ASSESSMENT OF HEAVY METAL POLLUTION WITHIN DOWNSTREAM OF PERAK RIVER BASIN USING GIS MAPPING

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by

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ABSTRAK (BM)

Objektif kajian adalah untuk mengukur parameter kualiti air yang terpilih di bahagian hiliran Lembangan Sungai Perak. Kemudian mengira Jumlah Beban Harian Maksimum (TMDL) dari parameter kualiti air yang diukur untuk menganggarkan mobiliti dan penyebaran bahan pencemar ini. Akhir sekali, memetakan pengangkutan dan penyebaran bahan pencemar menggunakan Pemetaan GIS. Empat ujian dilakukan di makmal, iaitu kekeruhan, Jumlah Pepejal Terampai (TSS), Jumlah Nitrogen Kjeldahl (TKN), dan logam berat (ICP-OES). Ujian ini melibatkan 36 sampel dari Hiliran Sungai Perak. Hasilnya, kepekatan kekeruhan mempunyai julat 23.51 hingga 87 NTU, kepekatan TSS berkisar antara 30.67 hingga 742 mg/L dan kepekatan TKN berkisar antara 0.448 hingga 4.928 mg/L. 19 logam berat hadir ketika dianalisis menggunakan Spectrometry Emission Optical Plasma Inductively Coupled (ICP-OES). Susunan menurun logam berat adalah Ca > Mg > Cu > Fe > TI > Pb > Mn > Sr > V > Ti > Mo > Sb > Ni > Cr > As > Be > Co > Li > Cd. Logam berat dipilih sebagai parameter didalam teknik Jumlah Beban Harian Maksimum (TMDL) untuk mencapai sasaran bagi kualiti dengan melakukan analisis pengurangan pencemaran. Taburan ruang untuk semua parameter dianalisis dalam ArcGIS 10.3.1 untuk mendapatkan peta ramalan geostatistik. Oleh itu, ujian kualiti air sangat penting dalam pemantauan alam sekitar kerana akan memberi kesan yang besar terhadap ekosistem dan kehidupan akuatik.

ABSTRACT (BI)

The objectives of the study are to measure selected water quality parameters in the downstream section of the Perak River basin. Next, to calculate the Total Maximum Daily Load (TMDL) of the measured water quality parameters to estimate the mobility and dispersion of these pollutants. Lastly, to map the transport and dispersion of the pollutants using GIS Mapping. Four tests were conducted in the laboratory, which are turbidity, Total Suspended Solid (TSS), Total Kjeldahl Nitrogen (TKN), and heavy metal (ICP-OES). These tests involved 36 samples from the Downstream of Perak River Basin. The results showed that turbidity concentration ranges from 23.51 to 87 NTU, TSS concentration ranged from 30.67 to 742 mg/L, and TKN concentration ranged from 0.45 to 4.93 mg/L. 19 heavy metals were present when analyzed using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). The descending order of heavy metal was Ca > Mg > Cu > Fe > TI > Pb > Mn > Sr >V > Ti > Mo >Sb > Ni > Cr > As > Be > Co > Li > Cd. Heavy metal was chosen in the Total Maximum Daily Load (TMDL) technique to met the target water quality by doing pollution reduction analysis. The spatial distribution of all parameters was analyzed in ArcGIS 10.3.1 to get the geostatistical prediction map. Therefore, water quality testing is crucial in environmental monitoring, as it will significantly impact on ecosystems and aquatic life.

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LIST OF ABBREVIATIONS

DOE	Department of Environment
TMDL	Total Maximum Daily Load
GIS	Geographic Information System
AOI	Area Of Interest
IDW	Inverse Distance Weighting
WQI	Water Quality Index
DO	Dissolved Oxygen
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
SS	Suspended Solid
AN	Ammoniacal Nitrogen
TDS	Total Dissolved Oxygen
NWQS	National Water Quality Standards
NDPES	National discharge pollutant elimination system
WLA	Waste Load Allocation
LA	Load Allocation
MOS	Margin Of Safety
BMPs	Best Management Practises
TSS	Total Suspended Solids
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry
NTU	Nephelometric Turbidity Unit
mg/L	milligram per Litre
ppm	parts per million

As	Arsenic
Be	Beryllium
Ca	Calcium
Cd	Cadmium
Co	Cobalt
Cr	Chromium
Cu	Copper
Fe	Iron
Li	Lithium
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
Ni	Nickel
Pb	Lead
Sb	Antimony
Sr	Strontium
Ti	Titanium
TI	Thallium
V	Vanadium
Zn	Zinc
Se	Selenium

