ASSESSMENT OF RIVER WATER QUALITY AND THREATS TO SAFE WATER SUPPLY IN MALAYSIA

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RESEARCH REPORT SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE MASTER OF SAFETY, HEALTH AND ENVIRONMENT ENGINEERING

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ABSTRACT

The spatial water quality trends of sixteen monitoring stations distributed along the Langat River basin are investigated in this study, which spans the years 2016 to 2020. The health and status of the stream were examined and appraised from numerous angles. First, agglomerative HCA was used, in which sixteen monitoring sites were grouped into four groups based on similar land use practices and contaminants. Then, using PCA, it was determined which contaminants were the most significant contributors to water contamination. BOD, COD, and NH3 were determined to be the main proponents based on PCA. The findings were further validated by the M-K test, which revealed a growing trend in COD and BOD. The findings of this study may enable decision-makers in developing a more comprehensive policy, including, without a doubt, upgrading treatment facilities into an upgraded water treatment plant that will aid in accomplishing smooth water supply operations. We can infer from this evaluation that statistical analysis can find substantial data on the geographical fluctuation of a vast and complex river water quality dataset.

Keywords: Water Quality, physical parameters, chemical parameters, biological parameters, statistical analysis

ABSTRAK

Trend kualiti air bagi enam belas stesen pemantauan yang ditempatkan di sepanjang lembangan Sungai Langat dari tahun 2016 sehingga tahun 2020 diselidik dalam kajian ini. Keadaan dan status aliran telah diperiksa dan dinilai dari pelbagai sudut. Pertama, HCA aglomeratif digunakan, di mana enam belas tapak pemantauan dikumpulkan ke dalam empat kumpulan berdasarkan amalan penggunaan tanah dan bahan cemar yang serupa. Kemudian, kaedah PCA digunakan bagi menentukan bahan cemar utama yang menyumbang kepada pencemaran air. Melalui kaedah PCA, BOD, COD, dan NH3 terbukti merupakan penyumbang utama kepada pencemaran. Penemuan ini disahkan melalui ujian M-K, yang mendedahkan trend yang semakin meningkat dalam COD dan BOD. Penemuan kajian ini boleh digunakan oleh pihak yang bertanggungjawab untuk membangunkan dasar yang lebih komprehensif tanpa keraguan untuk menaik taraf loji rawatan air yang akan menyumbang kepada kelancaran bekalan air. Melalui penilaian ini, dapat disimpulkan bahawa penggunaan analisis statistik boleh digunakan untuk mencari data geografi kualiti air sungai yang luas, sering berubah-ubah dan kompleks.

Kata kunci: Kualiti air, Parameter fizikal, Kimia fizikal, Biologi parameter, Analisis statistik

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LIST OF ABBREVIATION

Ag	-	Silver
Al	-	Aluminum
AN	–	Ammoniacal - Nitrogen
BOD	–	Biochemical Oxygen Demand
COD	–	Chemical Oxygen Demand
DAF	–	Dissolved Air Floatation
DID	–	Department Of Irrigation and Drainage
DOE	–	Department Of Environment
E. coli	-	Escherichia coli
FA	–	Factor Analysis
HCA	–	Hierarchical Cluster Analysis
MG/L	–	Milligram Per Liter
M-K	–	Mann-Kendall
MLD	–	Million Liters Per Day
NPS	-	Non-Point Source
NWQS	–	National Water Quality Standard
PCA	–	Principal Component Analysis
PS	-	Point Source
SDG	–	Sustainable Development Goals
Sg.	-	Sungai
SI	-	Subindex
SS	–	Suspended Solids

St.	-	Station
SWMA	–	Selangor Water Management Authority
WQI	-	Water Quality Index
WTP	–	Water Treatment Plant

LIST OF SYMBOLS

°	–	Degree
%	–	Percentage

CHAPTER 1: INTRODUCTION

1.1 Background of Research

Water is one of life's most necessities. As stated in Goal 6 of the Sustainable Development Goals for clean water and sanitation, it is critical that water ingested by humans and animals be pure and clean. If humans and animals drink contaminated and untreated water, it can have fatal consequences for their health (Spellman, 2017). Water contamination is defined as the continuous contamination of water bodies such as lakes, streams, oceans, springs, and groundwater by human activities. Water pollution also happens when an abundance of toxins, such as particles, synthetics, or polluting substances, are injected directly into bodies of water without enough treatment to remove harmful compounds. Water is still extremely important for both human and ecological wellness because it is used for drinking and nourishing both humans and animals. As a result, water contaminated with hazardous microbes or synthetic compounds may cause illness or, worse, death (Inyinbor Adejumoke et al.,2018).

The main river water supply for the Klang Valley in Selangor comes from the Sungai Selangor and Sungai Langat River basins (State of the river report 2015: Langat River, 2017). The illegal and inefficient wastewater treatment discharge of waste from industries into the two river basins has significantly polluted these two rivers. Aside from that, the rapid development of human populations and activity near the river has also contributed to the contaminants deposited in the rivers (Ukaogo, Ewuzie & Onwuka,2020). The effluent discharged from these operations contains varying concentrations of pollutants that may not only harm the aesthetics of the water bodies but may also be harmful to human life if consumed. As a result, water cuts have become commonplace for Klang Valley residents, as water treatment plants must be shut down to prevent contaminants from entering our homes ("Water supply cut in Klang Valley affects 5m people as plants shut due to contamination again", 2022).

In this study, statistical analysis was used as a technique to group data from the Langat River basin collected from the Department of Environment (DOE) to analyze pollution of supply river water quality with frequency of water shut offs. The right policy recommendations are based on industrial operations' desire to reduce waste.

1.2 Problem Statement and Hypothesis

River water contamination is still a big issue in developing countries such as Malaysia. Land used from both point and nonpoint contamination sources, such as sewage discharge, effluent discharged from industry, agricultural reasons, and urban run-offs, has a negative impact on water quality. Because Malaysia relies on rivers as its primary source of water, the contamination raised concerns about the sustainability of water assets. Several unannounced terminations of water treatment plants in different Malaysian provinces, particularly Selangor, have been reported in the recent past, resulting in water supply interruptions.

Scheduled monitoring and continuous assessment of river water quality are warranted for contamination identification, prevention, and control. Malaysian government agencies such as the Department of Environment (DOE) and the Department of Irrigation and Drainage (DID) monitor water quality. In any case, the previous water quality study required more evidence to demonstrate the major contaminants undermining Selangor's clean water supply. Evaluating the observed data can provide insights into potential toxin sources and changes in river water quality, which could aid in further developed water quality management. As a result, the goal of this study project is to use statistical analysis to assess the stream water quality in Sungai Langat and to investigate the threat of substantial toxins to a safe and consistent water supply.

1.3 Objectives of Research

The primary goal of this research is to:

1. Evaluate River water quality in Selangor using statistical analysis

2. To investigate the hazard posed by major contaminants in rivers to the safe and ongoing supply of water.

1.4 Scope of Research

The following is a list of the research's scope:

I. An established approach was used to analyze the data collected from DOE.

II. Statistical analysis was used to describe the river basins and acquire data on pollution levels from past years.

1.5 Significance of Research

The release of effluents containing an abundance of toxins such as trace metals, dyes, and other pollutants from urban, industrial, and agricultural industries near Sungai Langat water bodies damages the aesthetic nature of the receiving water bodies and causes toxicity to humans as the drinking water supply is dangerously contaminated or chemically polluted. When these toxins aren't handled, they can spread diseases including cholera, diarrhea, and polio. It is estimated that over 829 000 fatalities are connected to diarrhea disease alone, which is a preventable disease that can be averted when all risk factors are addressed. If left untreated and constantly supplied, it may cause harm to consumers ingesting contaminated drinking water.

Many researchers have demonstrated in recent studies that by strengthening strict policies and regulations implemented in primarily reducing the amount of waste entering water bodies, as well as continuous monitoring of waste discharge from industries and river water quality, can reduce the effect of unsafe drinking water, including unscheduled water interruptions.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Because water is one of the most basic needs of life for the earth and all living things, contamination of water is a serious problem that needs to be addressed by everyone. In natural water bodies, substances from human activity and everyday wastes are regularly detected (Alley,2007). Since the last decade, the presence of foreign substances in water has been observed and discussed. A variety of strategies and frameworks have been developed to avoid water tainting and remove contaminants from water. This is to ensure that both people and the environment have access to clean water on a consistent basis. The wastewater produced by companies frequently contains pollutant items that harm the environment, such as plastic, fertilizers, and colors. Most colors are carcinogenic and toxic (Wani, Jangid & Bhat, 2019). To protect people and sources from dyes, dyes and pollutants should be removed from wastewaters before they are released into the environment.

2.2 River Water Quality Classifications

River water quality and contamination prevention are critical because rivers provide 98% of the world's water. 70% of the country's water resources are used by the agriculture industry (Davis & Masten, 2004). As river water contamination increases, so does the concentration of existing pollutants. As a result, there is a bigger 'amount scarcity' of water as the amount of good water accessible for use declines, as well as higher water treatment expenses as additional contaminants are introduced. Furthermore, the biological condition of water bodies and the ecosystems around them deteriorates, harming aquatic life and living space, as well as leisure activities.

2.2.1 National Interim Water Quality Standard (INWQS)

In terms of water quality, the INWQS separates streams into six categories (I, IIA, IIB, III, IV, and V), with Class I being the "best" and Class V being the "worst" in terms of water quality. The INWQS defines the 6 classes to be used and treated as in **Table 2.2**.

Table 2.1 Parameter ranges for each class given by INWQS

National Water Quality Standards

Parameters	Unit	Classes					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.3	0.9	2.7	>2.7
BOD	mg/l	1.0	3.0	3.0	6.0	12.0	>12.0
COD	mg/l	10.0	25.0	25.0	50.0	100.0	>100.0
DO	mg/l	7.0	5.0-7.0	5.0-7.0	3.0-5.0	<3.0	<1.0
pH	-	6.5-8.5	6.0-9.0	6.0-9.0	5.0-9.0	5.0-9.0	-
Colour	TCU	15.0	150.0	150.0	-	-	-
Electrical Conductivity*	umhos/cm	1,000.0	1,000.0	-	-	6,000.0	-
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	1,000.0	-	-	4,000.0	-
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	5,000.0 (20,000.0)[a]	5,000.0 (20,000.0)[a]	-
Total Coliform	counts/100 mL	100.0	5,000.0	5,000.0	50,000.0	50,000.0	>50,000.0
Iron	mg/l	Natural 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	
Phosphorous	mg/l		0.2	0.2	0.1	-	
Oil & Grease	mg/l		0.04; N	0.04; N	N	-	

(Ministry of Health Malaysia, n.d.)

Table 2.2 Water Use Classes in the National Water Quality Standards

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. Fishery II - Sensitive aquatic species
Class IIB	Recreational use 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

(Ministry of Health Malaysia, n.d.)

2.2.2 Malaysian Water Quality Index (WQI)

A Water Quality Index (WQI) assigns a value to a total set of estimated boundaries based on quality. It usually consists of sub-record values assigned to each pre-defined boundary by contrasting its estimation with a boundary explicit rating bent, alternately weighted, and consolidated into the final index. The purpose of a WQI is to summarize water quality information for a specific stream in simple language that the public can understand. This makes it simple to understand for both river basin people and river basin management. The WQI, which is mostly used in Malaysia, is an evaluation of an opinion poll methodology in which a board of expert's advice on parameter selection and weighting for each parameter. Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Suspended Solids (SS), Ammoniacal Nitrogen (AN), and pH were chosen for the WQI. The formula for WQI can be seen below:

$$WQI = 0.22SIDO + 0.19SIBOD + 0.16SICOD + 0.16SISS + 0.15SINH3 - N + 0.12SIpH$$

Before that, the water quality index can be pre-determined using the best fit equations used to produce sub-indices of BOD, COD, and SS, and the equation's findings will be used to assess how contaminated the river is, as indicated in the table below:

Table 2.3 Index range for determination of river water pollution

SUB INDEX & WATER QUALITY INDEX	INDEX RANGE		
	CLEAN	SLIGHTLY POLLUTED	POLLUTED
Biochemical Oxygen Demand (BOD)	91-100	80-90	0-79
Ammoniacal Nitrogen (NH3-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

(Ministry of HealthMalaysia, n.d.)

