon, A., Rawdhoh, S., Yusof, M., & Ragunathan, S. (2019). *Water Quality Index of Perlis River , Malaysia. April 2013*.
- American Public Health Association (APHA). (2012). *Standard Methods for the Examination of Water and Wastewater*. 1496.
- Aris, A. Z., Lim, W. Y., Praveena, S. M., Yusoff, M. K., Ramli, M. F., & Juahir, H. (2014). Water quality status of selected rivers in Kota Marudu, Sabah, Malaysia and its suitability for usage. *Sains Malaysiana*, 43(3), 377–388.
- Azmizah, N., Andaman, B., Nilus, R., & Miun, J. (2017). *Report on the Assessment of Water Quality in Northern Gunung Rara (Ngr) Forest Reserve 2017*.
- Camara, M., Jamil, N. R., & Abdullah, A. F. Bin. (2019). Arazi kullanımlarının su kalitesi üzerindeki etkisi Malezya: bir inceleme - Impact of land uses on water quality in Malaysia: a review. *Ecological Processes*, 8(1).
- Cleophas, N., Isidore, F., Ka Han, L., & Bidin, K. (2013). Water quality status of Liwagu River. *Journal of Tropical Biology and Conservation*, 10(April), 67–73.
- Department of Environment (DOE). (2016). Annual Environmental Quality Report 2016. Department of Environment, Ministry of Natural Resources, Environment and Climate Change.
- Department of Environment (DOE). (2017). Annual Environmental Quality Report 2017. Department of Environment, Ministry of Natural Resources, Environment and Climate Change.
- Department of Environment (DOE). (2018). Annual Environmental Quality Report 2018. Department of Environment, Ministry of Natural Resources, Environment and Climate Change.
- Department of Environment (DOE). (2019). Annual Environmental Quality Report 2019. Department of Environment, Ministry of Natural Resources, Environment and Climate Change.
- Department of Environment (DOE). (2020). Annual Environmental Quality Report 2020. Department of Environment, Ministry of Natural Resources, Environment and Climate Change.

- Ellison, D., Morris, C. E., Locatelli, B., Sheil, D., Cohen, J., Murdiyarso, D., Gutierrez, V., Noordwijk, M. van, Creed, I. F., Pokorny, J., Gaveau, D., Spracklen, D. V., Tobella, A. B., Ilstedt, U., Teuling, A. J., Gebrehiwot, S. G., Sands, D. C., Muys, B., Verbist, B., ... Sullivan, C. A. (2017). Trees, forests and water: Cool insights for a hot world. *Global Environmental Change*, 43, 51–61. <https://doi.org/10.1016/j.gloenvcha.2017.01.002>
- Fahad, K. (2022). *How does deforestation affect the water cycle?* Earth Reminder. <https://www.earthreminder.com/how-does-deforestation-affect-the-water-cycle/>
- Goi, C. L. (2020). The river water quality before and during the Movement Control Order (MCO) in Malaysia. *Case Studies in Chemical and Environmental Engineering*, 2, 100027. <https://doi.org/10.1016/j.cscee.2020.100027>
- Hanisah, I., & Ahmad, A. K. (2013). Recreational stream assessment using Malaysia water quality index. *AIP Conference Proceedings*, 1571(December 2013), 620–624. <https://doi.org/10.1063/1.4858723>
- Harun, S., Al-Shami, S. A., Dambul, R., Mohamed, M., & Abdullah, M. H. (2015). Water quality and aquatic insects study at the Lower Kinabatangan River Catchment, Sabah: In response to weak La Niña event. *Sains Malaysiana*, 44(4), 545–558. <https://doi.org/10.17576/jsm-2015-4404-09>
- Hashem, A. O. A., Ahmad, W. A. A. W., & Yusuf, S. Y. (2021). Water quality status of Sungai Petani River, Kedah, Malaysia. *IOP Conference Series: Earth and Environmental Science*, 646(1). <https://doi.org/10.1088/1755-1315/646/1/012028>
- Hossain, M. A., Sujaul, I. M., & Nasly, M. A. (2013). Surface Water Quality Assessment of Tunggak River Gebeng, Pahang, Malaysia. *4th International Conference on Water & Flood Management (ICWFM-2013)*, 47–53. <http://umpir.ump.edu.my/3545/>
- Kasan, N. A., Ikhwanuddin, M., Manan, H., Zakaria, N. S., Kamaruzzan, A. S., Rahim, A. I. A., & Ishak, A. N. (2023). Assessment on Water Quality Parameter and Nutrients Level of Nyatuh River in Relations with *Macrobrachium Rosenbergii* Prawn Populations. *Tropical life sciences research*, 34(1), 51–66. <https://doi.org/10.21315/tlsr2023.34.1.4>
- Kazemi, Z., Hashim, N. B., & Ismail, M. (2013). Estimating the Mean Salinity, Dissolved Oxygen and Temperature of the West of Johor Strait, Malaysia. *Land and Water 2013, January*, 11. <https://doi.org/10.13140/2.1.2500.7049>
- Kozaki, D., Hasbi bin Ab. Rahim, M., Mohd Faizal bin Wan Ishak, W., Yusoff, M. M., Mori, M., Nakatani, N., & Tanaka, K. (2016). Assessment of the river water pollution levels in Kuantan, Malaysia, using ion-exclusion chromatographic data, water quality indices, and land usage patterns. *Air, Soil and Water Research*, 9, 1–11. <https://doi.org/10.4137/ASWr.S33017>