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

River in Malaysia is vitally essential for nature and humans to provide clean freshwater resources. Despite this, water quality is associated with few significant river management problems. According to the Department of Environment (DOE) (2017), there were 579 rivers in 2008, but there are only 477 rivers now. Based on the Malaysian Environmental Quality survey in 2016, only 47% of 477 monitored rivers were classified as clean, 43% is marginally contaminated, and 10% of the rest are infected (DOE, 2016; Lee, 2020). An audit in 2017 reported that out of 477 rivers, 51 rivers (11%) were contaminated, 207 rivers (43%) were slightly contaminated, and 219 rivers (46%) were classified as safe (DOE, 2017; Lee, 2020). In recent decades, heavy metal pollution has been one of the biggest environmental concerns due to the rapid growth of urbanization and industrialization (Salam et al., 2019). The decay of heavy metals in water is a global issue because these metals are robust and can have harmful impacts on living organisms when they are above a specific concentration. Human activities such as chemical processing, mining, municipal waste, and other anthropogenic practices are channelled into the water (Salam et al., 2019). Water pollution also can cause eutrophication which will affect the biodiversity of aquatic life. He further claimed that diarrhoea, cholera, typhoid, or skin infections are the consequences of drinking or contact with infected water. There are many activities along the Perak River basin, such as sand mining, development of the dental field, industrial zone, aquaculture, agricultural, and others (Yussof et al., 2016). The primary source of the heavy metals contamination is anthropogenic activities because the lower part Perak River basin becomes the main shipping route (Salam et al., 2019). They also stated the effluent from the industrial zone adjacent to the river also contributed to the contamination of heavy metals within this region.

According to Roy and Ritabrata (2018), the characteristics of water determine the water quality physically, biologically and chemically. He also stated that water has its suitability for designated uses, such as recreation, fisheries, drinking, industry, and agriculture. He further explains a few importance of water quality analysis, which are checking the water quality so that it is in line with existing standards and observing the system functionality in the water quality maintenance. Next, finding out the existing system changes if required and checking whether water quality follows the rules and regulations.

1.2 PROBLEM STATEMENT

Perak River is the second-longest river in Peninsular Malaysia. It is crucial to the state and people of Perak because it contributes to the 70% of raw water in Perak. This river is the primary source of clean freshwater in Perak. In order to understand the natural baseline levels, it is essential to research the distribution and pollution of heavy metals in the Perak River basin to attain and track any changes caused by anthropogenic activities. Due to the insufficient water quality data in the downstream part of Perak River basin, the representative mapping of water quality mapping is needed because of a lack of systematic presentation of the data and realistic visualization of the pollutants.

1.3 OBJECTIVE

- To measure selected water quality parameters in the downstream section of the Perak River basin (i.e. heavy metals concentration, Total Suspended Solid (TSS), turbidity and Total Kjeldahl Nitrogen (TKN).
- To calculate the Total Maximum Daily Load (TMDL) of the measured water quality parameters to estimate the mobility and dispersion of these pollutants.
- To map the transport and dispersion of the pollutants using GIS Mapping.

1.4 SCOPE OF STUDY

The following is a list of scopes of study:

- Analyze the selected water quality parameters in the lower part of the Perak River basin (i.e. heavy metals concentration, Total Suspended Solid (TSS), turbidity and Total Kjeldahl Nitrogen (TKN).
- Total Maximum Daily Load (TMDL) of the measured water quality parameters to estimate the load of these pollutants.
- The distribution of heavy metal using GIS Mapping software.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION TO RIVER WATER POLLUTION

When hazardous substances like microorganisms or chemicals contaminate a river, stream, lake, aquifer, ocean, or other body of water, the water quality deteriorates. This will cause the water to become harmful to ecosystems and humans. According to Afroz et al (2015), water pollution is a severe problem in Malaysia. They also mentioned that water pollution harms the sustainability of water resources. It also will affect the living plants and organisms as well as the health of the population, and the economy. They claimed that the total water availability significantly as the cost of treatment of contaminated water is too high.

Afroz et al (2015) and Ling (2020) state that in some cases, polluted water is not susceptible to consumption is reduced. Unfortunately, many water resources available in the basin do not guarantee an adequate supply to all users due to the river.