Another way of determining the WQI is by using the DOE water quality index classification as shown below (Table 2.4)

Table 2.4 Determination of WQI by using categorization of DOE water quality index

Parameter	UNIT	Class				
		I	II	III	IV	V
NH_3-N	mg/L	< 0.1	0.1 - 0.3	0.3 - 0.9	0.9 - 2.7	> 2.7
BOD	mg/L	< 1	1 - 3	3 - 6	6 - 12	> 12
COD	mg/L	< 10	10 - 25	25 - 50	50 - 100	> 100
DO	mg/L	> 7	5 - 7	3 - 5	1 - 3	< 1
pH	-	> 7	6 - 7	5 - 6	< 5	> 5
SS	mg/L	< 25	25 - 50	50 - 150	150 - 300	> 300
WQI	-	> 92.7	76.5 - 92.7	51.9 - 76.5	31.0 - 51.9	> 31.0

(Ministry of Health Malaysia, n.d.)

However, despite WQI is a simplified term that can be easily understood by the general population, it still has its own benefits and limitations in which is summarized in Table 2.5.

Table 2.5: Advantages and drawbacks of WQI

Water Quality Index	
Advantages	**Disadvantages**
• Simplifies way of expressing laboratory data	• Provides rundown of the chosen parameters

• Help in evaluation of water quality • Distinguish water quality patterns and trouble areas based on chosen parameters • Used as a screening device to additional assessment • Better communication and awareness with general society of water quality conditions	• Cannot give total data on water quality • Inclusive total water quality risk cannot be done • One- sided in their formulation • Depend on theoretical speculations that are not generally applicable • All scientists and statisticians oppose and criticize it.

(Uddin, Nash & Olbert,2021)

2.3 Water Quality Parameters

2.3.1 Physical Parameters

2.3.1.1 Temperature

The amount of dissolved oxygen in the water is influenced by the temperature of a stream. The amount of oxygen that breaks apart in water increases as the temperature drops. Water can hold 14.6 mg of oxygen per litre at 0°C, but it can hold 7.6 mg/L at 30°C. (Davis, 2010).

Temperature has an impact on viscosity, solubility, odours, and chemical reactions, among other things. As a result, temperature has an impact on the sedimentation, chlorination, and biological oxygen requirement processes (BOD). It also has an impact on the biosorption cycle of heavy metals that have been broken down in water. Researchers discovered that water with a temperature of 10-15°C is the most pleasant (Peavy, Rowe & Tchobanoglous,1985).

2.3.1.2 Turbidity

The most prevalent cause of turbidity is suspended material that absorbs and disperses light. These turbidity-causing colloidal and finely distributed elements are not ordered in a peaceful environment. Conditions and sedimentation are difficult to overcome (Federation & Aph Association,2005).

Turbidity is a significant boundary in water supply designing, on the grounds that both turbidities will prompt water cleanliness and necessitates to be treated with water treatment processes such as filtration and disinfection.

Turbidity is likewise used to show proof of the possibility of bacteria being present inside the water, (Kiprono ,2017). Nephelometric Turbidity Units are used to express turbidity estimations made with specialized nephelometric devices (NTU).

2.3.1.3 Electrical Conductivity

Electrical conductivity is one of the signs of water quality. Data on the conductivity can decide the solution concentration, identify foreign substances and decide the immaculateness of water (Omer,2019). YSI conductivity sensors use an AC voltage applied to nickel anodes to measure conductivity. The current passes through the anodes and the sample when these cathodes are placed in a water test (or other fluid). The conductivity of the arrangement is directly proportional to the current level.

Conductivity refers to a material's capacity to guide electrical flow. Placing plates/wires in the sample, applying a potential across them (typically a sine wave voltage), and estimating the current is the primary rule by which equipment assess conductivity. The voltage and current values, as stated by Ohm's regulation, are used to estimate conductivity, which is the inverse of resistance (Omer,2019).

The conductivity of a solution is proportional to its particle concentration because the charge on particles in solutions interacts with the conductance of electrical flow. Despite this, conductivity may not always equate directly to the concentration factor in some situations (Omer,2019). In a few extremely concentrated solutions, ionic concentrations can change the linear relationship between conductivity and concentration.

The siemens (S), often called the mho, is the basic unit of conductivity. Because cell computation has an impact on conductivity readings, normalized estimates are presented in specific conductivity units (S/cm) to account for differences in electrode characteristics (Omer, 2019).

In addition to temperature, conductivity estimations take into account salinity values, which are calculated. Conductivity meters can use a variety of sensors, including the non-wiped conductivity field sensor.

2.3.2 Chemical Parameters

2.3.2.1 pH

pH is one of the most significant water quality indicators to keep an eye on. The negative logarithm of the concentration of hydrogen particles in a water solution is what it's called (Spellman,2017) (Edzwald & American Water Works Association,2011). It is a one-dimensional integer that represents the acidity or basicity of a solution. When all is said and done, the pH level is a measure of how acidic or basic the water is. Additional hydrogen (H+) particles are present in acidic water, while additional hydroxyl (OH) particles are present in basic water.

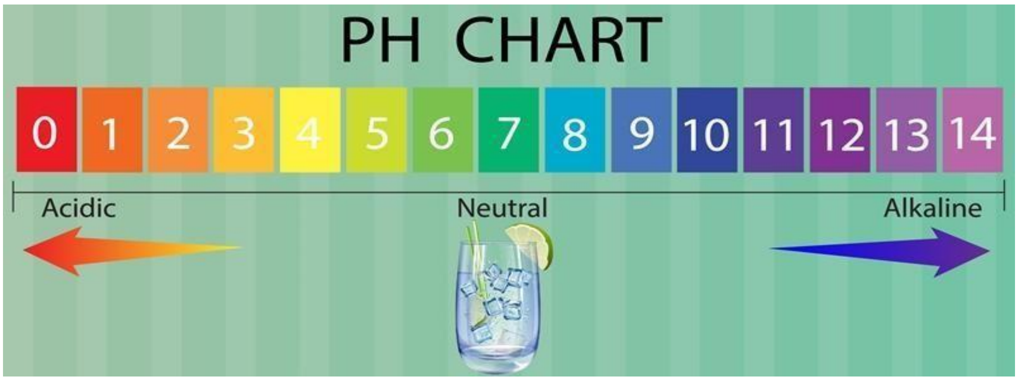

Figure 2.1 pH scale

pH ranges from 0 to 14, with 7 being impartial and neutral, as seen on the diagram above (Alley,2007). Acidity is indicated by a pH less than 7, while baseness is indicated by a pH more than 7. Pure water has a pH of roughly 7.0 at 25°C, which is neutral and in the middle. The pH of average rainfall is estimated to be around 5.6 (marginally acidic) based on climatic carbon dioxide gas (acid rain). pH values in drinking water should be between 6.5 and 8.5 for homegrown use and life species (Cole et al.,2000).

A 10-fold difference in pH is represented by a pH difference of one unit, so water with a pH of 7 is 10 times more acidic than water with a pH of 8, and water with a pH of 5 is 10 times more acidic than water with a pH of 7 (Cole et al.,2000). There are two ways for determining pH: electrometric and colorimetric.

Unnecessarily high and low pHs might impede water utilization by having a negative impact on consumption. A high pH affects the taste and lowers the efficacy of chlorine sterilization, necessitating the use of extra chlorine. Low-pH water, on the other hand, has a tendency to degrade metals and other substances.

Contamination can cause changes in the pH of water, which can affect aquatic life and plants. The following is a summary of pH's impacts on living things:

Most oceanic species and plants have adapted to exist in water with a specific pH and may be harmed by even minor changes.

- Most oceanic organisms and plants have developed to live in water with a specified pH, and even tiny changes can be harmful (Cole et al.,2000).
- Poisonous water has an exceptionally low or high pH. Only a few creatures can survive in water with a pH of less than 3 or more than 11, and most fish will perish if the pH is below 4 or beyond 10 (Kiprono, 2017).

- Low pH puts the lives of land and water creatures in jeopardy since their skin is extremely sensitive to foreign toxins. Several specialists suggest that low pH levels caused by corrosive rain may be to blame for the global fall in land and water skilled populations (Cole et al.,2000).

The following is a summary of how pH affects several synthetics in water:

- Cadmium, lead, and chromium are heavy metals that break down more quickly in acidic water (lower pH). This is necessary because many heavy metals become much more lethal when exposed to water.
- The pH of the water can be adjusted to modify the types of synthetics present. As a result, it may have an impact on marine plants and animals. In acidic water, for example, ammonia is considered harmless to fish, but it can be hazardous to the same creatures when the water becomes more alkaline.

Table 2.6 pH range for growth of organism

pH 4	pH 4-5	pH 5-6	pH 6-9	pH 9-11	pH 11
Acid death point	Acid stress, no reproduction, slow growth	Acid stress, reproduction may be less than normal, slow growth	Best range for growth and reproduction	Best range for growth and reproduction	Alkaline stress, reproduction and growth adversely affected

2.3.2.2 Dissolved Oxygen

One of the most important markers of water quality in streams, rivers, and lakes is dissolved oxygen (DO). It's an important technique for determining whether or not water is contaminated (APHA,2005). That is, if oxygen levels are high, water pollution levels are likely to be low. If oxygen levels are low, it is safe to assume that there is a high demand for oxygen and that the water is not in the greatest possible condition for consumption. Apart from revealing pollution levels, marine species depend on oxygen in the water to exist. If there is no or little oxygen available, fish and other species will perish. Diffusion and photosynthesis are two ways that allow oxygen to enter water.

1. Diffusion - When the water disruption generated by turbulence is increased, as when travelling through rapids and waterfalls, and when there is a strong wind blowing, the oxygen dispersion into the water is enhanced. Furthermore, oxygen diffuses more quickly in cold water than in warm water.

2. Photosynthesis - When there is sunshine, aquatic plants utilize the energy of the sun to make energy that they can use to build their own food. As a result of this cycle, oxygen enters the surrounding water.

The stream becomes increasingly strained as the level of dissolved oxygen in the stream exceeds or falls below specified thresholds. The accurate measurement of dissolved oxygen is affected by pressure, temperature, and salinity. Although dissolved oxygen has minimal direct impact on overall health, some people find it unpleasant to drink water with little or no oxygen (APHA,2005).

2.3.2.3 Biochemical Oxygen Demand (BOD)

Microbes and bacteria eat natural substances for nutrition. When they process natural resources, they use oxygen. The energy released by the bacteria is used by the bacteria for their own development and reproduction once the organics are broken down into simpler combinations like $CO2$ and $H2O$ (APHA,2005).

In water, the oxygen consumed is dissolved oxygen in the water. If oxygen is not routinely replenished in the water by natural or artificial means, the DO will fall as microorganisms destroy the natural components. The name for this oxygen need is biological oxygen interest (BOD). The more natural material in the water, the higher the

BOD eaten by the organisms (APHA,2005). The BOD is measured as a percentage of the sewage force; strong sewage has a high BOD, whereas weak sewage has a low BOD.

Microorganisms take a long time to completely disintegrate natural materials, usually 20 days or more under normal conditions. A definitive BOD or BODL is the quantity of oxygen used in a defined volume of water to totally break down or settle all biodegradable natural compounds (Omer,2019).

BOD is a time component. There will be no oxygen consumed at time = 0 and the BOD will be 0 (APHA,2005). The microbes consume oxygen each day, increasing BOD. Finally, the BODL is achieved, and all natural materials have decomposed completely.