- Leong, S. S., Ismail, J., Denil, N. A., Sarbini, S. R., Wasli, W., & Debbie, A. (2018). Microbiological and physicochemical water quality assessments of riverwater in an industrial region of the northwest coast of Borneo. *Water (Switzerland)*, 10(11). <https://doi.org/10.3390/w10111648>
- Ling, T. Y., Soo, C. L., Phan, T. P., Nyanti, L., Sim, S. F., & Grinang, J. (2017). Assessment of water quality of Batang Rajang at Pelagus area, Sarawak, Malaysia. *Sains Malaysiana*, 46(3), 401–411. <https://doi.org/10.17576/jsm-2017-4603-07>
- Loheswar, R. (2019). UTM don names Johor's 16 most polluted rivers: Yahoo news. <https://malaysia.news.yahoo.com/utm-don-names-johor-16-014758631.html>.
- Muhammad, B. G., Nadila, A. K., & Haniff, M. (2015). The influence of tidal activities on water quality of Paka River Terengganu, Malaysia. *Malaysian Journal of Analytical Sciences*, 19(5), 979–990.
- Naubi, I., Zardari, N. H., Shirazi, S. M., Ibrahim, N. F. B., & Baloo, L. (2016). Effectiveness of water quality index for monitoring Malaysian river water quality. *Polish Journal of Environmental Studies*, 25(1), 231–239. <https://doi.org/10.15244/pjoes/60109>
- Nayla, H. O. (2020). Water quality parameters. *IntechOpen eBooks*. <https://doi.org/10.5772/intechopen.89657>
- Nor Ain, M., R. (2020). *Can we keep the rivers clean post-MCO?* NST Online. <https://www.nst.com.my/news/nation/2020/04/588724/can-we-keep-rivers-clean-post-mco>
- Norhaziqah, M.A. (2014). *Determination of Water Quality Status of Similajau River According to Interim National Water Quality Standard (INWQS) and Water Quality Index (WQI)* [Unpublished undergraduate thesis]. University Putra Malaysia Bintulu Sarawak Campus.
- New Straits Times (NSTP). (2019). NST Leader: What's up, enforcers? <https://www.nst.com.my/opinion/leaders/2019/07/506380/nst-leader-whats-enforcers>
- Nuruzzaman, M., Mamun, A. A., & Salleh, M. N. B. (2018). Determining ammonia nitrogen decay rate of Malaysian river water in a laboratory flume. *International Journal of Environmental Science and Technology*, 15(6), 1249–1256. <https://doi.org/10.1007/s13762-017-1482-0>
- Nyambar, I. N., & Mohan, V. P. (2023). Assessment on urban lakes along the coastal region of Miri, NW Borneo: implication for hydrochemistry, water quality, and pollution risk. *Environmental Science and Pollution Research*, 0123456789. <https://doi.org/10.1007/s11356-023-25172-9>
- Peck Yen, T., & Rohasliney, H. (2013). Status of water quality subject to sand mining in