2.1.1 Effects of Water Pollution

Water pollution was responsible for 1.8 million deaths based on a report released in The Lancet in 2015. About one billion people become ill because of contaminated water every year. The primary source of illness that comes from polluted drinking water are disease-causing viruses and bacteria from animal and human waste. Cholera is one of the diseases spread by contaminated water. Illegal and accidental releases from drainage, fields, urban areas, and sewage treatment plants will add harmful pathogens to rivers. When contamination triggers an algal bloom in a marine ecosystem or lake, it will lower oxygen levels in the water. This is due to the increasing in algae and plant growth. A dead zone created due to eutrophication, where it will drown animals and plants. Neurotoxins produce by harmful algal blooms will have some effect on wildlife. Heavy metals and chemicals from wastewater and industrial toxins cause toxicity to marine life (Denchak, 2018).

2.2 FACTORS AFFECTING RIVER WATER POLLUTION

2.2.1 Urbanization

The degradation of urban waterways has been related to urbanization. Nutrients, oxygen-demanding chemicals, sediment, petroleum hydrocarbons, road salts, heavy metals, viruses, and bacteria are among the primary pollutants present in urban runoff. The highest mass of pollutant loadings from urban areas is suspended sediments. Sediment erosion is caused mainly by construction. Leaves, fertilizer use, defective septic tanks, grass clippings, and pet waste are bacterial and nutrient pollution sources. The majority of petroleum hydrocarbons come from automobiles (EHSO, 2021).

2.2.2 Industrialization

The industry is a major source of water pollution, emitting toxins, positively impacting the environment and humans. The usage of freshwater means transporting waste away from the plant and oceans, lakes, and rivers. Many pollutants are emitted by industrial sources such as petrochemicals, asbestos, and oils (Ohm, 2020).

2.2.3 Agricultural Developments

The leading source of water pollution in the world is agriculture. It also contributes to the breakdown of estuaries and groundwater. Chemicals, fertilizers, and animal waste from livestock and farm activities wash pollutants and pathogens such as viruses and bacteria that will absorb into rivers every time it rains. Nutrient contamination, which is caused by an abundance of nitrogen and phosphorus in water or the air, is the leading cause of algal blooms, a toxic soup of blue-green algae that can be harmful to wildlife and human (Denchak, 2018).

2.2.4 Pathogens

An organism that causes the disease is known as a pathogen. It is a form of organic pollution (biological hazard) that is caused by faecal contamination. Waterborne organisms such as bacteria, viruses, protozoa, and parasitic worms may be introduced into rivers because of faecal contamination (LENNTECH, 2021).

2.3 HISTORY OF RIVER WATER POLLUTION

2.3.1 Europe

At the end of the 19th century, the cities in Europe and United States becomes more populated. Thus, it causes most towns in that country to be exposed to lots of pollution such as waste from factories and industries. According to a report on River Pollution in 1897, the Tawe River in Wales was contaminated by copper works, alkali works, sulfuric acid liquid, sulfate of iron from tin-plate pieces, tiny coal, and slag (National Ocean Services, 2021).

2.3.2 USA

In the United States, toxic chemicals and wastes from industrial mills polluted the rivers in the Northeast. The example of chemicals and waste are sulphuric acid, dyes and wood pulp. In the 20th century, water pollution in metropolitan areas in this country started to rise. The

Cuyahoga River becomes contaminated, where it erupts into flames. A spark from a blowtorch ignited floating debris and oils, causing the first fire (National Ocean Services, 2021).

2.3.3 Asia

In the Philippines, the Marilao River flows from Metro Manila. Its pollution is a significant source of concern for both the Philippine government and the rest of the world. Plastic bottles and rubber slippers, among other non-recyclable products, are often found floating in the river. Furthermore, every day, hazardous industrial waste products are poured into the river and massive amounts of household garbage (The Asean Post Team, 2019).

The Citarum is a river located in Indonesia. The Citarum River is a vital source for irrigation, industry, fishing, electricity generation, and water supply. Today, it is clogged with tonnes of household and industrial waste. The mercury level in the river is increasing 100 times higher than the legal limit. There are three hydroelectric power plant dams along the river. However, these power plants are unable to operate due to the pollution that occurred. As a result, local communities are living without electricity (The Asean Post Team, 2019).