2.3.2.4 Chemical Oxygen Demand (COD)

The Chemical Oxygen Demand (COD) is a limit that takes into account both biodegradable and non-biodegradable species (Omer,2019). The capacity of water to use oxygen during the decomposition of natural stuff in the water is measured by COD. As a result, the amount of oxygen required to oxidize the natural matter present in a given volume of water. It is a chemical test that uses powerful oxidizing synthetics (potassium dichromate), sulfuric acid, and heat, and the results can be obtained in as little as two hours (Omer,2019). The majority of the time, COD characteristics are greater than BOD values for the same sample (Omer,2019).

The presence of high levels of COD in wastewater indicates organic convergences, which can lower the amount of dissolved oxygen in the water, resulting in negative ecological and regulatory consequences.

From a health standpoint, hardness up to 500 mg/L is safe to consume, but anything higher than that may have a laxative effect (Omer,2019). Titration with ethylene diamine tetra acidic corrosive or (EDTA) and Eriochrome Black and Blue indicators is commonly used to measure hardness. It's measured in milligrams per litre of CaCO3.

2.3.2.5 Ammonia Nitrogen

The decomposition of microbiological organisms and plant protein produces ammonia. Plants use it to make protein in a basic manner (Omer,2019). Ammonia and ammonia compounds are used as fertilizer in a straightforward manner. The emergence of ammonia nitrogen in surface water generally signals that it has already been contaminated at home. Ammonia is a common pollutant in groundwater and is produced by microbial activities.

Natural nitrogen, ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen are the four forms of nitrogen found in water and wastewater. When water is contaminated with sewage, most of the nitrogen is in the forms of organic and ammonia, which are converted to nitrites and nitrates by bacteria (Omer,2019). Nitrogen in the nitrate structure is an important supplement for plant development, but it can also be a growth-restricting agent.

A high nitrate concentration in surface water can serve as a catalyst for the rapid growth of algae, lowering water quality. Compound composts used in farming areas can leach nitrates into the groundwater. Excessive nitrate concentrations (more than 10 mg/L) in drinking water provide an immediate and serious health risk to newborns (Omer,2019). The nitrate particles react with blood hemoglobin, reducing the blood's ability to hold oxygen, resulting in a condition known as blue kid or methemoglobinemia (Omer,2019).

2.3.3 Biological Parameters

2.3.3.1 Algae

Algae are microscopic plants containing photosynthetic pigments such as chlorophyll (Choi, Dombrowski & Wiesmann,2007). They are autotrophic creatures that survive by converting inorganic materials into natural matter using solar energy; during this process, they absorb carbon dioxide and emit oxygen into the atmosphere. They're also important in stabilization ponds for wastewater treatment. Algae are parasites in the water supply because of the taste and odor problems they cause. Certain varieties of algae, for example, blue green algae, can kill cattle and other domesticated creatures if they consume water containing those species (Choi, Dombrowski & Wiesmann,2007).

2.3.3.2 Viruses

Viruses are the tiniest organic structures known to contain all critical hereditary info for their own development. Because they are so little, they can only be viewed using a powerful electronic magnifying lens (Omer,2019). Viruses are parasitic organisms that require a host to survive. They can pass through filters that prevent minute creatures from being sectioned. Infectious hepatitis and poliomyelitis are known to be spread by waterborne viral microorganisms. The sanitization interaction carried out at the water treatment plant can deactivate a major portion of the waterborne diseases.

2.3.3.3 Indicator Organisms

The accumulation of microorganisms known as coliforms is an important organic indication of water contamination (Tomar,1999). People's gastrointestinal systems are continually contaminated with pathogenic coliforms, and millions are ejected with bodily wastes. As a result, coliforms will always be present in water that has been contaminated with sewage.

Escherichia coli, or E. coli, is a type of coliform found in domestic sewage. They will almost certainly be discovered, regardless of how filthy the water is. In 100 mL of untreated sewage, there are around 3 million E. coli germs (Tomar,1999). Coliform microorganisms are hardy creatures that can survive in water for longer than other germs. The layer channel strategy and distinct cylinder aging techniques are the two most common methods for testing coliform bacteria.

2.4 Sources of River Water Pollution

Malaysian communities are mainly found along the banks of rivers and streams. Waterways provide water to persons, agricultural water systems, transportation water systems, a source of food in fisheries, hydro-electric generation, and water use for businesses in a variety of ways. Stream contamination occurs when water groups of streams are polluted, usually as a result of human activity. The pace of stream contamination is extremely concerning, as there has been a drop in the number of rivers over the last almost ten years, with 579 rivers in 2008 and only 477 in 2019 (NSTP, 2019). This is owing to the dangers of pollution from both point and nonpoint sources that flow into river systems, contaminating the water.

2.4.1 Point Source

Contamination that arises from a single source is known as point-source contamination. To emphasize, contamination from a known source, such as sewage treatment plants, agro-industry, sulfur or greywater from commercial and private properties, and pig farms, is the key cause of concern (Daud, 2009). In comparison to non-point source contamination, it is considerably easier to limit the risk and address the source of contamination to successfully treat it before it is released into the environment with point source contamination.

2.4.2 Non-Point Source

Nonpoint source contamination can be simply defined as "storm caused contamination." Water washes away contamination that has accumulated on land surfaces, rooftops, and vegetation, eventually depleting into water bodies, making it more difficult to identify and remove. Most contaminations are caused by humanactivities, with the remainder resulting from natural soil degradation and various aspects of the urban climate. Dregs, supplements, natural, inorganic, and hazardous compounds originating from land use activities or potentially from the environment and transported to surface water bodies by storm overflow are all examples of NPS contamination (Afroz, Masud,Akhtar & Duasa, 2014). When the pace of these pollutants entering water bodies exceeds normal levels, NPS contamination is said to occur. Non-Point Source pollution usually includes:

- Fertilizers, insecticides, and chemical cleaning product runoffs from farms and neighborhoods are examples of nonpoint source pollution.
- Car leakage and urban runoffs produce oil, grease, and hazardous substances.
- Microbes and nutrients from washed animal feces, corpses, and septic systems that have been poorly constructed and managed.
- Rainfall that is acidic

2.5 Impact of Water Pollution on Health in Malaysia

Target 6 of the Sustainable Development Goals demands for universal and equitable access to safe, affordable drinking water. In 2020, 5.8 billion people will have access to safely treated drinking water, while the remaining 2 billion will not (WHO, 2022). At least 2 billion people throughout the world consume water that has been contaminated with feces. Microbial contamination of drinking water due to excrement contamination is the most serious health risk to drinking-water security. Infections such as cholera, diarrhea, hepatitis A, typhoid, and polio have been linked to contaminated and unsterilized water. People are at danger of becoming ill due to inadequate or inadequately treated water and sterilizing services (WHO,2022).

2.6 Water Treatment Plant (WTP) Design

Air Selangor uses conventional water treatment plants, which have two phases: primary and tertiary treatment. The main treatment method is used to remove most large particles and organic waste from the water supply. If different types of pollution are still present in the treated water after the first treatments, the tertiary treatment is used to remove such materials as a polishing unit (Moghaddam & Arami,2010). These treatments often include a combination of procedures such as coagulation, flocculation, sedimentation, filtration, and sanitization to ensure that customers are protected and receive safe and aesthetically pleasing drinking water (Randtke,2012). The following are the goals of the water treatment process:

- Improve the appearance of water by removing odor and color.
- Remove hardness of water
- Remove unsafe organisms that cause infections from consuming the water
- Remove cloudiness and turbidity of water
- Dissolved gasses present in water
- Ensure water is reasonable to be used for different purposes like drinking, industrial and as per demand

2.6.1 Primary Treatment

Material that will drift or settle out by gravity is removed during the primary treatment procedure. Screening, comminution, grit removal, and sedimentation are all part of the process (Randtke,2012).

2.6.1.1 Intake and Screening

Large drifting objects, such as leaves and sticks, are separated from the mechanical equipment and pumps using screens to prevent damage. Coarseness removers and finer cross section screens are used to remove small size particles (Drinan & Spellman,2000). Furthermore, the more successful the screening, the less maintenance for subsequent treatment units is envisaged. It is generally aerated as it passes through so that it can react to the surrounding air and release its scents. After the water passes through the screens, deposits that are more difficult to settle are sent to the coagulation stage.

2.6.2 Tertiary Treatments

Tertiary treatments are additionally named as advance treatment strategies. This practice explicitly eliminates an astounding amount of phosphorus, nitrogen, biodegradable natural matter, weighty metals, microorganisms, and viruses (Pescod,1992). There are abundant advanced treatment techniques that have been created including sanitization, and electrodialysis. The benefits and drawbacks of regular water treatment strategies alongside tertiary treatment have been accounted for in the table underneath.

Table 2.7: Advantages and Disadvantages of Coagulation and Disinfection

Technology	Advantages	Disadvantages
Coagulation	● Low Principal Cost ● Effortless Procedure	● Generating a large quantity of sludge
Disinfection	● Cost-effective and easily accessible ● Solubility in water is high. Pathogens are poisoned by it. ● During oxidation, there is the potential to remove a large amount of iron, manganese, and nitrogen.	● Corrosive ● Due to its toxic nature, CL2 gas is difficult to handle.

(Pescod,1992)

2.6.2.1 Coagulation

The water treatment process of coagulation is defined as the expansion of the propensity of small particles to attach to each other and link to surfaces, such as the grains of a channel bed. Many surface water supplies contain particles too small to consider settling out of arrangement on their own. These tiny particles typically carry a small negative charge, which allows them to repel each other like magnet comparative magnets. Chemical compounds will be used in water systems to destroy these charges, help the particles in adhering to one another, and become heavy enough to settle out of the tank (Pescod,1992).

To eliminate these tiny charges, a coagulant ingredient is injected, and then the water is swiftly mixed. The rapid blending spreads the coagulant and strengthens the bond between these tiny particles (Pescod,1992). The advantages and disadvantages of the coagulation process are summarized in the table below.

Table 2.8: Advantages and disadvantages of Coagulation

Advantages	Limitations
Better Effluent Quality	Costly due to wear and tear of electrodes
Ability for metals to be recovered from solution	Inconsistency as results could be affected by various factors ● Size of particles ● Setup of the electrode
Energy saving as only low level of current is required	Frequent maintenance to ensure fine-tuning is done.

2.6.2.2 Flocculation

The raw water will flow forward to a flocculation tank when the coagulant fast mix processes have been completed. The flocculation treatment technique aims to increase the size of the flocs to increase their ability to settle out (Pescod,1992). Flocculants are added to the water to improve the floc arrangement and increase the robustness of the floc structure. Further down the water treatment process chain, larger flocs will be able to settle out of the water more quickly.

2.6.2.3 Sedimentation

After the flocs are present, the water is transferred to the sedimentation tank, or clarifier. The goal of this phase is to reduce the number of solids in the water before it is sifted in the next step of the treatment.

Water is now passed through a clarifier or sedimentation tank, together with the flocs. The massive flocs will settle out of suspension due to gravity, clumping together to form slime that is sufficiently heavy to sink, allowing cleaner water to proceed into the next stage (Pescod,1992). Following this contact, a few residual particles remain, which can be separated in the next stage. There are four stages to this cycle. First, the stream's speed is reduced to the point where it is evenly dispersed in the sedimentation tank. The next zone is used for settling; the water's speed has significantly slowed, and the suspended particles can be settled here. The third stage involves a smooth transition of water from the sedimentation tank to the filtering chambers, followed by the sludge zone, where the settled solids are gathered and removed. Clarifiers will be equipped with rakes to gather sludge and remove it from the clarifying tank on a regular basis. The method's advantages and disadvantages are listed below:

Table 2.9: Advantages and Limitations of Sedimentation

Advantages	Limitations
● Simple Method ● Precise Results ● Standardized procedures	● Tiny particles would cause accuracy issues

(Pescod,1992)

2.6.2.4 Filtration

The water will be sifted progressively through fine sand-like material in layers to remove any undesired particles, which could be a mixture of suspended organic and inorganic particles such as fine residues and debris, or microbes and growths (Pescod,1992). Filtration will remove these microorganisms, as well as any other suspended matter that has not settled out yet.

