WATER QUALITY INDEX (AMMONIACAL NITROGEN, BIOCHEMICAL OXYGEN DEMAND, CHEMICAL OXYGEN DEMAND) ASSESSMENT IN SUNGAI KEREH

MUD MAENAH

SCHOOL OF CIVIL ENGINEERING
UNIVERSITI SAINS MALAYSIA

2022

WATER QUALITY INDEX (AMMONIACAL NITROGEN, BIOCHEMICAL OXYGEN DEMAND, CHEMICAL OXYGEN DEMAND) ASSESSMENT IN SUNGAI KEREH

By

MUD MAENAH

This dissertation is submitted to

UNIVERSITI SAINS MALAYSIA

As partial fulfilment of requirement for the degree of

BACHELOR OF ENGINEERING (HONS.)
(CIVIL ENGINEERING)

School of Civil Engineering
Universiti Sains Malaysia

Aug 2022

Appendix A8

UNIVERSITI SAINS MALAYSIA

SCHOOL OF CIVIL ENGINEERING
ACADEMIC SESSION 2021/2022

FINAL YEAR PROJECT EAA492/6
DISSERTATION ENDORSEMENT FORM

Title: Water Quality Index (Ammoniacal Nitrogen, Biochemical Oxygen Demand, Chemical Oxygen Demand) Assessment in Sungai Kereh

Name of Student: Mud Maenah

I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

Signature:

Date : 9th August 2022

Approved by

DR NOOR AIDA SAAD
Lecturer
River Engineering And
Urban Drainage Research Center (REDAC)
Engineering Campus
Universiti Sains Malaysia
14300 Nibong Tebal, Penang.
Tel: 04-599 6538 Fax: 04-599 6926

(Signature of Supervisor)

Name of Supervisor :

Date :

Approved by:

(Signature of Examiner)

Name of Examiner : Puay How Tion

Date : 11/8/2022

ACKNOWLEDGEMENT

I would like to begin by expressing my gratitude to Allah SWT for granting me the ability and assisting me in completing this thesis. Thank you to my supervisor, Dr. Noor Aida Binti Saad, for your patience, guidance, and support. I have benefited from your abundance of knowledge, and I am grateful that you took me on as a student and continued to have faith in me over the final year project of this academic year. Thank you to Siti Multazimah Binti Mohamad Fauzi, PhD student of Dr. Noor Aida Binti Saad, for all your assistance. Last but not least, I owe a debt of gratitude to my parents and friends, whose unwavering love and encouragement keep me inspired and self-assured.

ABSTRAK

Sungai Kereh merupakan sebatang sungai di Pulau Pinang, Malaysia yang tercemar kesan daripada aktiviti penternakan khinzir. Satu kajian dijalankan di Sungai Kereh untuk menganalisis indeks kualiti air sungai ini semasa musim panas dan musim hujan berdasarkan parameter-parameter kualiti air iaitu DO, BOD, COD, pH, SS dan AN dengan tujuan mengklasifikasikan sungai ini mengikut WQI-DOE. Objektif bagi kajian ini ialah untuk menganalisis indeks kualiti air kini Sungai Kereh dan menentukan hubungan antara ammonia nitrogen (AN) dengan BOD dan COD. Setelah analisis dijalankan, didapati bahawa kualiti air lebih merosot semasa musim panas dibandingkan dengan kualiti air semasa musim hujan bagi sebahagian besar parameter kualiti air. Sungai Kereh boleh dikelaskan sebagai Kelas V di bahagian hulu Parit Cina, namun kualiti air meningkat kepada kelas IV di bahagian hilir Sungai Kereh untuk kedua-dua musim (musim panas dan musim hujan). Punca kemerosotan kualiti air Sungai Kereh adalah disebabkan oleh kepekatan ammonia nitrogen yang tinggi di dalam air sungai. Didapati bahawa aktiviti dari ladang ternakan khinzir merupakan punca utama pencemaran Sungai Kereh. Didapati bahawa kepekatan ammonia nitrogen (AN) yang tinggi telah memberi kesan kepada kepekatan BOD dan COD di dalam air sungai berbanding parameter-parameter lain seperti DO, pH dan SS.