2.3.4 Malaysia

Kim-Kim River located at Pasir Gudang, Johor was polluted. This situation occurred as a result of illegal toxic waste disposal and affecting almost 6000 people. This incident happened in 2019. 2775 people have been admitted to hospitals, 111 schools, 92 nurseries, and kindergarten have been closed (Chia, 2019; Lee, 2020). Many harmful gases such as methane and xylene were released. The crisis of Kim Kim River was unusual as it began with water pollution and progressed to air pollution (The Sun Daily, 2019; Lee, 2020).

Figure 2.1: Polluted Kim Kim River in Pasir Gudang, Johor

Penang is one of Malaysia's most developed and democratic nations, but it lacks one critical resource, which is clean water. Tengah River located at Nibong Tebal was suspected of one of the polluted rivers due to the effluent discharged from nearby factories and farms. This can be seen through the pitch-black water with a thick oil coating on the river's surface (Kata Malaysia, 2019; Lee, 2020).

Figure 2.2: Polluted Tengah River in Nibong Tebal, Penang

2.4 METHODS OF SAMPLING

2.4.1 Composite Sampling

The liquid matrix is assumed to be heterogeneous, varying in time, depth, or through several sampling locations, composite sampling is used. This sampling method combines several grab samples obtained at regular intervals to provide a representative sample for this form of a matrix. Volume-based sampling can be used if the flow is supposed to remain constant. If the flow varies, such as in a sewage line, sampling may be performed using a flow-based composite, which requires obtaining a sample equal to the discharge. A 24-hour duration with intervals of 1-3 hours is represented by time composite sampling. Only use composite samples for parameters that will not change under the sampling, preservation, or storage conditions (Gnanavelu, 2015).

2.4.2 Grab Sampling

Grab sampling is one of two primary techniques for sampling water quality in water sources like rivers and streams and temporary occurrences like stormwater. The grab sampling technique is a six-step procedure for taking a single sample or measurement at a particular time, depth, and location, resulting in a snapshot or single representation of the water quality now (Gnanavelu, 2015). Before collecting a grab sample, the sampler must first explain and recognize the sample's goals, assemble an equipment kit, and determine the sample's location. Although lab conditions differ, reliable lab testing necessitates the use of certified, non-contaminated equipment for sample collection and transport and preservatives, zip bags, properly labelled containers, cool boxes, and ice. Depending on the body of water being sampled, grab sampling can be difficult. In order to continuously track a river or lake by grab sampling, periods of heavy rainfall or drought will need to be taken into account, as the depth of the water will change. This can affect the sample's position and depth (International Environmental Technology, 2021).

2.5 WATER QUALITY STANDARDS

2.5.1 Water Quality Index, WQI

Department of Environment (DOE) has used Water Quality Index (WQI) to assess the state of river water quality (Yisa and Jimoh, 2010; Naubi et al., 2016). To assess river water quality, the WQI formula takes into account six factors, which are pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and temperature, suspended solids (SS), and Ammonia-nitrogen (AN) (Naubi et al., 2016).

Several water quality indexes have been established around the world to assess river water quality. These indexes take into account a variety of water quality parameters. As an example, Meher et al (2015) developed a water quality index for different parts of the Ganges River by using 14 parameters, including total dissolved solids (TDS), alkalinity, pH, dissolved oxygen (DO), turbidity, turbidity, and other parameters (Meher et al., 2015; Naubi et al., 2016). Al-Shujairi (2013) proposed a WQI formula that evaluated water quality in Tigris and Euphrates rivers in Iraq by using seven water quality parameters, which are total hardness, phosphate, TDS, pH, DO, biochemical oxygen demand (BOD), and nitrate (NO3) (Al-Shujairi, 2013; Naubi et al., 2016).

2.5.2 National Water Quality Standards, NWQS

The Malaysian government conducted a study titled "Development of Water Quality Criteria and Standards for Malaysia" in 1985. This study aimed to establish standards that will be used to monitor river water quality for fisheries and aquatic breeding, domestic water use, livestock drinking, agriculture, and recreation. The National Water Quality Standards (NWQS) established six river water classification classes which are Class I, IIA, IIB, III, IV, and V. This level of classes was based on the descending order of water quality where Class V is the "worst" and Class I is the "best" (Zainudin, 2010; Naubi et al., 2016). Table 2.1 displays the range values for different water quality parameters for various river water classes. Table 2.2 shows the DOE Water Quality Index Classification, and Table 2.3 represent the Water Classes and Uses.