When filtration is done correctly, the weight on the sterilizing process is greatly reduced, increasing the sterilization interaction's efficacy. Because the water source originates from streams, additional disinfection techniques, such as chlorination disinfection, can and will be used.

2.6.2.5 Chlorination Disinfection

Chlorination is just one of the many methods for sanitizing water. The primary goal of this chlorine process is to clean the water and maintain the chlorine residuals that will remain in the water as it passes through the distribution system to consumers (Pescod,1992). It is a type of compound sterilization practice that uses various types of chlorine or chlorine-containing substances to oxidize and disinfect the consumable water source. It inactivates microorganisms by damaging their cell membranes. When the cell layer is compromised, chlorine can enter the cell and disrupt cell respiration and DNA activity.

Table 2.10: Advantages and Limitations of Chlorination Disinfection

Advantages	Limitations
● Longer residual disinfectant ● Cheap and easy to be used ● Not form excess amount of disinfection by-product	● Proper Safety precautions need to be complied

2.6.2.6 Water Softening

Water softening is the process of softening hard water. Because of the presence of particles, water from rivers contains hardness. The hardness of the water prevents it from producing foam and causes problems in the pipe's framework (Pescod,1992). It even affects the flavor of water, and food prepared with hard water usually tastes extremely rubbery. As a result, the hardness removal method is as follows:

1. Dosage of Lime

2.6.2.6.1 Lime Dosing

One of the most common methods for reducing water hardness is the lime-soft drink water softening approach. This reaction necessitates a huge amount of lime (CaO), which is added to the hard water tank alongside the super-heated steam. Salts in water interact with chemical compounds. In a sedimentation tank, the reactive products are precipitated as carbonates and hydroxides as sludge (Pescod,1992). The sludge output is where you can get the shaped sludge. Aside from that, the cleaned water is sent via a sand screen into the sedimentation tank. To remove the suspended sludge particles, the soft water interacted with varied measured sand particles that were accessible in a sand channel.

2.6.2.7 Fluoride Dosing

The correct amount of fluoride should be added to water in most treatment plants. Fluoride is typically added to the water supply to reduce the rate of tooth cavities. For fluoridation of drinking water, three typical chemical compounds are used: hydrofluorosilicic acid (H2SiF6), sodium silicofluoride (Na2SiF6), and sodium fluoride (NaF)(Pescod,1992). The goal is to maintain a consistent fluoride level in the water treatment plants that meets the Ministry of Health's fluoride criteria of 0.7 - 1.0ppm. This is the amount recommended by the Ministry of Health and the World Health Organization to prevent tooth decay.

CHAPTER 3: METHODOLOGY

3.1 Study areas

Selangor is Malaysia's most densely populated state, home to the Klang Valley, the country's largest conurbation (DOSM, 2015). Selangor is home to over 6.56 million people, accounting for nearly 21% of Malaysia's population as of Quarter 2021. Selangor's geological location, in the heart of Peninsular Malaysia, is a major element in the state's rapid rise to prominence as Malaysia's transportation and industrial hub. This attracts many investors, resulting in many jobs and attracting visitors from many states as well as from abroad, mainly from Indonesia, the Philippines,Vietnam, Myanmar, and Bangladesh. Attributed to the growing urbanization and a large population residing in Selangor, it is vital that the state's water assets be continuously managed to ensure that everyone has access to clean water. Air Selangor primarily obtained water from two river basins, the Selangor and Langat rivers, for treatment and distribution throughout Selangor, Kuala Lumpur, and Putrajaya (Air Selangor, 2022). Thewater source for each region is depicted in the diagram below, which comes from either the Selangor or the Langat rivers. As a result, the focus of this study will be on the selected Langat River basins.

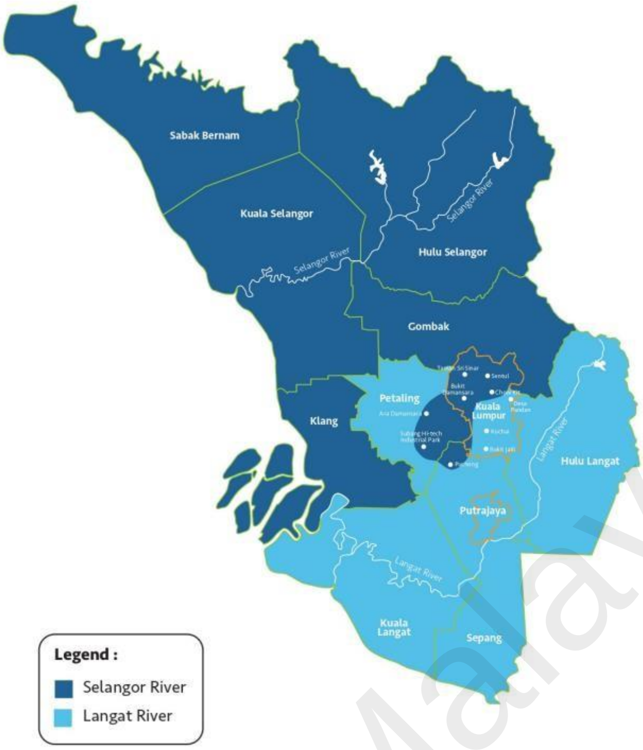

Figure 3.1 Selangor River Basins (Air Selangor, 2022)

3.1.1 Langat River

The Langat River Basin is located around 27 kilometers south of Kuala Lumpur and comprises 2,423 square kilometers, making it Selangor's second largest river basin. It flows for approximately 200 kilometers from the Titiwangsa Range in Gunung Nuang to the Straits of Melaka. Kuala Langat, Klang, Sepang, and Hulu Langat are the four districts along which the river Langat flows (State of the river report 2015; Langat River, 2017). The Langat River basin is located at latitude 02°50' 48" N and longitude 101°40' 48" E, with the highest peak being 820.8 m (2691 ft) above sea level. The river can offer roughly 1,000 million liters per day (MLD) of drinkable water, which is nearly 30 percent of both Kuala Lumpur and Selangor's total water supply requirements. The river's upstream portion is mostly in the Hulu Langat district, where forest cover accounts for 45.63 percent of the total land area. Built-up area and farmland accounted for 29.42% and 24.64 percent of the remaining land, respectively. The river's midstream flows through the

Putrajaya district, which is a commercialized and built-up area that takes up 93.47 percent of the land, with the remaining land set aside for tourism purposes to attract visitors to the Putrajaya Lake and Wetlands Park (State of the river report 2015: Langat River, 2017). The river's lower reaches flow through the Sepang district, where farmland and built-up areas account for 41.68 percent and 41.27 percent of the district's land use area, respectively. Water bodies account for 12.51% of the remaining land use, while forest land accounts for 4.54% (State of the river report 2015: Langat River, 2017). Before reaching the Malacca Straits, the river will pass through the Kuala Langat district, where agriculture accounts for 59.12 percent of the area. The built-up area comes in second at 24.93 percent, followed by the forest at 10.37 percent, and water bodies at 5.58 percent (State of the river report 2015: Langat River, 2017).

Figure 3.2 Langat River Basin

3.2 Data Collection and Monitoring Stations

Since roughly 1978, the Department of Environment (DOE) has been conducting the Water Quality Surveillance Program for Rivers. Beginning in 1995, the program was expanded to include a section of the country's major streams. As a result, to obtain current and historical water quality data for the Langat River, we requested the most recent 5 years of data for both rivers from 2016 to 2020 to assess trends and historical water quality data for 9 parameters, including ammonia nitrate, BOD, COD, dissolved oxygen, pH, suspended solids, and water quality index. We have requested three rivers from the Langat River Basin: the Langat River, the Semenyih River, and theLabu River. A total amount of data from 16 different stations had been given from DOE from 2016 up until 2020. Samplings were taken every 2 months consistently from 2016 up until 2020 from morning until noon. Table below summarizes the 16 stations latitude, longitude, ID station and location.

Table 3.1 Monitoring Stations Along Langat River Basin

Station No.	ID Station	Latitude	Longitude	Location
1	1LO1	2.87611	101.451639	Sg. Buaya
2	1L02	2.815335	101.512831	Telok Datok
3	1L03	2.855499	101.681547	Dengkil
4	1L04	2.96141	101.783797	Jalan Reko
5	1L05	2.993079	101.785532	Tabung Haji Kajang
6	1L07	3.167259	101.850525	Jambatan Gantung
7	1L08	2.787198	101.751546	Labu Lanjut
8	1L09	2.892121	101.749958	Bukit Unggul
9	1L10	2.946371	101.847649	Petronas Semenyih
10	1L11	3.008812	101.86893	Kg. Pasir Nirvana
11	1L15	3.040719	101.77367	Maybank Cheras
12	1L16	3.111312	101.816819	Balai Polis Bt 14 Hulu Langat
13	1L24	2.78164	101.798345	Jalan Kubur KTM
14	1L26	2.7872	101.701531	Jalan ke F1

15	2BLGT030	2.813262	101.642225	Jambatan Lama Bukit Changgang
16	2BLGT002	3.047051	101.776908	W.Intake Cheras sebelah toll saga

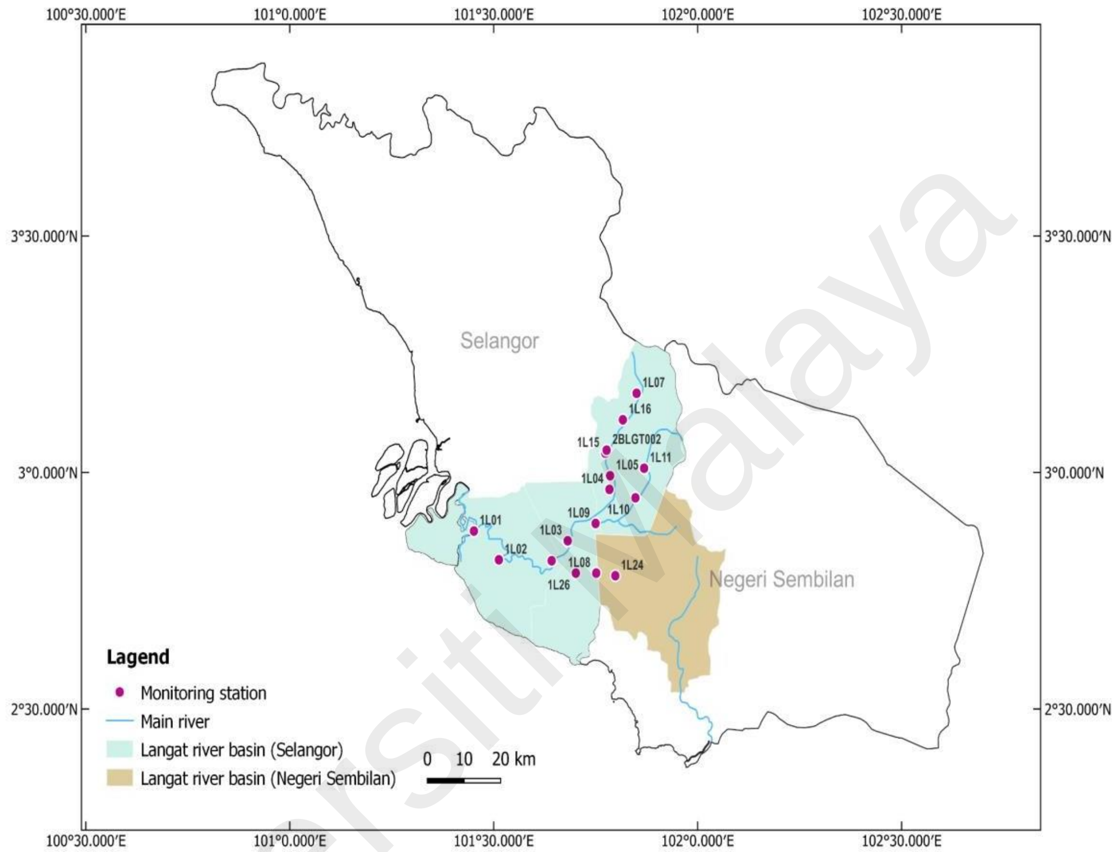

Figure 3.3 Location of river water quality monitoring sites

3.3 Data treatment

For data treatment, the water quality data was transferred from Microsoft Excel to Python. Python was used to aid for this statistical analysis due to the large number of selections of pre-built libraries which includes data processing and data visualization. Initially, the main thing that we did for data treatment is data cleansing as in data cleansing, we:

1. Validate data using correct data types and formats
2. Treat incomplete or blank values

3. Check and remove outliers

Box and whisker plot was chosen to visualize the data distribution for all the parameters to indicate whether the distribution is skewed or not and if there are potential unusual observations (also called outliers) present in the data set (Statistics Canada, 2021). For data that are:

Smaller than lower bound = lower_bound = Q1 - 1.5*IQR

And

Larger than upper bound = upper_bound = Q3 + 1.5*IQR

They are called outliers and are being removed from the original data. Illustration below represents how the box plot operates (**Figure 3.4**).