the kelantan river, kelantan. *Tropical life sciences research*, 24(1), 19–34.

Pei, G. P. (2021, November 9). *Sarawak to maximise natural gas utilisation through downstream industries*. NST Online.

<https://www.nst.com.my/news/nation/2021/11/743920/sarawak-maximise-natural-gas-utilisation-through-downstream-industries>

Rahmanian, N., Hajar, S., Ali, B., Homayoonfard, M., Ali, N. J., Rehan, M., Sadeq, Y., & Nizami, A. S. (2015). Analysis of physiochemical parameters to evaluate the drinking water quality in the State of Perak, Malaysia. *Journal of Chemistry*, 2015(Cd), 10.

Rowshon, M.K., Mbaruk, M.M., Marriott, M.J., Amin, M.S.M., Ahsan, A. and Loh, E.W.K. (2014) 'Geospatial water quality assessment system for the Sg. Buloh river basin in Malaysia', *Int. J. Water*, Vol. 8, No. 4, pp.401–421.

Roy, R. (2018). An Introduction to water quality analysis. *Essence - International Journal for Environmental Rehabilitation and Conservation*, 94–100.
<https://doi.org/10.31786/09756272.18.9.2.214>

Sahana, H. (2013). *WATER QUALITY DYNAMICS IN A LOWLAND TROPICAL CATCHMENT: THE KINABATANGAN RIVER, SABAH*, University of Birmingham Research Archive. February.

Shoukat, A., Hussain, M. S., & Shoukat, A. (2020). Effects of Temperature on Total dissolved Solid in water. *ResearchGate*.
https://www.researchgate.net/publication/339510087_Effects_of_Temperature_on_Total_dissolved_Solid_in_water

Sivaranjani, S., Rakshit, A., & Singh, S. (2015). Water Quality Assessment with Water Quality Indices. *International Journal of Bioresource Science*, 2(2), 85.
<https://doi.org/10.5958/2454-9541.2015.00003.1>

Srisunont, C., Srisunont, T., Intarachart, A., & Babel, S. (2022). Influence of climate on seawater quality and green mussel production. *Scientia Marina*, 86(1).
<https://doi.org/10.3989/scimar.05232.027>

Sujaul, I. M., Sobahan, M. A., Edriyana, A. A., Yahaya, F. M., & Yunus, R. M. (2015). *Wastewater Management Practice*. 17(5), 3027–3030.

Wahab, N. A., Khairul, M., Kamarudin, A., Toriman, M. E., Ata, F. M., Juahir, H., Ghazali, A., & Anuar, A. (2018). *The Evaluation of Dissolved Oxygen (DO), Total Suspended Solids (TSS) and Suspended Sediment Concentration (SSC) in Terengganu River , Malaysia*. 7, 44–48.