ABSTRACT

In the Malaysian state of Pulau Pinang, a river known as Sungai Kereh is significantly deteriorating due to the pollution caused by livestock farming, specifically pig farming. A study is conducted along the river to determine the water quality in Sungai Kereh during dry and wet seasons based on water quality parameters Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), pH, Suspended Solids (SS) and Ammoniacal Nitrogen (AN) to classify the river based on water quality index (WQI) from the Department of Environment (DOE). The objectives of this study are to assess the current water quality of Sungai Kereh using the WQI and to determine the relationship between the concentration of ammoniacal nitrogen (AN) with biochemical oxygen demand (BOD) and chemical oxygen demand (COD). It was discovered that the water quality deteriorates more during the dry season than during the wet season for most of the water quality parameters. During both seasons (dry and wet seasons), Sungai Kereh can be classified as Class V upstream of Parit Cina and consequently improves to Class IV, reaching downstream of Sungai Kereh. The leading cause of pollution in Sungai Kereh is due to the high concentration of ammoniacal nitrogen (AN). Pig farms are the primary source of pollution and water quality deterioration in this area. The high concentration of AN significantly affects BOD and COD concentration in the river compared to other parameters such as DO, pH and SS.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AN	Ammoniacal Nitrogen
APHA	American Public Health Association: Standard Methods for the Examination of Water and Wastewater
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DID	Department of Irrigation and Drainage
DO	Dissolved Oxygen
DOE	Department of Environment
GPS	Geographical Positioning System
INWQS	Interim National Water Quality Standards
PBAPP	Perbadanan Bekalan Air Pulau Pinang
PWI	Penang Water Supply Initiative
SI	Subindex
SPWSS	Seberang Perai Water Supply Scheme
SS	Suspended Solids
SWW	Swine and pig farm wastewater
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
WQI	Water Quality Index

LIST OF SYMBOLS

Ag_2SO_4	Argentum Sulfate
E	East
$HgSO_4$	Mercuric Sulfate
HNO_2	Nitrous Acid
H_2SO_4	Sulfuric Acid
$K_2Cr_2O_7$	Potassium Dichromate
mg/L	Milligram per litre
MLD	Million litres per day
N	North
NH_4+	Ammonium
NH_3	Ammonia
NH_3N	Ammoniacal Nitrogen
NO_2^-	Nitrite Ion
NTU	Nephelometric Turbidity unit
TCU	True Color Unit
µS/cm	MicroSiemens per cm
%	Percentage
°C	Degree Celcius

CHAPTER 1

INTRODUCTION

1.1 Introduction

Water is both one of the most valuable gifts that nature has to offer and a necessary component of all life. For millennia, river water has been able to sustain all living things, including humans and other organisms. Water quality is an essential determinant of environmental changes strongly linked to social and economic development. River water satisfies approximately 98 per cent of Malaysia's annual demand for freshwater, making the riverine ecosystem a crucial one in this country (Alssgeer et al., 2018). There is a need for water managers to keep an eye on river water quality because the majority of Malaysia's water supply comes from rivers. In addition to affecting river ecology, the deteriorating water quality threatens human health and makes ensuring a long-term supply of safe drinking water increasingly difficult (Ho et al., 2019). According to Perbadanan Bekalan Air Pulau Pinang (PBAPP), 1 073 million litres per day (MLD) of raw water from Sungai Muda and other natural water sources on Penang Island were produced in 2018 (Tan, 2019). PBAPP's water demand is estimated to be 1 883 million litres per day (MLD) until 2050. Sungai Muda, the primary raw water source for Kedah, Perlis, and Penang Island, is expected only to be able to meet each state's natural water needs until 2025 (Dermawan, 2019). The water quality in Malaysia's rivers has a pattern of deteriorating in parallel with the country's growing urbanization and economic activity. The river has some issues, particularly during the dry season, when there is insufficient water to dissolve the materials discharged into it. As a result, water pollution issues emerge (Abdul Rahman, 2021). Rivers become severely contaminated, and remediation is either prohibitively expensive or simply not feasible given the current state of technology. The population density growth, the expansion of metropolitan areas, and the establishment of more construction areas are the most critical factors in influencing hydrological processes. Increased water resource development and demand and higher levels of waterborne pollution are all part of the hydrological cycle. As a result, river water quality suffers (Abdul Rahman, 2021).

River water quality is expected to improve in 2020. The proportion of clean rivers has increased from 61 per cent in 2019 to 66 per cent in 2020. The polluted river percentage has decreased from 9 per cent in 2019 to 5 per cent in 2020 (DOE, 2020). Ammoniacal nitrogen (NH_3N) is a measure of the amount of ammonia found in waste products, and biochemical oxygen demand (BOD) is a rate for determining water quality (Abdul Rahman, 2021). Regarding the BOD subindex, 352 monitored rivers were deemed clean in 2020 (DOE, 2020).

Regarding the BOD subindex, the number of polluted rivers has decreased from 289 in 2019 to 84 in 2020. Reducing organic waste from various sources, including industrial, domestic, and commercial wastewater, has improved river water quality in the BOD subindex (DOE, 2020). Regarding the AN subindex, the number of clean rivers has increased from 211 in 2019 to 239 in 2020. The number of polluted rivers in the AN subindex parameter has decreased from 283 in 2019 to 220 in 2020. The reduction of discharge from treated and untreated sewage into rivers can be linked to an improvement in river water quality via the AN subindex (DOE, 2020).