Table 2.1: National Water Quality Standards (NWQS) for Malaysia (DOE, 2021)

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	15.0	150.0	150.0	-	-	-
Electrical Conductivity	umhos/cm	1000.0	1000.0	-	-	6000.0	-
Floatables	-	n	n	n	-	-	-
Odour	-	n	n	n	-	-	-
Salinity	%	0.5	1.0	-	-	2.0	-
Taste	-	n	n	n	-	-	-

Total Dissolved Solid	mg/l	500.0	1000.0	-	-	4000.0	-
Total Suspended Solid	mg/l	25.0	50.0	50.0	150.0	300.0	300.0
Temperature	°C	-	Normal +2°C	-	Normal +2°C	-	-
Turbidity	NTU	5.0	50.0	50.0	-	-	-
Faecal Coliform	counts/ 100 mL	10.0	100.0	400.0	5000.0 (20000.0)[a]	5000.0 (20000.0)[a]	-
Total Coliform	counts/ 100 mL	100.0	5000.0	5000.0	50000.0	50000.0	>50000.0
Iron	mg/l	Neutral levels or absent	1.0	1.0	1.0	1.0(leaf) 5.0(others)	Levels above IV
Manganese	mg/l		0.1	0.1	0.1	0.2	
Nitrate	mg/l		7.0	7.0	-	5.0	
Phosphorus	mg/l		0.2	0.2	0.1	-	
Oil & Grease	mg/l	<25	0.04;N	0.04; N	N	-	

Table 2.2: DOE Water Quality Index Classification (DOE, 2021)

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

Table 2.3: Water Classes and Uses (DOE, 2021)

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

2.6 GIS MAPPING

2.6.1 Introduction to GIS

According to RESEARCH GUIDES (2021), a Geographic Information System (GIS) is a tool for managing, storing, capturing, manipulating, analyzing, and presenting various types of geographic data. The data is spatial and is linked to geographic locations. Typically, this data is accompanied by tabular data. It is also known as attribute data, where it is helpful for additional information about each of the spatial features. GIS will be such a powerful problem-solving method for spatial analysis with the combination of these two data types.

2.6.2 GIS Concepts

Based on the RESEARCH GUIDE (2021), GIS can be used for data visualization in a spatial environment, decision-making processes, and problem-solving. GIS can evaluate features and their relationships to other features, how a particular area has changed over time. The density of features in a given space shows what is happening within an Area Of Interest

(AOI), determine where the most or least of a feature resides, and present what is happening near the feature or phenomenon. Many different data formats extension is used to build, exchange, and store geospatial information. Raster and vector are the two most common data forms. Points, lines, and polygons are all examples of vector data. Vectors are the best way to represent discrete (or thematic) data. Vector data is usually used to describe data that has a precise position or rigid boundaries. The point data showing the location of fire hydrants, roads, and railroads utilizing lines are examples of country borders.

On the other hand, raster data is better suited for continuous data or details with no locations or boundaries. The data is represented as a series of grid cells in raster, with each cell contains an amount representing the function being observed. Modelling surfaces such as precipitation, soil pH, temperature, and elevation can be grouped as raster data. These phenomena can be calculated at regular intervals like weather stations. The values in the middle are interpolated to produce a continuous surface. Satellite imagery and photography are examples of remote sensing. These examples are also included in the raster (RESEARCH GUIDE, 2021).

2.7 TOTAL MAXIMUM DAILY LOAD (TMDL)

2.7.1 Introduction to TMDL

According to StormwaterONE (2021), the number of load allocations (LAs) for non-point sources and natural background and individual waste load allocations (WLAs) for point sources is known as Total Maximum Daily Load (TMDL). The combined amount of point source WLA and the LAs for any non-point sources of contamination, tributaries, or adjacent segments if there is only one point source discharger in receiving water and natural background is the value of TMDL. It may be measured in terms of mass per unit of toxicity, time, or other.

StormwaterONE (2021) also state that WLA (Wasteload Allocation) is the component of the TMDL where it considers current and potential point sources (ex: sediment, concentrated flow channels). LA (Load Allocation) is the component of the TMDL that measures emissions from non-point sources and the natural background (rainwater flowing through vegetation while transporting nutrients). When determining a TMDL, Margin of Safety (MOS) is used to account for the volatility of relationships between receiving water quality and pollutant loads.