Wahab, N. A., Sultan, U., Abidin, Z., Shakir, A., & Saudi, M. (2020). *Seasonal Variation on Dissolved Oxygen , Biochemical Oxygen Demand and Chemical Oxygen Demand in Terengganu River Basin , Malaysia*. December.
<https://doi.org/10.47125/jesam/2020>

Wardani, T. A. K., Sudarno, Hardyanti, N., Syafrudin, Hadiwidodo, M., & Wardhana, I. W. (2021). Removal of ammonia in domestic wastewater by using multi soil layering. *IOP Conference Series: Earth and Environmental Science*, 802(1). <https://doi.org/10.1088/1755-1315/802/1/012005>

Westlab. (2023). How Does Temperature Affect pH? *Westlab*. <https://www.westlab.com/blog/how-does-temperature-affect-ph#:~:text=Temperature%20is%20one%20of%20the,decrease%20in%20the%20solution's%20pH>

World Wild Fund for Nature (WWF), (2004). *The Kinabatangan Catchment - problems and opportunities for change*. April, 1–6. https://wwf.panda.org/wwf_news/?12513%2FThe-Kinabatangan-Catchment-problems-and-opportunities-for-change

Zainudin, Z., & Mohamed, M. (2006). Industrial Effluent Load Characterization of Sungai Perembi Watershed. *Symposium Kimia Analisis Malaysia (SKAM---19)*, January, 2.

Appendix A

Result of ANOVA (exclude BOD and conductivity) analysis between sampling months.

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Temperature	Between Groups	80.816	3	26.939	64.936	.000
	Within Groups	28.210	68	.415		
	Total	109.026	71			
pH	Between Groups	10.164	3	3.388	3.760	.015
	Within Groups	61.277	68	.901		
	Total	71.441	71			
Turbidity	Between Groups	24963.874	3	8321.291	.978	.408
	Within Groups	578331.937	68	8504.881		
	Total	603295.811	71			
TDS	Between Groups	23872868.000	3	7957622.667	3.975	.011
	Within Groups	136140690.000	68	2002068.971		
	Total	160013558.000	71			
DO	Between Groups	11.042	3	3.681	3.025	.035
	Within Groups	82.746	68	1.217		
	Total	93.788	71			
Salinity	Between Groups	291.142	3	97.047	6.643	.001
	Within Groups	993.459	68	14.610		
	Total	1284.601	71			
TSS	Between Groups	4051.206	3	1350.402	3.568	.018
	Within Groups	25738.281	68	378.504		
	Total	29789.487	71			
NH ₃ -N	Between Groups	17.406	3	5.802	6.243	.001
	Within Groups	63.198	68	.929		
	Total	80.604	71			
COD	Between Groups	489.470	3	163.157	8.798	.000
	Within Groups	1261.082	68	18.545		
	Total	1750.552	71			

Appendix B

Result of Tukey alpha analysis (exclude BOD and conductivity) between sampling months.

Temperature				
Tukey B ^a				
Month	N	Subset for alpha = 0.05		
		1	2	3
4.00	18	28.0944		
1.00	18	28.2333		
2.00	18		28.9722	
3.00	18			30.7556

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 18.000.

pH			
Tukey B ^a			
Month	N	Subset for alpha = 0.05	
		1	2
1.00	18	5.2728	
2.00	18	5.5683	5.5683
3.00	18	5.7750	5.7750
4.00	18		6.3022

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 18.000.

Turbidity		
Tukey B ^a		
Month	N	Subset for alpha = 0.05
		1
4.00	18	64.4444
1.00	18	67.6944
3.00	18	77.9556
2.00	18	111.4628

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 18.000.

TDS			
Tukey B ^a			
Month	N	Subset for alpha = 0.05	
		1	2
4.00	18	38.8889	
3.00	18	1062.2222	1062.2222
1.00	18	1117.6667	1117.6667
2.00	18		1625.2222

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 18.000.

DO				
Tukey B ^a				
Month	N	Subset for alpha = 0.05		
		1	2	3
1.00	18	2.7417		
4.00	18	3.2578	3.2578	
3.00	18	3.4956	3.4956	
2.00	18			3.8144

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 18.000.

Salinity				
Tukey B ^a				
Month	N	Subset for alpha = 0.05		
		1	2	3
4.00	18	.0239		
1.00	18	1.5794	1.5794	
3.00	18		3.8144	3.8144
2.00	18			5.2533

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 18.000.