The water quality index (WQI) is vital in managing water resources because it makes it easier to express a complex set of water quality variables (Wei Sun et al., 2016). To facilitate water quality monitoring, WQI uses standardization to rating curves to consolidate water quality parameters into a single digit, allowing for straightforward monitoring interpretation (Kachroud et al., 2019). Water quality indicators (WQIs) significantly reduce the amount of data and make it easier to describe the current state of water quality with a single number or word. Calculating the WQI involves comparing the number of physical, chemical, and biological factors to standards (Li et al., 2014).

During determining the WQI, specific water quality parameters are selected. The most common of these parameters are chemical oxygen demand (COD), biochemical oxygen demand (BOD), and dissolved oxygen (DO) (Rajaee et al., 2020), where other variables may be incorporated based on the guidelines of the country. The Malaysian WQI is assessed by taking into account the combination of chemical and physical water quality variables of chemical oxygen demand (COD), biochemical oxygen demand (BOD), ammoniacal nitrogen (AN), suspended solids (SS), pH, and dissolved oxygen (DO). Eq. (1.1) gives the formula for computing the WQI (DOE, 2020). The WQI is used to assess a river's health and suitability for water use, and it is divided into five classes. According to the WQI and the Interim National Water Quality Standards for Malaysia (INWQS), water quality is classified into five classes: Class I, II, III, IV, and V (DOE, 2020).

$$\begin{aligned} \text{WQI} = {} & 0.22\ \text{SIDO} + 0.19\ \text{SIBOD} + 0.16\ \text{SICOD} + 0.16\ \text{SISS} + 0.15\ \text{SIAN} \\ & + 0.12\ \text{SIpH} \end{aligned} \tag{1.1}$$

SIDO = Subindex for DO

SIDO = Subindex for BOD

SICOD = Subindex for COD

SISS = Subindex for SS

SIAN = Subindex for AN

SIpH = Subindex for pH

Sewage disposal, small and medium-sized industry effluents, land clearance, logging, and other earth-work operations are the major sources of pollution in Malaysia's rivers. Poorly planned and uncontrolled land clearance activities contributed up to 42 per cent of suspended solids, 30 per cent of biological oxygen demand (BOD) from industrial discharges, and 28 per cent of ammoniacal nitrogen from animal farming activities and domestic sewage disposal. Furthermore, various human activities have influenced aquatic ecosystems due to toxic chemical discharge, hydrology changes, physicochemical water characteristics, and increased nutrient inputs. The activities associated with urbanization and agriculture are the primary causes of changes in the chemical composition of aquatic environments. Continuous water quality monitoring is required to determine the level of pollution in rivers (Alssgeer et al., 2018).

1.2 Scope of Study

This study aims to determine the current pollution levels in Sungai Kereh and create a pollution index. The water quality analysis will be based on dry and wet season conditions. The WQI developed by the Department of Environment (DOE) is used for selecting the parameters, namely biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), pH, suspended solids (SS), and ammoniacal nitrogen (AN).

The concentrations of the six indicators above can be used to determine the health of a river. Field and laboratory testing will be carried out for this study. The in-situ parameters are DO and pH, while the laboratory parameters are BOD, COD, SS, and AN.

There will be approximately six sampling points along the river, from 5°29'59.6"N, 100°30'10.3"E to 5°27'44.2"N, 100°27'36.0"E. This study will cover a stretch of the river approximately 8 kilometres long.

1.3 Problem Statement

Sungai Kereh is located in Tasek Gelugor, Seberang Perai Utara. According to DOE, water quality in Sungai Kereh is classified as Class III (Polluted). Ammoniacal nitrogen (NH_3N) has been identified as a significant pollutant in Sungai Kereh by DOE (DOE, 2020). This problem concerns the paddy fields downstream of Sungai Kereh that rely on water from Sungai Kereh as their primary supply source. According to this situation, six sampling points along Sungai Kereh will be investigated to calculate and monitor the water quality index (WQI), beginning at the potential pollution source and making way to the upstream, middle stream, and downstream of the river in this study.

According to (PBA Holdings Bhd Annual Report 2019, 2020), the "Master Plan Study for Potable Water Supply in Penang until 2050" estimates that Sungai Muda can serve as Penang's primary raw water source until 2025. If Penang does not tap another primary natural water source by 2025, it will face a high risk of a water supply crisis. Penang Water Supply Initiative 2050 (PWI 2050) by Penang Water Supply Corporation Sdn. Bhd (PBAPP) outlined three potential options to encounter this problem. Seberang Perai Water Supply Scheme (SPWSS) is one of the considerations, and it aims to use the Perai River as an additional raw water supply. Sungai Kereh is a tributary of the Perai River. It is essential to monitor the water quality of Sungai Kereh closely.

Pig farming in Kampung Selamat is a significant cause of nitrate contamination in the surrounding surface and water sources. According to the Land and District

Office, pig farming was the third-highest land use in Kampung Selamat, occupying 13% of the total land area, or 72.43 hectares. Residential regions take up the most land. Villagers in Sungai Kereh and Kampung Selamat often complain about the foul odours emanating from the site. Meanwhile, palm oil plantations are the second most common land use. It does not impact the river's water quality because no palm oil factories are operating in Kampung Selamat, which will pollute the river.

In Kampung Selamat, there are 67 pig farms, with the majority of the farms still using open-house system and emitting foul odours into the surrounding area. Due to the lack of maintenance of the lagoon treatment system from the pig farms, wastewater containing pollution flows into the river. Wastewater from Kampung Selamat is then flushed through Parit Cina, an artificial drainage system, polluting the watershed upstream of Sungai Kereh.

1.4 Objectives

i. To assess the current water quality of Sungai Kereh using the water quality index (WQI).

ii. To determine the relationship between the concentration of ammoniacal nitrogen (AN) with biochemical oxygen demand (BOD) and chemical oxygen demand (COD).

1.5 Significance of Study

It is essential to investigate the current pollution level in the river and locate the sources of the pollution to formulate appropriate recommendations for dealing with the issue. Data analysis stems from the desire to document the current water quality conditions in Sungai Kereh, which may be helpful for future reference and research. Furthermore, classifying Sungai Kereh based on each water quality parameter is critical for identifying the rivers' significant constituents and their origins. Following that, it will be possible to implement appropriate mitigation measures.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Toxins from polluted rivers and lakes can harm the overall ecosystem, causing a decrease in critical habitats, biodiversity, and residents (Isiyaka et al., 2019). By conducting frequent water quality monitoring and assessment, it is possible to develop management strategies to combat surface water pollution in growing urbanisation and anthropogenic stress on available water resources (Kachroud et al., 2019).

A number of the water quality measures need to be monitored and analysed. Simply put, determining the water quality based on predefined parameters requires a lot of time and money. Therefore, to obtain the necessary water quality index for rivers in Malaysia, the current study has focused on important water quality parameters that must be monitored for WQI, which requires fewer water quality parameters and less time and costs to perform the analysis (Ho *et al.*, 2019). Regarding river pollution, BOD, AN, and SS remained significant parameters. High BOD levels can be attributed to inadequate sewage or effluent treatment in agricultural and manufacturing industries (DOE, 2020). The most relevant parameters (corresponding to the relative weights indicated in Eq. (1.1) that have a more significant association with WQI prediction are BOD, COD, and DO. (Ho et al., 2019).

2.2 Sources of River Pollution

According to DOE, the water quality in Sungai Kereh is classified as Class III (Polluted). Moreover, according to (DOE, 2020) water quality data, Sungai Kereh has a high concentration of ammoniacal nitrogen pollution. Ammoniacal nitrogen contamination is typically caused by agricultural practices, particularly those that take place in the livestock and poultry industries (Zhang et al., 2018). Because of the high concentrations of ammonium, wastewater from pig farms is a highly toxic substance (Nagarajan et al., 2019). Pig farm waste, such as the water used to clean pig excrement, faeces, urine, and food scraps, is terrible for the environment. Pig farm effluent often contains significant levels of organic matter, phosphorus, ammonium, and trace amounts of heavy metal irons such as copper and iron (Jian et al., 2021). The presence of high levels of ammonium and nitrate nitrogen in rivers can generally harm the quality of surface water, which can lead to problems such as eutrophication. Anthropogenic nitrogen can be obtained from various sources, such as organic nitrogen in the soil, mineral fertilisers, manure from livestock, and effluents from sewage treatment plants. The effluent from swine excreta treatment facilities, which are often located in intensive livestock agricultural watersheds because their effluents contain high ammonium nitrogen concentrations, is one of the most significant contributors to surface water pollution. Identifying multiple nitrogen sources in intensive livestock agricultural watersheds is thus crucial for long-term water quality management (Ryu et al., 2021).

Using Pearson correlation analysis, it was discovered that the BOD positively interacted with AN polluting agent such as AN in organic fertilisers and cleaning agents like soap. Additionally, a higher BOD value can lead to a lower DO concentration since the biodegradation of organic matter in the water requires oxygen gas to decompose. The polluting compounds could also be detected by using the COD parameter. Previous research has indicated that unpolluted rivers have low COD concentrations, whereas river ecosystems with high effluent pollutant flow have high COD concentrations (Ahmad et al., 2015). The Department of Environment (DOE, 2020) states that COD is the primary indication of chemical pollution. A high concentration of AN will affects the pulse, respiration rate, aquatic life balance, and metabolic rates. Animal manure, agricultural waste, and domestic sewage can pollute rivers with high levels of ammoniacal nitrogen. Waste disposal, rubber manufacturing, and agriculture-based businesses contribute to pollution, and AN is a significant indicator parameter. Animal and agricultural waste and human waste from upstream rivers may lead to AN formation. In a Pearson correlation analysis, ammoniacal nitrogen was found to have a negative connection with dissolved oxygen. As mentioned before, the biodegradation of organic matter in the water, which involves the consumption of oxygen gas during the breakdown process, might reduce DO concentration (Ahmad et al., 2015).

2.3 Literature Review from Previous Research

Table 2.1: Literature review from previous research

Author/Year	Objective of Study	Problem Statement	Methodology	Findings
(Lu et al., 2021)	In this study, researchers examined sediments' impact on river water quality.	The urban Shamao River is heavily polluted. A year of water quality monitoring indicated Shamao River was below class V (bad water quality). Industrial sewage along the bank and urban wastewater is dumped into it, polluting the river and causing residents to notice its black color and stinky odor.	1. Samples of sediment and water were collected. Pollutant indicators, such as COD, NH_3N, and total phosphorus, have been rigorously tested and evaluated. The influence of pollutants discharged from sediment was tested using a laboratory water column modelling experiment.	1. The two most significant pollution components were ammonia nitrogen and total phosphorus. 2. COD and NH_3N concentrations in sediments demonstrated relatively limited correlation with overlying water samples, while total phosphorus concentrations did correlate. 3. NH_3N and TP concentrations in the overlying water continued to rise with time, and sediment effluent affected the overlying water quality, which might be considered a "source" of secondary pollution.

(Chan et al., 2020)	Researchers studied the effects of several seasons (dry and wet) on pig farm discharges along the Bang Pakong River in Thailand.	Wastewater treatment management remains inadequate although pig farms in Thailand have been impressively expanded. Pig farming contributes significantly to the pollution load in Thailand's central area, notably from the discharge of raw pig faeces on small farms and effluent overflow from large-farm liquid treatment systems.	1. Carried out water quality analysis including BOD, COD, SS, total Kjeldahl nitrogen (TKN), nitrite, nitrate and phosphorus.	1. Higher COD levels were found on farms with two to three lagoons. 2. The highest COD was discovered in medium farms, followed by small and big farms. NH_3N had no link to farm size. 3. Higher COD in medium farm effluent may be produced by high wastewater loading and inadequate lagoon treatment system performance. 4. The highest pH fell from 7.8 during the dry season to 6.5 during the rainy season.
(Fitri et al., 2020)	From 2005 to 2018, this study sought to present the trend of water	The reported water quality trend is supposed to give water managers vital information for	1. PH and DO concentrations were measured in situ with a YSI meter, while BOD, COD, TSS, and AN	1. Dissolved oxygen concentrations were much lower during the monsoon season compared to the dry season.

	quality status in the Kelantan River downstream, Peninsular Malaysia.	controlling freshwater quality in Kelantan River and minimizing pollution-oriented concerns so that the water can be used for varied uses with adequate quality.	were tested in the lab using APHA procedure.	2. There was a steady rise in TSS, COD, BOD, and AN concentration between 2005 and 2018, with greater concentration levels detected during the monsoon season. 3. Increases in TSS, BOD, COD, and AN lowered DO in freshwater. 4. In 2005, during the dry season, the Kelantan River had Class II water quality. The river water is safe for sensitive aquatic species and can be treated for water supply. During the monsoon season in 2006, TSS, BOD, COD, and AN concentration increased, lowering the water quality.
(Alssgeer et al., 2018)	This study aimed to assess land use changes from the past (2000-2013) to the present (2016).	Population increases and fast development along the Nerus River have caused land use changes. Land use changes harm Nerus River water quality. Seasonal fluctuations and	1. The Malaysian Ministry of Environment provided water quality data for 2000 to 2013, while sampling and lab testing provided 2016 data. 2. The river water quality was determined using the DOE	1. Due to seasonal changes in rainfall, pH lowers during the rainy period and then rises during the dry period, causing photosynthetic algae to consume dissolved carbon dioxide and raise pH levels. 2. Palm oil, untreated sewage from residential areas due to lack of treatment, surface runoff from animal farms, and fertilizer runoff from agricultural districts along the

		pollutant sources were studied.	Malaysia's WQI formula. 3. Correlation analysis was used to find water quality relationships. One-way ANOVA ($p<0.05$) was used to measure water quality parameter variation among stations between 2000, 2013, and 2016.	river cause low DO levels at the stations. 3. Faulty sewer systems and non-point source pollution may cause high BOD in villages. Organic pollution sources include leaking sewer lines, combined sewer overflows, livestock waste in nearby areas, and agricultural runoff and leaky septic tanks in villages. 4. Due to storm water runoff from land use, COD values decreased from upstream to downstream sites. COD has a substantial positive association with BOD, TSS, and NH_3N. 5. COD readings decreased from upstream to downstream stations due to storm water runoff from land use operations, which contains high amounts of organic and inorganic materials. The correlation analysis showed that COD has a substantial positive connection with BOD, TSS, and NH_3N. 6. Widespread fertiliser use and poor farming management in the region

				may cause rainwater NH_3N pollution. Due to NO_3, nitrogen's final oxidation product, NH_3N correlated positively with BOD and COD.
(Chen Ching et al., 2015)	The purpose of this research is to analyze the effects of flooding on the water quality of the Muar River.	Before and during the first flood wave, rainfall correlated strongly with WQI and water quality parameters. This study could support management strategies to mitigate flood effects on surface water resources.	1. The Department of Irrigation and Drainage (DID) Malaysia and the Department of Environment (DOE) Malaysia provided two years of water quality data (January 2006 to November 2007) for nine Muar River monitoring sites. 2. DO, COD, BOD, pH, AN, and SS were evaluated at each location to determine the Muar River's WQI.	1. AN concentration was the only variable significantly correlated with all five water quality parameters, with AN having a strong positive relation with BOD, COD, and SS. AN, on the other hand, has a strong negative relation with DO and pH. 2. High concentration of SS in Muar River led to an increase in AN and a drop in pH, according to the correlation between water quality parameters.
(Salleh Ahmad et al., 2015)	To measure the WQI of Sungai Langat.	Increased water demand, population growth, and agriculture in the vicinity polluted the Sungai Langat, affecting its function.	1. The YSI 556 MPS was used to detect site temperature, pH, and DO. SS, BOD, COD, and AN were tested in a lab.	1. The results demonstrate that the sampling stations' WQI falls into three categories, ranging from class I to class III. 2. Using a Pearson correlation analysis, researchers observed that the BOD had a significant positive correlation with ammonia nitrogen.

2.4 Location of Study Area

Sungai Kereh is located on Seberang Perai in Pulau Pinang. Sungai Kereh is located in Tasek Gelugor, Seberang Perai Utara. Tasek Gelugor, a bustling town in Malaysia's North Seberang Perai region, sits next to the river. As of 2018, the population of Pulau Pinang was around 1.767 million, with a population density of 1,684 people per square kilometre (4,360 people per square mile). Pulau Pinang has more people per square mile than any other state, making it one of the most densely populated in Malaysia. Perai is the second-largest city in Malaysia in terms of population, after Kuala Lumpur. Mainly, its population comprises people from a wide range of ethnic and religious backgrounds. Sungai Kereh will be the subject of an eight kilometres study.

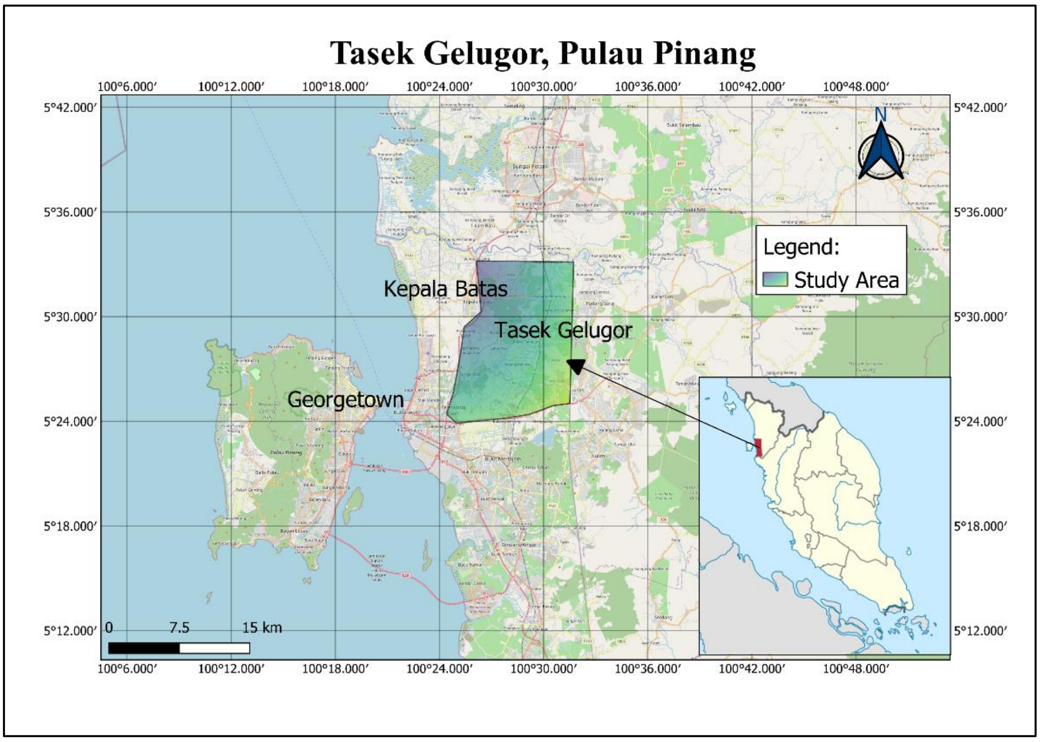

Figure 2.1: Location of the study area

2.5 Land use along Sungai Kereh

Sungai Kereh is a river in Tasek Gelugor that runs through the pig farms of Kampung Selamat. It is dark in color, foul-smelling, and full of pig waste.

According to the Land and District Office, pig farming nominated the third-highest land use in Kampung Selamat, with 13% of total land use, 72.43 hectares. The first highest land use is the residential area meanwhile the second highest land use is palm oil plantations. On the other hand, there are 67 pig farms in Kampung Selamat, and most farms still use the open-house system. The lack of maintenance of the lagoon treatment system from the pig farms is the main cause of wastewater containing pollution flowing freely into the river. Figure 2.2 and Figure 2.3 show that the lagoon treatment system at the pig farms is ineffective as the wastewater is still dark, indicating the wastewater is not well treated. Thus, the wastewater from the pig farms in Kampung Selamat is polluting the upstream of Sungai Kereh (Figure 2.4).

Figure 2.2: Lagoon treatment system at one of the pig farms in Kampung Selamat

Figure 2.3: Lagoon treatment system at another pig farm in Kampung Selamat

Figure 2.4: Condition upstream of Sungai Kereh

2.6 Water Quality Parameters

2.6.1 Dissolved Oxygen (DO)

For freshwater, the most critical parameter in determining the water's quality is the dissolved oxygen concentration. In freshwater, changes in dissolved oxygen concentration can impact the biological and chemical processes within the body of water (Fitri et al., 2021). For aquatic life to flourish, the concentration of dissolved oxygen (DO) in the water is critical in determining how pollution has impacted the water's ecology. In addition to nitrification and marine respiration, DO sinks include the breakdown of organic components (Ahmed and Lin, 2021). Unpolluted fresh water concentrations will be around 10 mg/L. Numerous studies show that a big and diverse fish population can be sustained with as little as 4–5 mg/L of DO. If DO concentration is too low, below 2mg/L, fish will die (Chen Ching et al., 2015).

2.6.2 Biochemical Oxygen Demand (BOD)

The organic wastes produced in wastewater treatment plants, industrial effluents, and agricultural runoff are biodegradable. It is called biochemical oxygen demand to describe how much oxygen is needed to break down biodegradable organics. In decomposition, microorganisms like bacteria and fungi eat organic matter until it is oxidized. These microorganisms use a lot of oxygen during aerobic oxidation of organic matter, measured by BOD. BOD is a crucial parameter in determining the quality of the river's water and the amount of dissolved oxygen present. Pollutants degrade naturally in rivers, and biological decay is one of the most common methods for removing them from the environment (Nuruzzaman, Al-Mamun, and Salleh, 2018). High BOD concentrations indicate that the wastewater contains a high microbial load (Yaakob et al., 2018).

2.6.3 Chemical Oxygen Demand (COD)

Chemical oxygen demand (COD) is a water quality parameter that indicates the water's pollution level based on chemical characteristics and measures the amount of oxygen required to oxidize organic matter chemically by dichromate and sulfuric acid. COD is an estimate of the quantity of organic and reduced matter present in water, also known as the amount of oxygen necessary to decompose organic matter in water chemically. Chemical reactions are triggered when oxidizable chemicals are added to natural water. COD results from chemical reactions are measured in the laboratory.

The BOD and COD tests determine how much oxygen-depleting a waste contaminant affects the environment. Both are widely used to assess the impact of pollution. Only biodegradable pollutants can be measured by BOD tests, whereas COD tests can measure only pollutants that are not biodegradable. In water, COD almost always outweighs BOD. In addition, the COD/BOD ratio reveals whether or not wastewater can be treated biologically (Tchobanoglous et al., 2003).

2.6.4 pH

Several aspects influence the nitrification process, including pH, DO, water temperature, substrate content, and the number of nitrifying bacteria. pH is one of these parameters that significantly impacts the nitrification process. This is because it influences the bacterial growth rates and modifies the acid-base equilibriums NO_2^- /HNO_2 and NH_4+/NH_3 (Le, Fettig and Meon, 2019).

2.6.5 Ammoniacal Nitrogen

The most reactive form of nitrogen is ammonia when it comes to water. Soil mineralization, fertiliser, animal waste, atmospheric deposition, and municipal and industrial point sources are the primary sources of ammonia nitrogen (NH_3N). It is poisonous to aquatic organisms at high concentrations and can adhere to soils and sediments, making it an environmental concern. When ammonia nitrogen is present, phytoplankton and other aquatic plants eat it up quickly. Nitrogen is a potent stimulant for plant and algae growth when it enters the water supply. Bacterial degradation of plant and algal material can decrease DO levels, which is bad news for aquatic animals like fish. The toxicity of ammonia nitrogen to fish varies with water pH, as has long been known (Jiang et al., 2019).

2.6.6 Suspended Solids

Organic and inorganic particles dispersed in water are considered total suspended solids (TSS) (Ariffin et al., 2019). When comparing TSS levels, Rosli et al. (2010) found that a level less than 30.0 mg/L was considered low, while a value more excellent than 50.0% was defined as "high." The maximum TSS concentration in Malaysian rivers is 150 mg/L (DOE, 2020). The high content of suspended solids can degrade water quality by raising the temperature and density of the water, reducing the solubility of oxygen gas and decreasing the clarity of the water, as well as influencing freshwater organism osmoregulation (Chen Ching et al., 2015).

2.7 River Classification in Malaysia

Using six parameters, Malaysia's Department of Environment (DOE) developed a WQI system to track changes in river water quality. Regarding water quality indices, the WQI is like many other systems. It uses the same method or model of computation to combine multiple water quality parameters into one number.

The primary goal of the WQI system is to serve as a primary method for evaluating a body of water to determine whether or not it complies with the standards established for five different classes of beneficial uses. Tables 2.2 shows the river classification based on the DOE-WQI. Next, Table 2.3 shows how rivers are typically classified based on their practical uses. Furthermore, Table 2.4 shows the calculation of subindex properties for each parameter to obtain the WQI value, and lastly, Table 2.5 depicts the INWQS classification and the parameters involved.

Table 2.2: DOE Water Quality Index Classification (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 Solids	mg/l	<25	25-50	50-150	150-300	>300
Water Quality Index (WQI)		>92.7	76.5-92.7	51.9-76.5	31.0-51.9	<31.0

Table 2.3: Water Classes and Uses (DOE, 2020)

Class	**Uses**
Class I	Conservation of natural environment Water Supply I – Practically no treatment necessary Fishery I – Very sensitive aquatic species
Class IIA	Water Supply II – Conventional treatment is required Fishery II – Sensitive aquatic species
Class IIB	Recreational use with body contact

Class III	Water Supply III – Extensive treatment required Fishery III – Common of economic value and tolerant species; livestock drinking
Class IV	Irrigation
Class V	None of the above

Table 2.4: Subindex parameters to calculate WQI (DOE, 2020)

Parameter	Subindex equation	Value
DO	$SIDO = 0$ $SIDO = 100$ $SIDO = -0.395 + 0.030x^2 - 0.00020x^3$	For $x \leq 8$ For $x \geq 92$ For $8 < x < 92$
BOD	$SIBOD = 100.4 - 4.23x$ $SIBOD = 108 * \exp(-0.055x) - 0.1x$	For $x \leq 5$ For $x > 5$
COD	$SICOD = -1.33x + 99.1$ $SICOD = 103 * \exp(-0.0157x) - 0.04x$	For $x \leq 20$ For $x > 20$
NH_3-N	$SIAN = 100.5 - 105x$ $SIAN = 94 * \exp(-0.573x) - 5 * \lvert x - 2 \rvert$ $SIAN = 0$	For $x \leq 0.3$ For $0.3 < x < 4$ For $x \geq 4$
SS	$SISS = 97.5 * \exp(0.00676x) + 0.05x$ $SISS = 71 * \exp(-0.0016x) - 0.015x$ $SISS = 0$	For $x \leq 100$ For $100 < x < 1000$ For $x \geq 1000$
pH	$SIpH = 17.2 - 17.2x + 5.02x^2$ $SIpH = -242 + 95.5x - 6.67x^2$ $SIpH = -181 + 82.4x - 6.05x^2$ $SIpH = 536 - 77.0x + 2.76x^2$	For $x < 5.5$ For $5.5 \leq x < 7$ For $7 \leq x < 8.75$ For $x \geq 8.75$

Note: *means multiply with