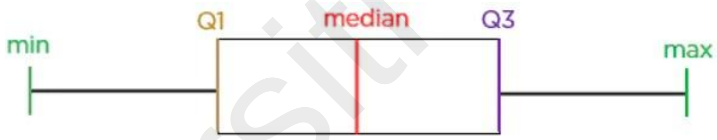

Figure 3.4: Box and Whisker Plot

- Median (Q2/ 50th percentile): The middle value of the dataset
- First Quartile (Q1): The 25th percentile of the dataset
- Third Quartile (Q3): The 75th percentile of the dataset
- IQR = Q3 - Q1

After removing the outliers, we then proceed with standardization technique as it is a scaling technique where it transforms the data to a scale-free format by converting the statistical distribution of the data into the below format:

$$z = \frac{x - \mu}{\sigma}$$

3.4 Hierarchical clustering analysis

Clustering is a technique for organizing large amounts of unstructured data. It entails assembling and categorizing a variety of data that is like one another. These groups are known as clusters, and they are formed based on how similar the data or the set metric characterized are (Bock, 2022).

The methodology we are using is the agglomerative clustering technique, which is a base up hierarchy generator that accepts all data as discrete groups and then consolidates them two at a time in each iteration (Johnson,1967).

The generation and analysis of a dendrogram is the only idea behind hierarchical clustering. A dendrogram is a tree-like structure that explains the relationship between all of the data points of importance in the framework, and it is often regarded as the most perfect method to view the hierarchy (Bock, 2022). The Euclidean dissimilarity metric and Ward's linkage algorithm were used to cluster sixteen observing stations based on their water quality index (WQI).

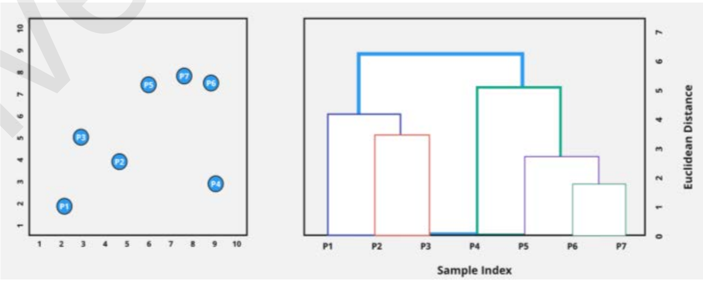

Figure 3.5: Hierarchical Clustering Dendrogram Example

3.5 Principal Component Analysis

PCA, or Principal Component Analysis, is a dimensional reduction approach that is frequently used to reduce the dimensionality of large informative data sets by converting a complex set of variables into a smaller, simpler set that contains the majority of the data in the larger set. (Li, 2019) (Abdi & Williams,2010). The purpose of using it is to determine which boundary is more important in contributing to contamination. To execute PCA, we went through the following five steps:

1. Creating a set of initial variables that are all the same.
2. Separate connections using the covariance matrix
3. Separate the relevant components using the covariance matrix's eigenvectors and eigenvalues.
4. Create an element vector to help you decide the main sections to preserve.
5. Recast the information along the principal component’s axes.

3.6 Mann-Kendall Trend Test

A Mann-Kendall Trend Test is a non-parametric test that we used to see if there was a pattern in the data (McLeod,2005). To detect and analyze the meaning of a pattern, we used Mann-Kendall trend tests. The Mann-Kendall trend test was used to distinguish the pattern of water quality data at Langat River in this study. The link between the parameters and their time series is crucial to the test. After that, the results of the Mann-Kendall patterns test are deciphered.

DATA COLLECTION FROM DOE

Data that was collected by DOE from 16 sampling stations across the Langat River were requested from 2016-2020 for 9 parameters

↓

DATA CLEANING

Raw sampling data from the 16 stations were treated to filter incomplete values, to check and remove outliers, to calculate the mean, standard deviation, range, and interquartile range for each parameter based on stations.

↓

DATA ANALYSATION

Hierarchical Clustering Analysis was done to identify distinct clusters within monitoring stations and to illustrate using Dendrogram to present clusters and proximity.

Principal Component Analysis/Factor Analysis was done to identify which parameter is most significant in contributing to pollution.

Man-Kendall Trend test was done to visualise the trend for parameters

↓

EFFECTIVE WATER RESOURCE MANAGEMENT

Recommendations and standard operating procedures are being implemented to prevent the threats from rapid expansion and business districts to ensure the sustainability of water assets and river basin management.

CHAPTER 4: RESULTS & DISCUSSION

4.1 River Water Quality

Data on river water quality from 2016 to 2020 was examined using a total of 2,212 samples collected by DOE. DO, BOD, COD, SS, pH, Ammonia-Nitrate, and the WQI were the seven metrics studied. The 5th and 95th percentiles, respectively, represent the range of least and greatest values in the table below. Aside from that, **Table 4.2** shows the mean for each station throughout the course of five years of data. The Engineering Services Division of the Ministry of Health Malaysia (MOH) defined the recommended raw water quality, as well as the NSDWQS river water quality requirements (Appendix).

Table 4.1 Standard for water quality

Reference	pH	DO mg/L	BOD mg/L	COD mg/L	SS mg/L	NH3-N mg/L	WQI
Water Quality Index (Class III – Extensive treatment required)	5-6	3-5	3-6	25-50	50 - 150	0.3- 0.9	51.9 - 76.5
National Standard for Raw Water Quality Malaysia	5.5 – 9.0	-	6.0	10.0	-	1.5	-

Table 4.2 Descriptive statistics of water quality constituents in Langat River basins

Stations		pH	DO mg/L	BOD mg/L	COD mg/L	SS mg/L	NH3-N mg/L	WQI
1 (1L01)	Range	6.45-7.42	2.59-5.37	2.9-9.3	11.8-31.3	26.5-246.6	0.277-2.017	60.83-76.05
	Mean	6.82	4.13	5.62	21.86	112.71	0.74	69.70
2 (1L02)	Range	6.53-7.42	2.97-5.37	2-9.3	12.85-31.3	35.65-246.6	0.476-2.017	53.7-76.05

	Mean	6.99	4.31	6.55	25.6	102.3	1.61	65.54
3 (1L03)	Range	6.59-7.54	4.91-6.73	2.05-9.95	12.1-34.95	37.55-279.15	0.24-3.13	61.05-81
	Mean	7.12	5.92	5.95	21.72	132.36	1.44	72.3
4 (1L04)	Range	6.67-7.57	3.70 - 6.06	3.7-12.3	16.1-42.6	43.4-259.2	0.437-3.36	55.7-78.3
	Mean	7.06	5.07	8.2	30.27	106.27	1.97	65.6
5 (1L05)	Range	7.02-7.70	3.83-6.53	3.55-11.45	14.1-43.05	20.5-247.15	0.52-2.89	56.83-77.9
	Mean	7.34	5.11	7.42	26.33	100	1.85	66.98
6 (1L07)	Range	7.11-7.82	7.25-8.99	2.15-10.55	7.3-39.2	4-59.55	0.003-0.15	81.6-93
	Mean	7.50	8.26	4.83	17.38	23.58	0.070	88.98
7 (1L08)	Range	6.60-7.42	5.19-6.92	2-9	11.85-27.5	21.85-110.65	0.42-3.43	63.34-81.45
	Mean	7.06	6.22	5.22	19.28	65.72	1.89	74.06
8 (1L09)	Range	6.43-7.82	4.88-7.25	2-9	10.5-32.75	54.5-289.75	0.12-1.04	67.35-84.75
	Mean	7.10	6.28	5.08	19.62	148.38	0.54	76.62
9 (1L10)	Range	6.81-7.42	5.95-7.89	2.85-5.6	10.85-24.4	49.7-336.75	0.12-1.04	71.9-85.15
	Mean	7.08	6.97	4.22	17.28	138.72	0.62	79.07
10 (1L11)	Range	6.80-7.84	6.85-8.42	2.95-10.05	9.95-40	43.4-225.95	0.049-0.43	73.62-86.05
	Mean	7.36	7.79	4.8	18.4	116.7	0.303	81.49
11 (1L15)	Range	6.82-7.80	4.31-7.55	2-12	15-33.5	29-265	0.25-3.49	62.58-85
	Mean	7.19	6.35	6	22.46	127.85	1.63	72.57
12 (1L16)	Range	6.96-7.89	7.16-9.19	2.05-8.9	8.1-25.95	5-80.65	0.021-0.28	80.96-93.85
	Mean	7.47	8.19	4.23	15.5	34.09	0.13	87.84
13 (1L24)	Range	6.65-7.64	6.78-8.49	2-7.5	10.9-36.3	12.8-167.6	0.038-0.244	79.63-91
	Mean	7.18	7.35	4.42	18.42	51	0.12	86.87

14 (1L26)	Range	6.47-7.51	4.08-7.02	2-12	11.85-35.2	29.75-140.3	0.24-022	64.72-79.05
	Mean	7.01	5.65	5.59	20.64	80	1.31	72.98
15 (2BLGT 030)	Range	6.99-7.58	4.31-7.48	2-9	12.8-29.6	31.3-236.8	0.33-3.14	61.6-86.3
	Mean	7.18	6.37	5.42	21.84	119.53	1.60	73.17
16 (2BLGT 002)	Range	6.44-7.40	4.35-6.51	2.55-7.9	15.55-35.8	36.55-265.05	0.249-3.10	62.55-78.45
	Mean	6.97	5.62	5	21	138.83	1.55	71.75

Information:

Best
Good
Moderate
Bad
Worst

Living organisms are affected by pH. When pH falls below 4 or exceeds 10 and remains there for an hour or more, most sea-going organisms will die. Even though oceanic organic entities experience a wide range of pH, the ideal pH for their health is between 6 and 9 (Hounslow,2018). As a result, it's critical to monitor pH on a regular basis, as anything below or above the recommended range has an evident impact on the customer's long-term health. Furthermore, if the water is extremely acidic, it may scrap metals from the pipelines that carry the water, making it dangerous and containing heavy metal. In any event, according to the table above, the lowest pH (5th percentile) is 6.43 and the highest (95th percentile) is 7.89 at each of the stations. As a result, assuming that the pH for each station is between Class II and Class I according to the WQI, and that it is within the acceptable and indicated range, it is safe to be used as water supply after conventional treatment.