Appendix C

TSS			
Tukey B ^a			
Month	N	Subset for alpha = 0.05	
		1	2
1.00	18	11.5278	
4.00	18	19.7222	19.7222
3.00	18		29.3978
2.00	18		29.5278
Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 18.000.			

COD			
Tukey B ^a			
Month	N	Subset for alpha = 0.05	
		1	2
3.00	18	20.4733	
1.00	18	21.6867	
2.00	18	23.3222	
4.00	18		27.3778
Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 18.000.			

NH ₃ -N			
Tukey B ^a			
Month	N	Subset for alpha = 0.05	
		1	2
4.00	18	.6894	
1.00	18	.8194	
2.00	18	1.0733	
3.00	18		1.9506
Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 18.000.			

Appendix D

Result of ANOVA (exclude BOD and conductivity) analysis between sampling zones.

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Temperature	Between Groups	7.389	2	3.694	2.508	.089
	Within Groups	101.637	69	1.473		
	Total	109.026	71			
pH	Between Groups	8.481	2	4.240	4.647	.013
	Within Groups	62.960	69	.912		
	Total	71.441	71			
Turbidity	Between Groups	31904.324	2	15952.162	1.926	.153
	Within Groups	571391.487	69	8281.036		
	Total	603295.811	71			
TDS	Between Groups	35392537.000	2	17696268.500	9.798	.000
	Within Groups	124621021.000	69	1806101.754		
	Total	160013558.000	71			
DO	Between Groups	7.354	2	3.677	2.935	.060
	Within Groups	86.434	69	1.253		
	Total	93.788	71			
Salinity	Between Groups	541.541	2	270.770	25.144	.000
	Within Groups	743.060	69	10.769		
	Total	1284.601	71			
TSS	Between Groups	11457.277	2	5728.639	21.562	.000
	Within Groups	18332.210	69	265.684		
	Total	29789.487	71			
NH ₃ -N	Between Groups	10.111	2	5.055	4.948	.010
	Within Groups	70.493	69	1.022		
	Total	80.604	71			
COD	Between Groups	154.459	2	77.230	3.339	.041
	Within Groups	1596.093	69	23.132		
	Total	1750.552	71			

Appendix E

Result of Tukey alpha analysis (excluding BOD and conductivity) between sampling zones.

Temperature		
Tukey B ^a		
Zone	N	Subset for alpha = 0.05
		1
1.00	24	28.5792
3.00	24	29.1208
2.00	24	29.3417
Means for groups in homogeneous subsets are displayed.		
a. Uses Harmonic Mean Sample Size = 24.000.		

Turbidity		
Tukey B ^a		
Zone	N	Subset for alpha = 0.05
		1
1.00	24	50.6583
3.00	24	93.9413
2.00	24	96.5683
Means for groups in homogeneous subsets are displayed.		
a. Uses Harmonic Mean Sample Size = 24.000.		

DO		
Tukey B ^a		
Zone	N	Subset for alpha = 0.05
		1
2.00	24	2.9796
3.00	24	3.2513
1.00	24	3.7513
Means for groups in homogeneous subsets are displayed.		
a. Uses Harmonic Mean Sample Size = 24.000.		

pH			
Tukey B ^a			
Zone	N	Subset for alpha = 0.05	
		1	2
1.00	24	5.2588	
2.00	24	5.8629	5.8629
3.00	24		6.0671
Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 24.000.			

TDS			
Tukey B ^a			
Zone	N	Subset for alpha = 0.05	
		1	2
1.00	24	33.4167	
2.00	24		1121.4167
3.00	24		1728.1667
Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 24.000.			

Salinity			
Tukey B ^a			
Zone	N	Subset for alpha = 0.05	
		1	2
1.00	24	.0179	
2.00	24	1.5400	
3.00	24		6.4454
Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 24.000.			