2.7.2 Development of TMDL

EPA (2018) state that a TMDL aims to assess the loading capacity and distribute the load between various pollutant sources. Since it acts as a link between control measures and water quality requirements, the TMDL process is crucial for improving water quality. TMDLs can be generated in many ways, ranging from basic mass balance calculations to sophisticated water quality modelling. The analysis depends on a few factors such as the complexity of flow conditions, form of pollutant, and waterbody causing the damage. Both pollutant contributors are listed and allotted a portion of the permissible load, which typically entails a reduction in pollution discharge to aid in the problem's solution. The allocations take into account seasonal fluctuations, natural context sources, and a margin of safety. There are five steps to creating a TMDL, which are an estimation of the assimilative capacity of the waterbody like loading capacity. Next, selection of the pollutant(s) to consider and investigation of the current pollutant load. Then, estimation of pollutant loading to the waterbody from all sources and investigation of the pollutant load and to meet assimilative potential. Lastly, allocation with a margin of safety of permissible pollutant load among the various pollutant sources. The ties between waterbody usage disability, the causes of impairment, and the pollutant load reductions required to meet the relevant water quality requirements should be identified in TMDLs.

2.8 THE SUMMARY OF LITERATURE REVIEW

In conclusion, water quality testing is very crucial to monitor the condition of the environment. When water quality is contaminated, it will have a destructive impact on the ecosystem and sea. Next, water quality models can be valuable tools for simulating and predicting chemical pollutant levels, risks, and distributions in a water body. The results from the modelling tools can provide a foundation and methodology support for lots of environmental agencies for research and works. GIS has emerged as a powerful tool for analyzing, storing, and displaying spatial data and using that data to make decisions in various fields.

CHAPTER 3

METHODOLOGY

3.1 RESEARCH METHODOLOGY

This part will go into how the work will be carried out in order to fulfil the goals and the approaches that will be used. The consideration of these factors will aid in a better understanding of the research approach used and its potential to deliver appropriate responses to the study subjects.

The research began with a literature review that include the introduction to river water pollution that consists of effects and factors affecting the pollution. Next, history of river water pollution, method of sampling and water quality standards used in Malaysia is very important in determination of river water quality. A deeper reading on GIS Mapping software and Total Maximum Daily Load (TMDL) were also needed to a have a better understanding on these topic.

Experimental works that consists of 4 types of experiments were done in laboratory, which are Total Suspended Solid (TSS), Total Kjeldahl Nitrogen (TKN), turbidity and Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) for heavy metal.

Data obtained from the experimental works will be analysed to measure the selected water quality parameter, calculation of Total Maximum Daily Load (TMDL) of the measured water quality parameters to estimate the mobility and dispersion of these pollutants and map the transport and dispersion of the pollutants using GIS Mapping software. A comprehensive database is created using the analysed data in the hopes of assisting local governments in developing appropriate prevention of river water pollution.

3.1.1 Study Area

Salam et al (2019) state that Perak has the second largest land area in Malaysia, which is 21,006 km^2. Kedah and Thailand border this state on the north, on the west by the Strait of Malacca, on the east by Kelantan and Pahang, and on the south by Selangor. There is no dry season in Perak, but it has a tropical rainforest climate. The temperature can range from 22°C to 24°C during the winter. During the summer, the temperature varies from 32°C to 34°C.

According to Wakif et al (2020), Perak River is the second-longest river in Peninsular Malaysia after Pahang River. Perak River is around 400 km long and has a basin area of 14 900 km^2. The river flows through the Belum Forest Reserve, beginning at the mountainous Perak - Kelantan -Thailand border and ending in the Malacca Straits. Perak River is essential to Perak and its inhabitants as it is the second-longest river of Peninsular Malaysia. Perak's primary source of raw water, providing over 70% of the natural water used by the population.

3.1.2 Sampling Location

Perak River are vital river in the state of Perak Darul Ridzuan. Many activities arise in this river, such as industrial, agricultural, and domestic activities (Wakif et al., 2020). Thus, it was chosen in this study. The selection of sampling points is very vital in sampling. A total of 140 water samples were collected from 36 sampling locations. For this project, only 36 water samples will be tested in the lab due to limited time. Each sample will be test triplicate to get the average results. Table 3.1 shows the coordinates of sampling location while each sampling is shown in Figure 3.1.

Table 3.1: The coordinates of 36 sampling location

Sampling location	Latitude	Longitude
1	3.9965	100.7519
2	3.9983	100.7753
3	4.0011	100.7949
4	4.0246	100.8075
5	4.0407	100.8252
6	4.0423	100.8529
7	4.0297	100.8632
8	4.0079	100.8568
9	3.9818	100.8537
10	3.9648	100.8650
11	3.9660	100.8870
12	3.9534	100.9058
13	3.9646	100.9261
14	3.9496	100.9359
15	3.9417	100.9531
16	3.9601	100.9573
17	3.9743	100.9533
18	3.9662	100.9723
19	3.9834	100.9838
20	4.0020	100.9815
21	4.0006	100.9933
22	4.0081	101.0099
23	4.0255	101.0115
24	4.0324	100.9938
25	4.0421	101.0084
26	4.0371	101.0253
27	4.0578	101.0171
28	4.0669	101.0029
29	4.0848	101.0133
30	4.1019	101.0012
31	4.1161	100.9893
32	4.1302	100.9795
33	4.1453	100.9797
34	4.1615	100.9647
35	4.1749	100.9468
36	4.1821	100.9282

Figure 3.1: 36 sampling point at Downstream of Perak River Basin

The water samples were collected from the river. Laboratory experiments such as Total Suspended Solid (TSS), Total Kjeldahl Nitrogen (TKN) and turbidity were conducted at Environmental Laboratory 1. In contrast, Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) for heavy metal was conducted at Environmental Laboratory 2. Both laboratories are in the School of Civil Engineering, University Sains Malaysia.

3.2 FLOW OF WORKS

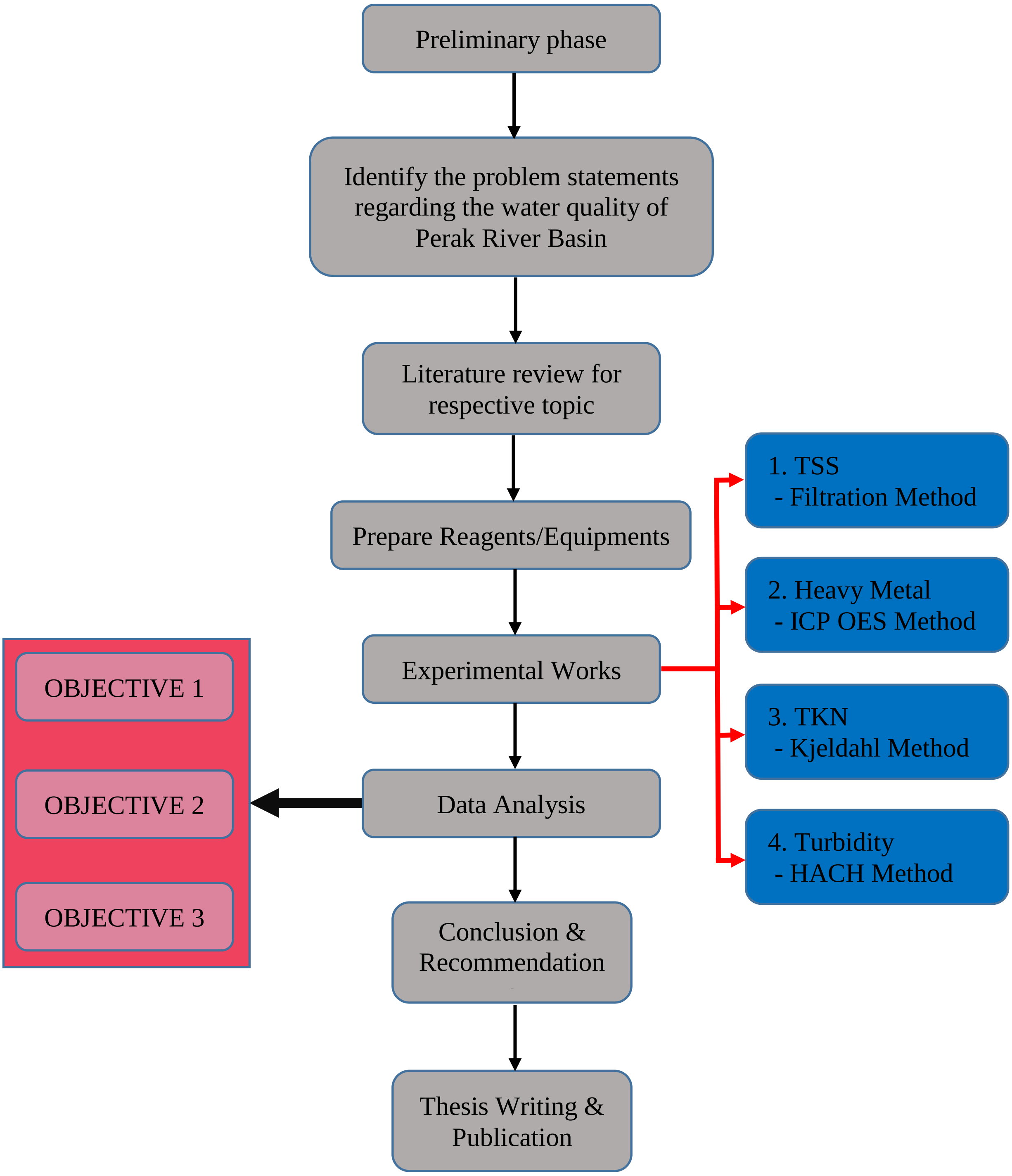

Figure 3.2: Overall flow chart of the methodology conducted in this research

3.3 SAMPLE COLLECTION

3.3.1 Grab Sampling

According to International Environmental Technology (2021), a grab sample is a single sample taken at a given time. The standard method of sampling is grab sampling. This sampling provides an immediate sample and suitable for some in situ tests such as pH and Dissolved Oxygen (DO). Grab sampling can be done by hand or by suspension when collected in an open container or bottle. The sample was taken standing downstream, with the empty container facing upstream. The container must be soaked into the water to collect the sample.

3.3.2 Composite Sampling

According to EPA (2017), a mixture of several individual samples known as a composite sample. The other name for a composite sample is an integrated sample. Each sample was taken in proportion to the amount of flow and was collected at regular intervals. The capability of composite samples to consider account for the changes in flow and other water characteristics over time is their greatest strength. Composite samples cannot be used to detect water properties that change over time, such as dissolved gases or water properties that change when samples are mixed, such as pH.

3.4 EXPERIMENTAL ANALYSIS

3.4.1 Total Suspended Solids (TSS)

One of the method specified analytes is Total Suspended Solids (TSS). A total suspended solid does not have any chemical formula. In other words, TSS is something that is captured by passing a sample aliquot through a pore size filter of a particular pore size. Suspended solids may include anything from silt or sand to plant material, including leaves or stems. TSS may consist of insect larvae and eggs as well as other species. TSS levels above a certain threshold can make a body of water look unsightly. The water's colour or overall turbidity will be affected in any way (International Environmental Technology, 2021).

The filter paper was weighed to get the constant weight before starting the sample filtration. The constant weight of filter paper must be less than 0.5 mg and heated for 15 minutes. Next, shake the sample. The sample volume was transferred to the graduated cylinder. Wet the graduated cylinder with a small amount of distilled water and place the pre-weight filter on the filtration apparatus. Turn on the pump and pour the sample into the filter holder. Rinse both the graduated cylinder and the funnel three times with distilled water. Continue running the pump until all of the distilled water in the funnel has been drained. Turn the pump off. Using forceps, transfer the filter to a crucible. Place the filter in an oven and dry it for at least 1 hour at 130-150°C. Cool the filter in a desiccator until it reaches room temperature. After the filter has cooled down, weigh it. Repeat the steps from the heating process of filter paper for 1 hour until the weight is steady, which is 0.5 mg (Cole-Parmer, 2021). The pictures of TSS experiment were in Appendix A.

The calculation for TSS:

$$mg\ Total\ Suspended\ Solids, L = \frac{(A - B) \times 1000}{Sample\ volume\ (mL)} \qquad (1)$$

Where,

A = Weight final (g)

B = Weight initial (g)

3.4.2 Heavy Metals

3.4.2(a) ICP – OES

USGS (2019) state that ICP-OES stands for Inductively Coupled Plasma Optical Emission Spectrometry. It is a method for detecting trace metals and a type of emission spectroscopy. The production of excited ions and atoms emit electromagnetic radiation at wavelengths specific to a given feature. The ICP and optical spectrometer are the two main components of ICP-OES.

According to USGS (2019), an intense magnetic field was created when the torch is turned on. The argon gas is ionized and flows into the magnetic field. Thus it will create a stable and high-temperature plasma of around 7000 K. An aqueous sample is delivered via a peristaltic pump to a nebulizer. This is the part where it is atomized and introduced into the plasma flame. The sample is instantly broken down into charged ions after it collides with electrons and other charged ions in the plasma. The various molecules disintegrate into their constituent atoms, which lost electrons and recombine in the plasma in a typical pattern and emitting the elements' characteristic wavelengths. Move lenses to focus reflected light onto a diffraction grating in an optical spectrometer, where it is separated into its component radiation.