Dissolved oxygen (DO) is a measure of how much vaporous oxygen is present in a given volume of water. DO should be present in high-quality water that can sustain life. Estimating DO in water and treating it to maintain legal DO levels are important job responsibilities that must be addressed carefully in water treatment applications. This is because, while DO is beneficial to life and treatment processes, it can also be harmful, generating oxidation that damages equipment, hardware, and end products. Aside from that, DO concentration determines the source water's type. Water that lacks sufficient DO becomes filthy, affecting the aquatic water system, drinking water, and other objects. According to the table above, only two stations (1 and 2) have a mean of 4.13 mg/L and 4.31 mg/L, respectively, putting them in class III of the WQI classification. Regardless of whether they are within the allowed range for water treatment plants, they will undergo extensive treatment to ensure that they are safe to drink for human consumption. The remaining 14 sites have shown superior observational results, with 10 stations classified as class II, requiring conventional therapy, and the remaining four classified as class I, implying that no treatment is necessary.

Biochemical oxygen demand (BOD) is a significant limit in water treatment. High organism concentrations can reduce the amount of oxygen in water, resulting in detrimental ecological repercussions. BOD is a fundamental parameter that aids in the estimation and helps with determining the effect. Three monitoring stations indicated an unacceptable range based on observation, as they all exceeded the raw water quality for BOD at 6.0 mg/L with a mean of 6.55 mg/L (Station 2), 8.2 mg/L (Station 4) and 7.42 mg/L (Station 5), putting them in class IV. Inadequate treatment of sewage or effluent from agro-based and manufacturing enterprises can cause high BOD levels (State of the river report 2015: Langat River, 2017).

The chemical oxygen demand (COD) is the amount of oxygen required to oxidize all soluble and insoluble organic molecules in each volume of water. High COD in water indicates higher levels of oxidizable organic matter and, as a result, a lower DO value. Worse, a decline in DO because of natural pollution may result in the extinction of oceanic life. Three stations (stations 2, 4, and 5) were classified as class 3 from the samplings, while the remainder were classified as class 2. Regardless, all the stations that had a concentration greater than 10 mg/L failed to meet the NSRWQ standards. Which indicates that a thorough treatment shall be made which could cause stress to the WTPs the study region's high COD level focuses on hazardous water contamination.

The presence of suspended solids (SS) indicates the quality of the water. The number of suspended solids indicates how cloudy the water is. It is mostly concerned with wastewater because it directly influences the cost of water treatment. Station 6 was classified as class I, while station 12 was classified as class II, and the remaining 14 stations were classified as class III. Because there are no suggested raw water quality standards, the WQI standards serve as a substitute. What can be asserted is that improper earthworks and land clearing efforts were responsible for a major number of the SS hotspots.

Ammoniacal nitrogen (AN) is a measure of how much ammonia is present in a sample. Animal farming and domestic sewage are two of the most common sources of AN. As a result, the health of water bodies was monitored since high levels of ammonia can be fatal. According to observation, a major number of the monitoring stations are heavily contaminated with AN, as nine observing stations are classified as class 4, which is only suitable for irrigation. Despite being classified as a class IV station, two of the stations meet the NSRWQM limit of less than 1.5 mg/L. As a result, the remaining 7 stations are classified as Class IV and do not meet NSRWQM requirements.

The WQI could now be calculated using all six boundaries. WQI is a single number that indicates the general water quality at a certain location and time based on a few water quality thresholds. Based on the calculations, eight stations were classified as class III, implying that extensive treatment is required. 1 (69.70), 2 (65.54), 3 (72.3), 4 (65.6), 5 (66.98), 7 (74.06), 11 (72.57), 14 (72.98), 15 (73.17), and 16 (73.17). (71.75). The remaining 6 monitoring stations are designated as class II, indicating that a standard treatment will be sufficient. 6 (88.98), 8 (76.62), 9 (79.07), 10 (81.49), 12 (87.84), and 13 (87.84) are the class II stations (86.87).

4.2 Spatial variation among 16 stations

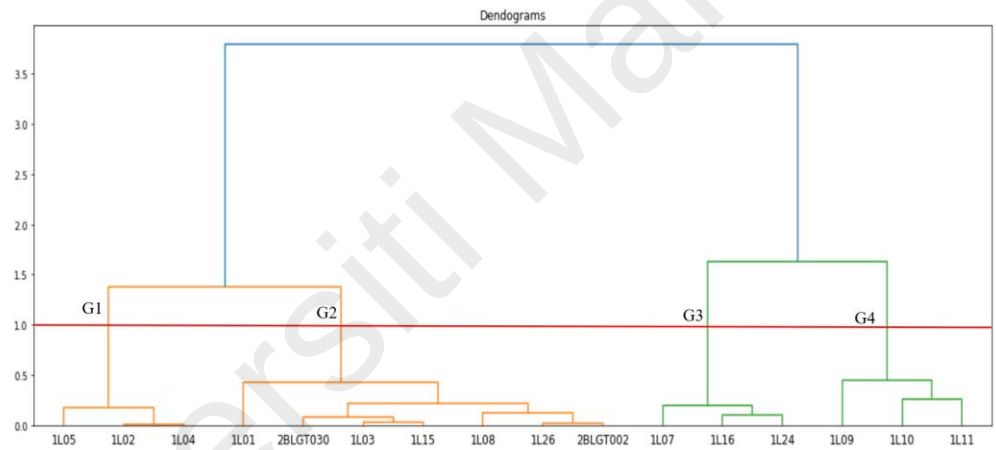

Figure 4.1 Dendrogram Plot Showing clusters

Figure 4.1 shows a dendrogram that visually depicts a certain cluster formation. Near the right side of the plot, columns that are close together (have a modest dissimilarity) will be linked. We noticed that Station 1L02 and Station 1L04 are remarkably similar, for example.

By drawing a vertical line at a certain Cluster Cut-off value and counting the number of lines that the vertical line contacts, the number of clusters that will develop at that value may be readily calculated from this plot. We've drawn a vertical line at 1.0 for discussion, resulting in four groups. Three clusters will have three stations each, while the other will have seven.

Table 4.3 Clusters and Stations

Cluster	ID Station
1 (High Pollution)	2 (1L02)
	4 (1L04)
	5 (1L05)
2 (Moderate Pollution)	1 (1L01)
	3 (1L03)
	7 (1L08)
	11 (1L15)
	14 (1L26)
	15 (2BLGT030)
	16 (2BLGT002)
3 (Least Pollution)	6 (1L07)
	12 (1L16)
	13 (1L24)
4 (Low Pollution)	8 (1L09)
	9 (1L10)
	10 (1L11)

Cluster 1 (stations 2,4 and 5) deals with significant contamination from the Langat river basin, Cluster 2 (stations 1,3,7,11,14,15, and 16) with moderate contamination, Cluster 3 (stations 6,12 and 13) with the least contamination, and finally Cluster 4 (stations 8,9 and10) with low contamination. What can be deduced from these clusters is that each group has similar constituent characteristics and, as a result, will be impacted by similar land use practices and contamination sources.

Stations 2,4, and 5 are part of Group 1, and are located near Telok Datok, Jalan Reko, and Tabung Haji Kajang, respectively. Cluster 1 has the second longest Euclidean distance, suggesting that the land usage is completely different when compared to the other clusters. Cluster 1 has the appearance of being a densely populated residential and business area. Telok Datok, which has a population of roughly 48,240 people, also has a lot of industry located adjacent to the monitory station (State of the river report 2015: Langat River, 2017).

Group 3, which consists of stations 6, 12, and 13, should be able to see the longest Euclidean distance. The three locations are mainly covered by forest and palm oil estate, according to observation. The business and local location are small since they are not well established, and the primary feature is that they are located in the upstream section of their respective stream basins (State of the river report 2015: Langat River, 2017).

Group 2 has the most monitoring stations, at seven. According to common observation, the observing stations are in the middle of their respective waterway basins, with a substantial percentage of the regions consisting of relatively populated business and residential areas. Some of the stations, such as stations 1 and 15, are located near palm oil plantations (State of the river report 2015: Langat River, 2017).

The results demonstrate that HCA provides data that might be useful for key parties to review the determination of areas for monitoring location enhancement, particularly group 2. The cost of examining could be minimized and reduced by reducing the number of stations (Juahir et al.,2011). This grouping technique has also been shown to provide reliable surface water characterizations across a variety of stream basins around the state.

4.3 Pollutant Source Apportionment

Table 4.4 Descriptive Statistics

	Mean	**Std. Deviation**	**Analysis N**
DO	.00000	1.001586	316
BOD	.00000	1.001586	316
COD	.00000	1.001586	316
SS	.0000	1.00159	316
NH3	.0000	1.00159	316

Table 4.5 Correlation Matrix

Correlation	DO	BOD	COD	SS	NH3
DO	1.000	-.327	-.355	-.187	-.507
BOD	-.327	1.000	.787	.208	.310
COD	-.355	.787	1.000	.239	.329
SS	-.187	.208	.239	1.000	.147
NH3	-.507	.310	.329	.147	1.000

Table 4.6 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.652
Bartlett's Test of Sphericity	Approx. Chi-Square	473.23
	df	10
	Sig.	.000

Prior to PCA, the Bartlett test of sphericity and the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (often referred to as the MSA) were used. The Bartlett Test of Sphericity compares the correlation matrix to a matrix of zero correlations (officially referred to as the identity matrix, which contains all zeros save the ones along the diagonal). The Kaiser-Meyer-Olkin Measure of Sampling Adequacy ranges from 0 to 1, with higher values indicating better sampling. A minimum value of 0.6 is recommended (Shreshta,2021).

We can see from the table above that we have good values for all variables for the MSA, but the total value is a little low at 0.652; nonetheless, Bartlett's Test of Sphericity has an associated P value of 0.001 because by default SPSS presents p values of less than 0.001 as 0.000, which suggests that we may now continue and perform a valid factor analysis based on the above results. Except for SS, which is lower than we would prefer, all communalities imply that the combined two components explain 70% or more of the variance in each variable.

Table 4.7 Communalities

Correlation	Initial	Extraction
DO	1.000	.744
BOD	1.000	.843
COD	1.000	.854
SS	1.000	.201
NH3	1.000	.763

Table 4.8 Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.431	48.625	48.625	2.431	48.625	48.625	1.891	37.820	37.820
2	.975	19.504	68.129	.975	19.504	68.129	1.515	30.309	68.129
3	.890	17.803	85.933	-	-	-	-	-	-
4	.491	9.824	95.757	-	-	-	-	-	-
5	.212	4.243	100.000	-	-	-	-	-	-

The variation explained by each component, as well as the total variance explained by all components, is reported in the table above. The amount of variance described by the component in the complete set of variables is referred to as the variance explained (s). Component 2 in the item's variance-covariance matrix, for example, explains 19.504 percent of the variance. We might also argue that the two retrieved components explained 68.129 percent of the variation in our items.

Figure 4.2 Scree Plot

The eigenvalue is graphed against the component number in the scree plot. The values in the first two columns of the table immediately above can be seen based on the plot. The line becomes practically flat after the third component, indicating that each succeeding component accounts for a smaller and decreasing proportion of the total variance. We're only interested in keeping principal components with eigenvalues bigger than 0.95 in general. Hence only components 1 and 2 are further studied.

Table 4.9 Component Matrix

Parameter	Component	
	1	2
DO	-.680	.531
BOD	.818	.418
COD	.838	.391
SS	.415	.170
NH3	.653	-.580

Table 4.10 Rotated Component Matrix

Parameter	Component	
	1	2
DO	-.216	-.835
BOD	.903	.166
COD	.902	.200
SS	.433	.118
NH3	.165	.858

Table 4.11 Component Transformation Matrix

Component	1	2
1	.793	.609
2	.609	-.793

The loadings of the five variables on the two extracted factors are shown in the table above. The more the factor contributes to the variable, the higher the absolute value of the loading. We extracted two variables from the five questions, dividing them into two categories based on the most essential items that had similar replies in components 1 and

2. The loadings values of less than 0.5 imply that they do not contribute significantly to the variables. As a result of the need for precise computation of each factor component, the table above shows that cross loading exists. Because the cross-loading is so significant, these cross-loadings must be removed to obtain more accurate findings. The answer is to rotate the component matrix to redistribute the factor loading, and then check the rotated component matrix for component identification.

The goal of rotation, on the other hand, is to limit the number of factors on which the variables under inquiry have large loadings. Rotation has no effect on the analysis itself, but it does make it easier to read. We can observe from the table above that NH3 is heavily loaded on Component 2. BOD and COD, on the other hand, are heavily loaded on Component 1. Variable loading can occur on two or more components at times. As a result, it is necessary to check the factor loading value. If one of the components has a value greater than the required value of 0.5, that variable may be considered for further investigation. As in the table above all variables can be considered for further analysis.

By merging a few constituents into essential variables, the PCA/FA analysis resulted in a significant reduction in information. BOD, COD, and NH3 were the significant indicators that engaged with river water contamination for all the monitoring sites, according to the analysis. We discovered that high BOD can be attributed to inadequate sewage or effluent treatment from agro-based and manufacturing industries, whereas the primary sources of AN could be linked to animal farming and domestic sewage, which added to the pollution sources in the study region (State of the river report 2015: Langat River, 2017).

4.4 Water Pollution threat to safe water supply and its trend

From 2012 until 2020, WTPs inside the Sungai Langat basin experienced closures for stretched out time frames because of water disturbances. A portion of the notable incidents are:

- In 2012 and 2013, Cheras Batu 11 intake halted their operation for 10 hours and 15 hours individually because of diesel spillage. (State of the river report 2015: Langat River, 2017).
- In 2014, Cheras Batu 11 and Bukit Tampoi intake needed to close down tasks for a lengthy time of 1,278 and 1,271 hours individually because of elevated degrees of pH and ammonia as well as diesel spillage and scent. (State of the river report 2015

  : Langat River, 2017).
- In 2015, Sungai Pang soon admission needed to close down intake for five hours due to elevated degrees of turbidity. In like manner, the intake at Cheras Mile 11 halted tasks for 9 hours because of diesel spillage. Bukit Tampoi intake additionally shut down for 145 hours due to high levels of ammonia. (State of the river report 2015: Langat River, 2017).
- In 2016, toxic contamination in the Langat River basin caused the closure of Semenyih River WTP. Later, the Sungai Semenyih Water Treatment Plant was likewise closed on 22 September after authorities confirmed raw water contamination in the plant (Fong, 2016).
- In 2018, Sungai Semenyih WTP needed to undergo maintenance that caused 3 days of scheduled water cuts during the month of October (Amry & Miscon, 2018).
- In 2019, odor pollution was identified along the Sungai Semenyih and its tributaries that caused Sungai Semenyih WTP to be fully shut down (New Straits Times, 2019).

- In 2020, water treatment plants in Semenyih and Bukit Tampoi were shut down due to odor contamination from the Nilai Industrial Estate in Negeri Sembilan, which entered Sungai Semenyih from Sungai Batang Benar (Zainal, 2020).

According to the Ministry of Water, Land and Natural Resources (KATS), Selangor was the No. 1 state in the country in terms of the number of "unscheduled water" supply interruptions from 2014 to 2017 (Lim, 2019). When compared nationwide in 2014, Selangor's "unscheduled" water cuts hit 84,796 of 174,997 (48.45 percent) cases, 81,969 of 167,055 (49 percent) cases in 2015, before a considerable decline in 2017. (19,061 of 61,517 or 31 percent). Selangor also came in last in terms of "planned" water cuts, with 2,256 events in 2014, 1,760 incidents in 2015, and 798 incidents in 2017 (Lim, 2019).

As a result, data from DOE's monitoring program was used in this study to create a5-year trend. The M-K test was used to uncover patterns in the water quality boundaries of concern from three perspectives: nutrient (ammonia-nitrate), organic (BOD and COD), and sediment (SS). Where numerous closure incidents had occurred, the trends for all water monitoring stations were reviewed and analyzed. The outcomes of the M-K test pattern are presented in the table below.

Table 4.12 Mann Kendall Trend Test

Variables	Trend	z-value	p-value
Ammonia	No trend	0.4800	0.6311
Nitrate	No trend	-1.2984	0.1941
BOD	Increasing	11.2927	0.0000
COD	Increasing	5.6698	0.0000
Suspended Solids	No trend	1.2862	0.1983

4.4.1 Ammonia Nitrate

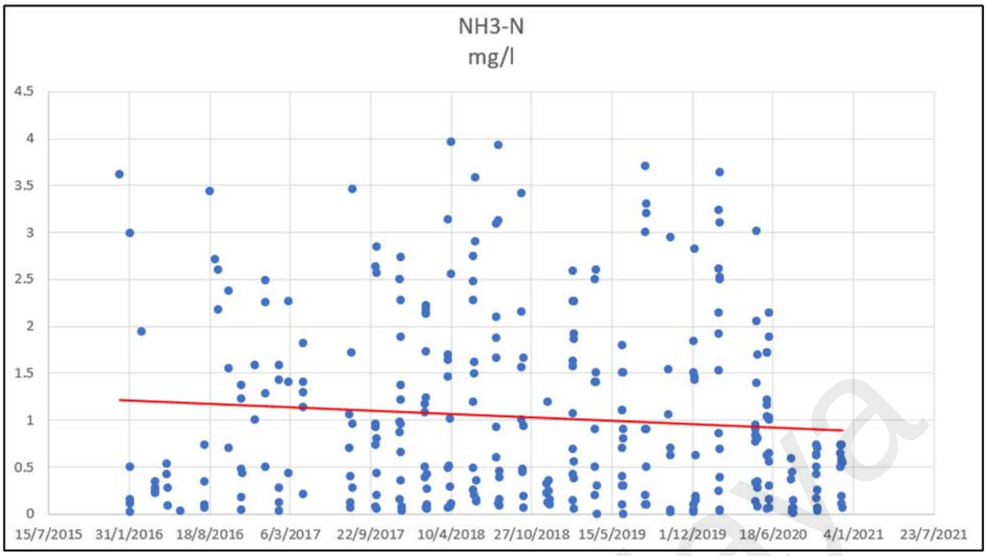

Figure 4.3 Time- Series trend of ammonia nitrate for Langat River Basin

The M-K test (Table) revealed that the AN border had no pattern, a z-value of 0.48, and a p-value of 0.63. As a result, one can conclude that the M-K test does not reveal any significant patterns. As a result, a regression line was used to determine the pattern for the AN boundary. When a period series pattern was plotted, the regression line revealed a modest decrease from 2016 to 2020. According to AN, the number of clean streams increased from 211 in 2019 to 239 in 2020. AN's improvement of stream water quality can be linked to a reduction in sewage discharge into the environment, both treated and untreated. AN's improvement of stream water quality is linked to a reduction in sewage discharge into waterways, both treated and untreated (Ref). Similarly, the executions of the Movement Control Order (MCO) turned out to be a surprisingly positive outcome as Langat's WQI has decreased slightly (Goi, 2020).

4.4.2 BOD and COD

Only two variables, BOD and COD, have significant tests with p values less than 0.05, as seen in the table above, and the tendency is increasing. Pollution levels are skyrocketing as the world becomes more industrialized. Large amounts of wastewater are generated in factories. Paper mills and food processing plants are two businesses that generate large amounts of wastewater. Surface runoff, floating debris, dead animals and plants, soil erosion, and other environmental variables all contribute to an increase in BOD. Along the Sungai Langat, many livestock farms, notably pig farms, can be seen, with direct discharge from the farms badly impacting coastal mangroves. Despite standards stating that swine farms should treat wastewater in three treatment ponds before discharging it, some farms are still not following best practices (State of theriver report 2015: Langat River, 2017). Worse, there have been allegations of odors arising from the excessive concentration of pigs in a small facility.

4.4.3 Suspended Solids

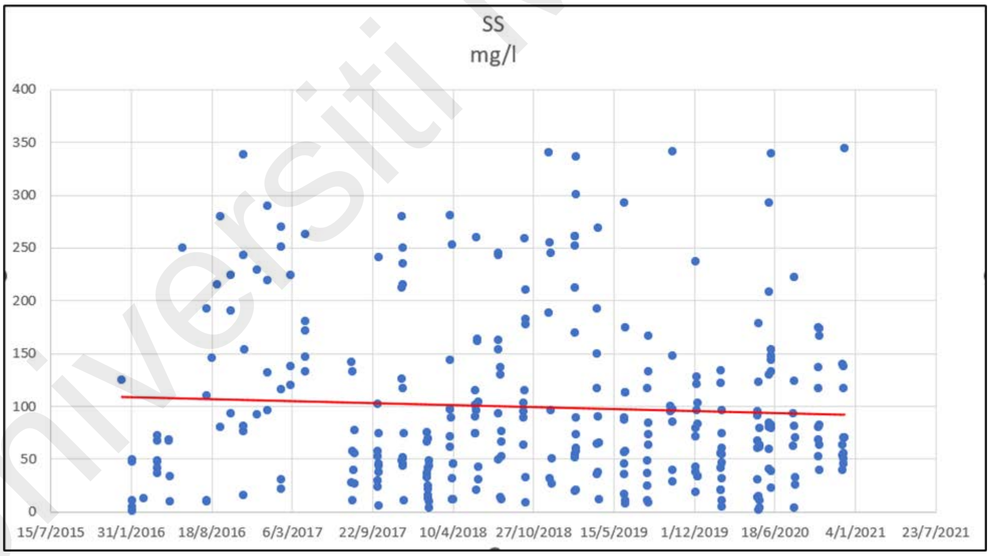

Figure 4.4 Time- Series trend of suspended solids for Langat River Basin

The M-K test (Table) revealed that the SS limit has no trend, a z-value of 1.29, and a p-value of 0.19, respectively. The M-K test can't be used to determine a crucial trend because there isn't one. A regression line was utilized to create a trend for the SS parameter. The regression line revealed a small drop from 2016 to the end of 2020 when a period series design was shown. In terms of SS, the number of clean waterways has increased from 456 in 2019 to 480 in 2020. As far as SS is concerned, the number of contaminated streams has fallen from 133 in 2019 to 119 in 2020. This can be attributed to a successful command of earthworks and land clearing operations in specific places, as well as the COVID-19 epidemic, which has slowed the development of our country's development area (State of the river report 2015: Langat River, 2017).

4.5 Effective water resource management

The management of water resources and stream basins in Malaysia's Langat River Basin has begun with the implementation of IWRM at the basin level. Although the basin is small, it has developed several challenges similar to those found in larger river basins. This is because rivers play an important role in agriculture and drinking water supply, but they are under threat from rapid expansion in business districts and urbanization in the basin. As a result, the portions of IWRM and IRBM must have been implemented in Langat as practical methods to sustainable water assets and river basin management.

The government bears primary responsibility for the planning, improvement, and implementation of water assets initiatives in the country. State legislatures and their organizations play an important role in water resource management. A few government offices oversee a specific component or function related to water resources. An effective administration of water assets necessitates the complete participation and effort of all stakeholders, as well as a comprehensive method of articulating the primary issues of disagreement. As a result, coordinating water resource management requires a standard operating procedure. What should be possible is to establish a national water plan, as well as comprehensive water regulations and guidelines, so that a more formal description of its requirements can aid decision-making.

In light of PCA/FA, this study has proven that using WQI alone as an indicator is insufficient. BOD, COD, and NH3 are the three primary limits that strongly contribute to water contamination. With the important parameters identified, a more strategic methodology should be achievable, as well as more stringent control. For example, to move toward integrated river basin management, one method that can be used is to administer waterway basins using an environmental approach to limit water contamination. Outlining all river basins and encouraging river basin grouping to direct future climate control exercises are examples of action plans that can be made in recognizing it. For the treatment of BOD, COD, and NH3, broad new work in the technological sector should be possible in the areas of water and wastewater treatment, as well as water reuse and recycling. Aside from that, the existing conventional approach for treating water is insufficient because most of the criteria are classified as Class III, indicating that the water supply requires considerable treatment. AN is usually seen as class II and class III in all monitoring sites. This reveals that Selangor's current sewage treatment plants are ineffective at handling household wastewater. Selangor might imitate the Hai Basin project, as annual wastewater release in the 16 venture areas was 129.34 million tonnes less in 2010 than in 2004, with COD and AN release of 69,758 tonnes and 7,488 tonnes, respectively (The World Bank, 2013).

Historically, there have been unplanned water shortages. The direct source, one may argue, is primarily due to industrial effluent, spills, and unlawful dumping. As a result, authoritative control should be used to prevent this type of contamination. A harsh regulation should be offered, as well as the revocation of organization licenses for those who do not follow the rules that were agreed to during the permit application. Respective government organizations should also monitor enterprises to see if they are following the agreed-upon procedures and update policies based on the feedback. As a result, it can be stated that water resource management can establish its profitability if the authorities and business owners put in the necessary effort in preventing and overseeing water contamination.

CHAPTER 5: CONCLUSION

5.1 Result Summary

This research looked at the distribution of contaminants in the Langat River basin, which included sixteen monitoring sites spread across Sungai Langat, Sungai Semenyih, and Sungai Batang Labu. Agglomerative HCA has successfully divided all sixteen monitoring stations into four separate groups, G1, G2, G3, and G4. According to HCA, the number of monitoring stations might be decreased from sixteen to four because the stations in each cluster are similar in terms of their build-up use and physicochemical characteristics. It is possible to achieve a vastly enhanced monitoring strategy in this manner. From there, the data was subjected to principal component analysis/factor evaluation in order to determine which boundaries contribute the most to water contamination. The main contributors were discovered to be BOD, COD, and Ammonia. Furthermore, the current WQI has some flaws, such as being overly simplistic and unable to accurately describe the water quality state of specific places. From there, a pattern test was performed to visualize the pattern for five different boundaries: ammonia, nitrate, BOD, COD, and SS. Only BOD and COD were shown to be significant in the M-K test, with a p-value of less than 0.05 and an increasing pattern. The regression line was also used to break down ammonia, nitrate, and SS, and the results show that there is a drop in pattern for each of the three boundaries. This study is significant because it identified the major sources of water contamination and provides a thorough picture of the Langat River Basin's stream water quality state from 2016 to 2020. As a result, government entities may take appropriate actions to review policies and increase fines that must be paid in order to reduce the impact of BOD, COD, and AN contamination. This study also recommends that Air Selangor modernize its water treatment plants, as the traditional water treatment plants are insufficient to deal with raw water contamination, as most of the criteria require considerable treatment. Finally, current practices such as river water monitoring should be continued, and when paired with a tougher policy regulation and redesigned water treatment plants, the chronic water deficiency might be significantly reduced.

5.2 Future Study

DOE has only provided statistics on the langsat river basin for the previous five years. In the future, it is advised that 10 years' worth of data be used, because five years' worth of data is good, but ten years' worth of data will be better because more data can be used for statistical analysis.

Aside from that, instead of using only the six parameters (pH, SS, BOD, COD, Ammonia-Nitrogen, and DO), other factors such as Color, Turbidity, Hardness, DS, Fe, Mn, and Mg might be used in this study.

Finally, comparing the upstream, midstream, and end stream clusters from two basins can be done for future assessment. This will allow us to see if the position of monitoring stations affects pollution or the activities that take place near the river.

REFERENCES

Abdi, H., & Williams, L. J. (2010). Principal component analysis. *Wiley interdisciplinary reviews: computational statistics*, *2*(4), 433-459.

Afroz, R., Masud, M. M., Akhtar, R., & Duasa, J. B. (2014). Water pollution: Challenges and future direction for water resource management policies in Malaysia. *Environment and urbanization ASIA*, *5*(1), 63-81.

Air Selangor. (2022). *Water Handbook : Sustainbale Consumption and Conservation for Indiciduals and Organisation* [Ebook]. Retrieved from http://file:///C:/Users/adamh/OneDrive%20-%20Universiti%20Malaya/Research%20Project/Papers/New/Air-Selangor-Water-Handbook-2.pdf

Alley, E. R. (2007). *Water quality control handbook* (Vol. 2). New York: McGraw-Hill.

Amry, S., & Miscon, S. (2018). Retrieved 6 June 2022, from https://www.nst.com.my/news/nation/2018/10/419692/water-supply-selangor-restored

APHA AWWA, W. E. F. (2005). Standard methods for the examination of water and wastewater. *APHA WEF AWWA*.

Bernama. (2019). Public apathy, illegal factories are the main causes of river pollution. Retrieved 6 June 2022, from https://www.thesundaily.my/local/public-apathy-illegal-factories-main-causes-of-river-pollution-CX707271

Choi, I. S., Dombrowski, E. M., & Wiesmann, U. (2007). *Fundamentals of biological wastewater treatment*. John Wiley & Sons.

Cole, S., Codling, I. D., Parr, W., Zabel, T., Nature, E., & Heritage, S. N. (2000). Guidelines for managing water quality impacts within UK European Marine sites. *Natura*.

Daud, H. (2009). Legislative Approach to Water Quality Management in Malaysia-Success and Challenges. *Department of Environment, Ministry of Natural Resources and Environment, Malaysia*.

Davis, M. L. (2010). *Water and wastewater engineering: design principles and practice*. McGraw-Hill Education.

Davis, M. L., & Masten, S. J. (2004). Principles of Environmental Engineering and Science McGraw-Hill Companies. *Inc.: New York*.

DOSM. (2015). Department of Statistics Malaysia Official Portal. Retrieved 6 June 2022, from https://www.dosm.gov.my/v1/index.php?r=column/ctheme&menu_id=L0pheU43NWJwRWVSZklWdzQ4TlhUUT09&bul_id=MDMxdHZjWTk1SjFzTzNkRXYzcVZjdz09

Drinan, J., Drinan, J. E., & Spellman, F. (2000). *Water and wastewater treatment: A guide for the nonengineering professional*. Crc Press.

Edzwald, J., & American Water Works Association. (2011). *Water quality & treatment: a handbook on drinking water*. McGraw-Hill Education.

Federation, W. E., & Aph Association. (2005). Standard methods for the examination of water and wastewater. *American Public Health Association (APHA): Washington, DC, USA*, *21*.

Fong, F. (2016). Retrieved 6 June 2022, from https://www.nst.com.my/news/2016/10/183918/sg-semenyih-pollution-crisis-tests-reveal-presence-poison

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.

Hounslow, A. W. (2018). *Water quality data: analysis and interpretation*. CRC press.

Inyinbor Adejumoke, A., Adebesin Babatunde, O., Oluyori Abimbola, P., Adelani Akande Tabitha, A., Dada Adewumi, O., & Oreofe Toyin, A. (2018). Water pollution: effects, prevention, and climatic impact. *Water Challenges of an Urbanizing World*, *33*, 33-47.

Johnson, S. C. (1967). Hierarchical clustering schemes. *Psychometrika*, *32*(3), 241-254.

Juahir, H., Zain, S. M., Yusoff, M. K., Hanidza, T. I., Armi, A. S., Toriman, M. E., & Mokhtar, M. (2011). Spatial water quality assessment of Langat River Basin (Malaysia) using environmetric techniques. *Environmental monitoring and assessment*, *173*(1), 625-641.

Kiprono, S. W. (2017). Fish parasites and fisheries productivity in relation to extreme flooding of Lake Baringo, Kenya. *Published Master's Thesis. Kenyatta University*.

Lembaga Urus Air Selangor. (2017). *State of the river report 2015 : Langat River* [Ebook] (3rd ed.). Retrieved from https://www.luas.gov.my/en/luas/publications/selangor-state-of-river-report

Li, L. (2019). Principal Component Analysis for Dimensionality Reduction. Retrieved 6 June 2022, from https://towardsdatascience.com/principal-component-analysis-for-dimensionality-reduction-115a3d157bad

Lim, I. (2019). Klang Valley water disruption: Why does it happen so often?. Retrieved 6 June 2022, from https://www.malaymail.com/news/malaysia/2019/08/06/klang-valley-water-disruption-why-does-it-happen-so-often/1777926

Loi, J., Chua, A., Rabuni, M., Tan, C., Lai, S., Takemura, Y., & Syutsubo, K. (2022). Water quality assessment and pollution threat to safe water supply for three river basins in Malaysia. *Science Of The Total Environment*, *832*, 155067. doi: 10.1016/j.scitotenv.2022.155067

McLeod, A. I. (2005). Kendall rank correlation and Mann-Kendall trend test. *R Package Kendall*.

Ministry of Health Malaysia, E. *Drinking Water Quality Standard* [Ebook].

Moghaddam, S. S., Moghaddam, M. A., & Arami, M. (2010). Coagulation/flocculation process for dye removal using sludge from water treatment plant: optimization through response surface methodology. *Journal of hazardous materials*, *175*(1-3), 651-657.

NSTP. (2019). NST Leader: What's up, enforcers? Retrieved 6 June 2022, from https://www.nst.com.my/opinion/leaders/2019/07/506380/nst-leader-whats-enforcers

NSTP. (2019). NST Leader: What's up, enforcers?. Retrieved 6 June 2022, from https://www.nst.com.my/opinion/leaders/2019/07/506380/nst-leader-whats-enforcers

Omer, N. H. (2019). Water quality parameters. *Water quality-science, assessments and policy*, *18*.

Peavy, H. S., Rowe, D. R., & Tchobanoglous, G. (1985). *Environmental engineering* (Vol. 2985). New York: McGraw-Hill.

Pescod, M. B. (1992). Wastewater treatment and use in agriculture-FAO irrigation and drainage paper 47. *Food and Agriculture Organization of the United Nations, Rome*.

Randtke, S. J., & Horsley, M. B. (2012). *Water treatment plant design*. McGraw-Hill.

Shrestha, N. (2021). Factor analysis as a tool for survey analysis. *American Journal of Applied Mathematics and Statistics*, *9*(1), 4-11.

Spellman, F. R. (2017). *The drinking water handbook*. CRC Press.

Statistics Canada. (2021). 4.5.2 Visualizing the box and whisker plot. Retrieved 6 June 2022, from https://www150.statcan.gc.ca/n1/edu/power-pouvoir/ch12/5214889-eng.htm

The World Bank. (2013). China: Improving Water Resource Management & Pollution Control in the Hai Basin. Retrieved 6 June 2022, from https://www.worldbank.org/en/results/2013/04/09/china-improving-water-resource-management-pollution-control-in-hai-basin

Tomar, M. (1999). *Quality assessment of water and wastewater*. CRC press.

Uddin, M. G., Nash, S., & Olbert, A. I. (2021). A review of water quality index models and their use for assessing surface water quality. *Ecological Indicators*, *122*, 107218.

Ukaogo, P. O., Ewuzie, U., & Onwuka, C. V. (2020). Environmental pollution: causes, effects, and the remedies. In *Microorganisms for sustainable environment and health* (pp. 419-429). Elsevier.

Wani, K. A., Jangid, N. K., & Bhat, A. R. (Eds.). (2019). *Impact of Textile Dyes on Public Health and the Environment*. IGI Globa

Water supply cut in Klang Valley affects 5m people as plants shut due to contamination again. (2022). Retrieved 6 June 2022, from https://www.straitstimes.com/asia/se-asia/water-cuts-in-selangor-to-over-1m-accounts-as-plants-shut-down-due-to-contamination

WHO. (2022). Drinking-water. Retrieved 6 June 2022, from https://www.who.int/news-room/fact-sheets/detail/drinking-water

World Health Organization, WHO., & World Health Organisation Staff. (2004). *Guidelines for drinking-water quality* (Vol. 1). World Health Organization.

Zainal, F. (2020). Water cuts: Source of Sg Semenyih pollution traced to industrial zone in Negri Sembilan, says Environment Minister. Retrieved 6 June 2022, from https://www.thestar.com.my/news/nation/2020/10/04/water-cuts-source-of-sg-semenyih-pollution-traced-to-industrial-zone-in-negri-sembilan-says-environment-minister