Appendix F

TSS			
Tukey B ^a			
Zone	N	Subset for alpha = 0.05	
		1	2
1.00	24	9.0900	
2.00	24	19.1250	
3.00	24		39.4167
Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 24.000.			

NH₃-N			
Tukey B ^a			
Zone	N	Subset for alpha = 0.05	
		1	2
3.00	24	.6408	
1.00	24	1.2096	1.2096
2.00	24		1.5492
Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 24.000.			

COD			
Tukey B ^a			
Zone	N	Subset for alpha = 0.05	
		1	
1.00	24	21.1450	
3.00	24	24.1850	
2.00	24	24.3150	
Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 24.000.			

Appendix G

Result of ANOVA (exclude BOD and conductivity) analysis between sampling stations

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Temperature	Between Groups	18.704	5	3.741	2.734	.026
	Within Groups	90.322	66	1.369		
	Total	109.026	71			
pH	Between Groups	30.006	5	6.001	9.559	.000
	Within Groups	41.435	66	.628		
	Total	71.441	71			
Turbidity	Between Groups	65671.082	5	13134.216	1.612	.169
	Within Groups	537624.729	66	8145.829		
	Total	603295.811	71			
TDS	Between Groups	44994899.833	5	8998979.967	5.164	.000
	Within Groups	115018658.167	66	1742706.942		
	Total	160013558.000	71			
DO	Between Groups	34.411	5	6.882	7.650	.000
	Within Groups	59.377	66	.900		
	Total	93.788	71			
Salinity	Between Groups	570.547	5	114.109	10.547	.000
	Within Groups	714.055	66	10.819		
	Total	1284.601	71			
TSS	Between Groups	11948.040	5	2389.608	8.840	.000
	Within Groups	17841.447	66	270.325		
	Total	29789.487	71			
NH ₃ -N	Between Groups	29.785	5	5.957	7.737	.000
	Within Groups	50.819	66	.770		
	Total	80.604	71			
COD	Between Groups	221.269	5	44.254	1.910	.104
	Within Groups	1529.283	66	23.171		
	Total	1750.552	71			

Appendix H

Result of Tukey alpha analysis (exclude BOD and conductivity) between sampling stations.

Temperature			
Tukey B ^a			
Station	N	Subset for alpha = 0.05	
		1	2
1.00	12	28.0250	
4.00	12	28.9667	28.9
6.00	12	28.9667	28.9
2.00	12	29.1333	29.1
5.00	12	29.2750	29.2
3.00	12		29.7

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 12.000.

pH				
Tukey B ^a				
Station	N	Subset for alpha = 0.05		
		1	2	3
2.00	12	4.6300		
4.00	12	5.2817	5.2817	
5.00	12		5.6625	5.
1.00	12		5.8875	5.
3.00	12			6.
6.00	12			6.

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 12.000.

Turbidity		
Tukey B ^a		
Station	N	Subset for alpha = 0.05
		1
1.00	12	35.7583
4.00	12	62.6783
2.00	12	65.5583
5.00	12	87.9075
6.00	12	99.9750
3.00	12	130.4583

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 12.000.

TDS			
Tukey B ^a			
Station	N	Subset for alpha = 0.05	
		1	2
1.00	12	17.0000	
2.00	12	49.8333	
3.00	12	577.9167	577.9167
6.00	12	1405.0000	1405.0000
4.00	12		1664.9167
5.00	12		2051.3333

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 12.000.

NH₃-N			
Tukey B ^a			
Station	N	Subset for alpha = 0.05	
		1	2
6.00	12	.5283	
1.00	12	.6475	
5.00	12	.7533	
4.00	12	.8483	
2.00	12		1.7717
3.00	12		2.2500

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 12.000.

APPENDIX I

COD		
Tukey B ^a		
Station	N	Subset for alpha = 0.05
		1
1.00	12	20.3533
2.00	12	21.9367
6.00	12	22.9333
3.00	12	23.5467
4.00	12	25.0833
5.00	12	25.4367
Means for groups in homogeneous subsets are displayed.		
a. Uses Harmonic Mean Sample Size = 12.000.		

TSS			
Tukey B ^a			
Station	N	Subset for alpha = 0.05	
		1	2
1.00	12	4.7500	
2.00	12	13.4300	
3.00	12	18.2917	
4.00	12	19.9583	
6.00	12		38.4583
5.00	12		40.3750
Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 12.000.			

Appendix 4.8: Result of ANOVA (BOD and conductivity) analysis between sampling months.

ANOVA					
BOD					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	210.221	2	105.111	47.523	.000
Within Groups	112.802	51	2.212		
Total	323.023	53			

ANOVA					
Conductivity					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.065	2	2.032	10.166	.000
Within Groups	10.195	51	.200		
Total	14.259	53			

APPENDIX J

Result of ANOVA (BOD and conductivity) analysis between sampling zones

ANOVA					
BOD					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	36.486	2	18.243	3.247	.047
Within Groups	286.537	51	5.618		
Total	323.023	53			

ANOVA					
Conductivity					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.098	2	2.549	14.190	.000
Within Groups	9.161	51	.180		
Total	14.259	53			

Appendix 4.9: Result of ANOVA (BOD and conductivity) analysis between sampling stations

ANOVA					
BOD					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	43.703	5	8.741	1.502	.207
Within Groups	279.320	48	5.819		
Total	323.023	53			

ANOVA					
Conductivity					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.171	5	1.034	5.462	.000
Within Groups	9.088	48	.189		
Total	14.259	53			

APPENDIX K

Appendix 4.10: Result of Tukey alpha analysis (BOD and conductivity) between sampling months.

BOD					Conductivity			
Tukey B ^a					Tukey B ^a			
Month	N	Subset for alpha = 0.05			Month	N	Subset for alpha = 0.05	
		1	2	3			1	2
2.00	18	.9972			4.00	18	.0065	
4.00	18		3.1778		1.00	18	.2966	
3.00	18			5.8228	3.00	18		.6765
Means for groups in homogeneous subsets are displayed.					Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 18.000.					a. Uses Harmonic Mean Sample Size = 18.000.			

Appendix 4.11: Result of Tukey alpha analysis (BOD and conductivity) between sampling zones.

BOD				Conductivity			
Tukey B ^a				Tukey B ^a			
Zone	N	Subset for alpha = 0.05		Zone	N	Subset for alpha = 0.05	
		1				1	2
3.00	18		2.7189	1.00	18	.0052	
1.00	18		2.7844	2.00	18	.2339	
2.00	18		4.4944	3.00	18		.7405
Means for groups in homogeneous subsets are displayed.				Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 18.000.				a. Uses Harmonic Mean Sample Size = 18.000.			

APPENDIX L

Result of Tukey alpha analysis (BOD and conductivity) between sampling stations.

BOD			Conductivity			
Tukey B ^a			Tukey B ^a			
Station	N	Subset for alpha = 0.05	Subset for alpha = 0.05			
		1	1	2	3	
5.00	9	2.3100	.0036			
1.00	9	2.4044	.0067			
6.00	9	3.1278	.1925	.1925		
2.00	9	3.1644	.2753	.2753	.2753	
4.00	9	4.1956		.6921	.6921	
3.00	9	4.7933			.7889	
Means for groups in homogeneous subsets are displayed.			Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 9.000.			a. Uses Harmonic Mean Sample Size = 9.000.			

PUBLICATION OF THE PROJECT UNDERTAKING

This is to certify that I have no objection to publishing the project entitled **“Assessment of Water Quality Status in UPM-Sebiew-Kemena River System in Bintulu Sarawak”** by the supervisor in a joint authorship. However, it has to be evaluated by the Faculty of Agricultural Science and Forestry, University Putra Malaysia Bintulu Sarawak Campus and published in the form approved by the faculty.



Nurliyana Binti Yahya

Date: