ASSESSTMENT OF WATER QUALITY AROUND PENGKALAN HULU, PERAK

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ASSESSMENT OF WATER QUALITY AROUND PENGKALAN HULU, PERAK

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DECLARATION

I hereby declare that I have conducted, completed the research work and written the dissertation entitled 'Thesis Title'. I also declare that it has not been previously submitted for the award of any degree and diploma or other similar title of this for any other examining body or University.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

º C	Degree Celsius
ppm	Part Per Million
mg/L	Milligram Per Litre

LIST OF ABBREVIATIONS

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
TSS	Totals Suspended Solid
DO	Dissolved Oxygen
NH_3^-N	Ammoniacal Nitrogen

LIST OF APPENDICES

PENILAIAN KUALITI AIR DI SEKELILING PENGKALAN HULU, PERAK

ABSTRAK

Kualiti air Sungai Pengkalan Hulu, Perak dipengaruhi oleh beberapa faktor seperti hidrogeokimia kawasan kajian dan aktiviti antropogenik. Kajian ini mengesyorkan agar aktiviti antropogenik di kawasan Pengkalan Hulu dipantau memandangkan urbanisasi berlaku dengan pantas dan kesannya mencemarkan air. Matlamat kajian ini adalah untuk menilai parameter fizikokimia (BOD, COD, TSS, nitrogen ammonia, pH, perubahan suhu dan DO) dalam air permukaan Pengkalan Hulu, Perak sebagai fungsi indeks kualiti air (WQI) air oleh Kementerian Kesihatan dan menentukan kepekatan logam berat di permukaan air oleh ICP-OES. Di samping itu, dalam kajian ini, perisian ArcGIS digunakan untuk memaparkan taburan ruang bagi parameter yang dikaji supaya dapat melihat corak perubahan dalam nilai ini sebagai fungsi julat warna yang berbeza. Sampel diambil daripada sepuluh stesen yang berbeza dan pengambilan sampel sebanyak dua kali. Parameter ini dibahagikan kepada dua jenis iaitu pengukuran in situ dan pengukuran makmal. Berdasarkan kepekatan pH, suhu, kekeruhan, Oksigen terlarut (DO), Permintaan Oksigen Biokimia (BOD), Permintaan Oksigen Kimia (COD), Nitrogen Ammonia (NH-3N) dan Jumlah Pepejal Terampai (TSS) sungai Pengkalan Hulu di semua stesen sedikit tercemar kecuali stesen 1 dan 2 yang dianggap bersih. Berdasarkan data dari ICP-OES, menunjukkan bahawa kepekatan arsenik (As) dan Kadmium (Cd) adalah sangat rendah di mana bawah dari nilai 0.001 mg/L. Bagi logam berat yang lain seperti plumbum (Pb) dan Kuprum (Cu), nilainya berbeza bergantung pada stesen tersendiri. Oleh itu, dapat disimpulkan bahawa pencemaran pada permukaan air di Pengkalan Hulu bukan hanya disebabkan oleh aktiviti ekonomi seperti industri perlombongan dan pembalakan tetapi juga kerana faktor mineralnya.

ABSTRACT

Numerous elements, including the hydro geochemistry of the study region and anthropogenic activity, have an impact on the water quality in Sungai Pengkalan Hulu, Perak. This study recommends that the anthropogenic activities within Pengkalan Hulu area be monitored as the urbanizations are rapidly taking place and the effects are polluting the water. The purpose of this study was to assess the relationship between the water quality index and the physicochemical parameters (BOD, COD, TSS, ammonia nitrogen, pH, temperature change,and DO) in the surface water of Pengkalan Hulu, Perak. ICP-OES is used to measurethe content of heavy metals on the water's surface and WQI) water by the Ministry ofHealth. Additionally, in order to see the spatial distribution of the researched parameters and observe the pattern of change in this value as a function of the colourspace, ArcGIS software was employed in this study. Ten separate sites were used for sampling, and sampling was twice. The data are compared to the MOH and the Water Quality Index (WQI) raw water standards. These parameters are separated into two groups, namely in situ measurements and laboratory measurements. The Pengkalan Hulu river at all stations is considered slightly polluted, except for stations 1 and 2, which are considered clean, based on pH concentration, temperature, dissolvable oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen (NH-3N), and total suspended solids (TSS). According to ICP-OES data, arsenic (As) and cadmium (Cd) contents are extremely low, falling below the value of 0.001 mg/L. The value of other heavy metals, such as copper (Cu) and lead (Pb), varies depending on the station. Thus, it can be concluded that contaminationof surface water in Pengkalan Hulu is not just because of the economic activities such as mining industries and logging activities but also due to its mineralization factor.

CHAPTER 1

INTRODUCTION

1.1 Significant of Research Work

Water is a natural resource that is essential to humanity's survival. Water from the seas and oceans covers around 70% of the Earth's surface. Meanwhile, water originates from rivers and lakes, which account for around 0.3 percent of the world's surface area and are used for various purposes. Even today, a major portion of the world's population relies on it as a source of drinking water, residential, industrial, and other uses. As a result, water quality is critical to us since it has an impact on livestock output and the country's economy (Gleick, 1993).

In 2015, the Department of the Environment (DOE) resumed its river water quality monitoring programme to evaluate the current state of river water quality and detect changes. Water samples were collected from selected locations at regular intervals for in-situ and laboratory examination to assess its physicochemical and biological features. Which according to the National Water Quality Standards for Malaysia (NWQS), the Water Quality Index (WQI) is used to determine the amount of pollution and the accompanying acceptability in terms of water applications (ANNEX). Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH3 -N), Suspended Solids (SS), and pH are all factors considered by the WQI (W.A.Amneera, 2013).

Besides, according to Environmental Quality Report (EQP) 2017, 54 percent of the country's rivers were found to be contaminated out of a total of 477 rivers. Over half of these river were contaminated, which would undoubtedly be Malaysia's most serious problem. In terms of river pollution, the Biochemical Oxygen Demand (BOD), Ammoniacal Nitrogen (NH3-N), and Suspended Solids (SS) were considerable, as they had been in prior years. Inadequate treatment of sewage or effluent from agro-based and manufacturing businesses is one cause of high BOD. Animal farms and home sewage were the primary sources of NH3-N. Meanwhile, poor earthworks and land clearing operations were the major causes of Suspended Solids (Baginda and Zainuddin, 2009).

For this reason, a research study is being undertaken at the northernmost section of Peninsular Malaysia, which borders Thailand and encompasses an area of 873.70km2 and borders Baling Kedah, Gerik Perak, and Betong Thailand, and is known locally as Pengkalan Hulu, Perak. For 200 years, this location has been renowned as a rich mineral deposit, mainly tin, in Malaysia, and it presently produces more than 70% of Malaysia's tin. Numerous metallic minerals such as pyrite, arsenopyrite, magnetite, pyrhotite, chalcopyrite, and others were (Sapari et al., 2016).

It comes as no surprise that human activities like mining dominate in this area given that the geology and mineralogy of the land have a very high potential for mineral deposits and that it is a very advantageous location to extract these rich minerals. As previously mentioned, a lot of people protested one of these harmful acts that contributed to water contamination. But it's also important to emphasise the natural characteristics, such as the geology and mineralogy of the area. In order to learn more about the qualities of the water that originates in Pengkalan Hulu, Perak, this research study was done.

According to the Environmental Quality Report (EQR) 2017, there are three categories of water quality parameters: physical, chemical, and biological. These categories include turbidity, pH, temperature, and heavy metals. Physical parameters include dissolve oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solid (TSS), and ammoniacal nitrogen (AN). This study is designed to examine the water quality of major water resources and classify it in accordance with Malaysia's Ministry of Health (MOH) standards for drinking and raw water, the Water Quality Index (WQI), and the Interim National Water Quality Standard (INWQS). A water quality indicator, or WQI, is used to calculate the physicochemical characteristics of surface water.

1.2 Problem Statement

Mining activity often related to water pollution. Discharge of acid mine drainage (AMD) without proper treatment management result to impairment of ecosystem. An elevation number of heavy metals (HMs) due to mining activities have been reported contaminating the natural aquatic environment (Son et al., 2020). Few researchers have addressed the river sulfide bearing minerals. (Hanafiah et al., 2018). The exploitation of sulfide minerals such as pyrite results in the aerobic oxidation of iron and sulfur when exposed to air and water. Generally, the extreme acidity mobilizes (produces soluble forms carried by drainage waters metals released from the sulfide minerals that oxidize and from associated minerals. This mobilization occurs because several metals including Al, Cu, Fe, Hg, Ni, Pb, Zn, As become more soluble in water as pH declines.

Acid drainage also produces waters that contain high concentrations of dissolved mineral salts including the sulphates produced by mineral oxidation, mobilized acid-soluble metals, and other mineral components that become soluble due to mineral dissolution caused by the extreme acidity (Fulazzaky et al., 2010).

HMs can be changed upon their characteristics and the properties of the environment where they are concerned. The chemicals' transport, fate and behaviour of HMs is interrelated with air-water-soil-biota which adsorption and redox potential affect the fate and transport of HMs. In order to improve the metal removal, the AMD conditions and physio-chemical must be characterized. Flow, acidity and alkalinity, metal, redox potential, and dissolved oxygen concentrations are critical parameters. Previous work has focused on the Water Quality. Therefore, utilising Arc-GIS Software to detect the geospatial distribution along the Pengkalan Hulu area based on its physiochemical parameters is an alternate approach that can be applied. Hence, the study area of Northern part of Peninsular Malaysia, which is well known as primary tin deposit for 200 years ago, has been chosen as a study area, where physio-chemical water quality is needed to correlate with heavy metal removal mechanism specifically.

In order to offer appropriate solutions to the problem, it is necessary to investigate the present quality of water on the major source of water. Besides, it is important to identify the other sources of the water pollution such as logging, agriculture, and building construction. Physicochemical characteristics distribution along with each sampling point can be shown more clearly by using Arc-GIS software, which can aid in locating the source of the river's contamination. This is to guarantee that the surrounding people have access to clean water and maintain the people health while also protecting the river's habitat.

1.3 Objective

The main objectives of this research work:

1) To investigate the physicochemical parameters in surface water at Pengkalan Hulu, Perak on the basis of Water Quality Index (WQI).
2) To determine the heavy metal concentration of a river by using ICP-OES.
3) To identify the distribution of physicochemical parameters and heavy metals along the study area by using ArcGIS.

1.4 Scope of Study

The goal of this study is to determine the present quality of the major water supply in Pengkalan Hulu, Perak. Numerous physicochemical parameters, such as pH, temperature, dissolved oxygen level (DO), and turbidity, were measured in-situ in order to obtain the current water quality, and then other tests, referred to as laboratory tests, were performed in the laboratory, including Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (NH3-N), Suspended Solid (SS), and heavy metal concentration determination.

The water samples were then analysed using Malaysian Ministry of Health (MOH) standards to determine the water's criteria by comparing them to raw and drinking water standards, and then further analysis to classify the level of contamination using the Water Quality Index (WQI) and Interim National Water Quality Standard (INWQS).

The data collected from the lab test is then tabulated in Excel to allow for comparisons between each sampling point. The data from the excel file is then imported into the ArcGIS software to create a spatial distribution for each parameter that was tested in the lab. According to the various colour ranges, the distribution along the sampling area will demonstrate the changes in value at each sampling point. In view of the ArcGIS results, it is important to have a discussion about which areas are more contaminated due to high concentrations of WQI parameters and heavy metals.

1.5 Study Limitation

The quality and accuracy of this study may be significantly impacted by a number of things. Because of these considerations, the findings of this study might be different from those of other research papers that have been done by other researchers. First of all, it has to do with the small number of samples. This is owing to the fact that only the safe site can be used as the point to take the sample at some locations where it is rather dangerous to do so because it is surrounded by vast forests and mountainous terrain. Additionally, the sampling site is located deep within a forest and is inaccessible by car due to a rough dirt road.

The equipment limitation comes next. Some are prone to mistakes, inaccurate readings, and functional faults, which are made worse when the equipment being used breaks down suddenly and takes a very long time to fix. due to the fact that numerous students utilise the same equipment, the consumption of it should be regulated. This case study is harder than people initially believed. Some parameters, like the BOD test, have their own limits. Since the sample cannot be preserved since doing so can affect the lifespan of microorganisms, this test must be performed within 24 hours of the sample being taken.

1.6 Thesis Outline

This thesis is organized into five main chapters:

Chapter 1 Briefly introduces the coverage of the thesis, including the overview of the research background, problem statement, objectives, and scope of this research work.

Chapter 2 covers in detail the existing literature on the background of area, source of contribution of water pollution, properties of water, effects, and regulations. Information on the equipment and method of measurement.

Chapter 3 presents the overall flow of this study and experiments conducted information about the location, equipment, and methodology of the experimental work.

Chapter 4 presents and discusses results from the data and result tabulated. Explain the importance of findings and acknowledge any mistake or limitation in experiment.

Chapter 5 summarizes and draw conclusions for this study and its' objective

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Water is an essential requirement of human life and activities associated with industry, agriculture, and others, and it considers one of the most delicate parts of the environment (Al-Badaii et al., 2013). Water is the most crucial element in human life because it makes up 70% of our body. Most of the fresh water utilised in drinking, or any other economic sector comes from rivers. Rivers are essential as drinking water and for irrigation and fishing as they are the sources of natural water (Maliki Abdullah et al., 2020).

Malaysia's Department of Environment (DOE) classifies rivers based on a water quality index (WQI). The developed WQI may be used to assess water quality, which is divided into five categories: very good, good, moderate, polluted, and extremely contaminated. It might also be used to analyse and compare water quality between different river sections or between different watersheds. The WQI was used to analyse a watercourse in terms of pollutant load categorization and the assignment of classes of beneficial uses as outlined in Malaysia's National Water Quality Standards (NWQS) (W.A.Amneera, 2013).

In 2010, Malaysia had a total of 1,055 water quality monitoring stations spread along 570 rivers. 527 (50 percent) of the 1,055 monitoring sites were judged to be clean, 417 (40 percent) mildly polluted, and 111 (10 percent) seriously polluted. The drop in the number of clean rivers was linked to an increase in polluting sources such as sewage treatment facilities and agro-based enterprises, which contributed to a high pollution loading (W.A.Amneera, 2013).

Rapid urbanisation, which results from the development of residential, commercial, and industrial sites, as well as infrastructure and other facilities, are the primary causes of river pollution. Aside from that, the destruction of rainforests and water catchments, as well as the resulting erosion of soils and excessively silted run-offs, may poison rivers. Sediment run-off, industrial waste, home waste, agriculture, livestock, and heavy metals are the key elements influencing water quality in Malaysia (W.A.Amneera, 2013).

2.2 Water Pollutants

Rivers have been used to fulfil the urbanisation process in the quest of nation-building, resulting in changes to the natural conditions and ecology of rivers in river basins. The capacity and system of the entire river to fulfil vital activities is being harmed by the degradation of river water quality, resulting in substantial implications that result in long-term economic losses and damage the population's quality of life (Maliki Abdullah et al., 2020).

According to the Department of Environment's Malaysia Environmental Quality Report, human activities, particularly livestock and agriculture significantly impact river water, among other pollutants. Ammonia nitrogen, organic and inorganic nitrogen compounds, and dangerous microorganisms are all present in significant amounts in cattle wastewater. Furthermore, substantial environmental harm caused by animal faeces has been widely documented in rivers that receive nutrient-rich waste runoff, which has resulted in oxygen depletion and increased algal production (Al-Badaii et al., 2013).

Due to effluents from municipal sewage, animal wastewater, industry, agricultural operations, and urban runoff that flow into the river, the study of surface water contamination of the river is vital. Furthermore, depending on the degree of change in land use, the range of deterioration in river water quality differed. As a result, land use activities in the basin must be carefully planned and managed to safeguard the water supply and its quality (Al-Badaii et al., 2013).

The physicochemical and microbiological parameters were measured and classified based on the National Water Quality Standard (NWQS) to identify the effects of anthropogenic land use activities on the water quality condition, according to a study conducted by Fawaz Al-Badaii about Water Quality Assessment of the Semenyih River, Selangor, Malaysia. Furthermore, multivariate statistical techniques such as cluster analysis and principal component analysis were applied to the obtained data set in order to recognize water quality parameters for seasonal changes in river water quality, to compare and contrast sampling stations, and to determine the impact of pollution sources on the water quality parameters of the Semenyih River basin.

2.2.1 Hydro geochemistry of the Prospecting Area

Geology is the study of rocks that were present at a certain time and place and that have undergone a variety of events that have caused them to change over geologic time. This earth science research has a lot to do with the chemistry of surface waters, especially the connection between the chemical properties, local water quality, and local geology, also known as the hydro geochemistry. Any hydrogeochemical information offers a comprehensive, regionally extended understanding of the local geological systems. The type of rocks and minerals, geological processes occurring within the aquifer, the speed and direction of water flow, and the length of time the water has been in touch with reactive minerals are all factors that come into play when studying the hydro geochemistry of source water (Dinka et al., 2015).

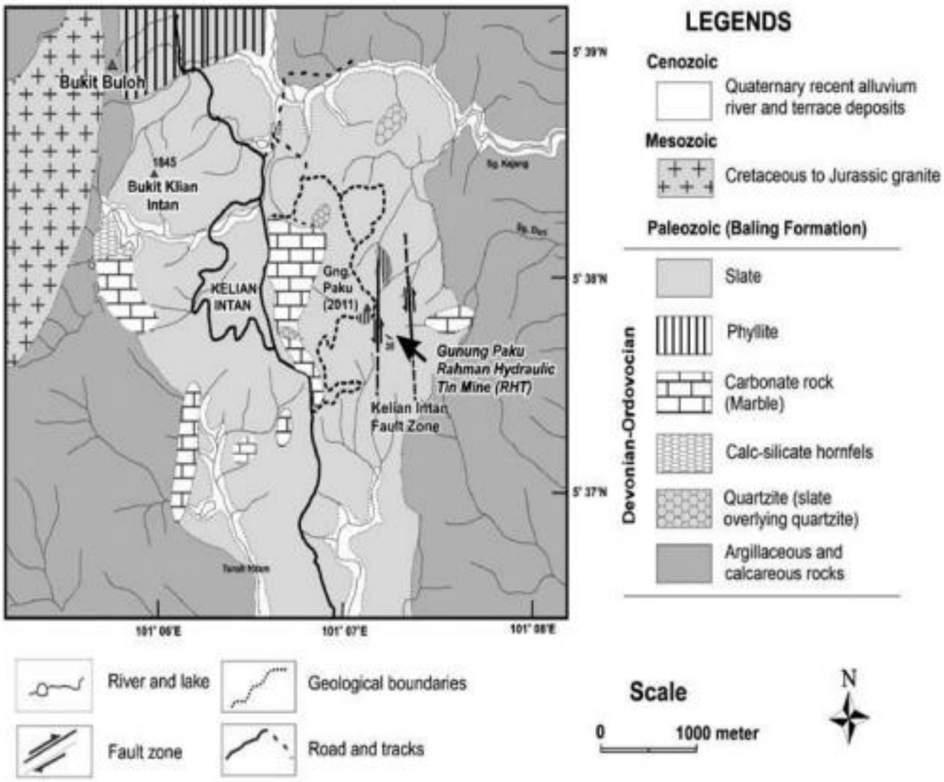

Figure 2.1 Geological Map of Gunung Paku Tin Deposit (Sapari et al., 2016)

2.2.2 Point Source Pollution

Water pollution can come from a variety of sources, including point sources. A source of water pollution that is emitted from a known source or a single source that discharges from a specific site is referred to as a point source. The majority of point source pollution is caused by mining activities, industrial facilities, municipal sewage, and home sewage. This sort of source pollution can be reduced through waste minimization and effective waste treatment before discharge to a natural water body, even if it can negatively influence the ecosystem and pose a serious health concern (Peirce, 1998).

Mining is any activity involving the extraction of valuable minerals, whether metallic or non-metallic, with high market value.

But today's Malaysian mining industries have a substantial negative influence on the environment. The negative effects on the neighborhood worsen as a result of client demand and industry development pressure. These activities have a severe negative impact on the ecosystem, particularly the quality of the river water. An earlier Malaysian investigation revealed that the primary cause of the water's heavy metal contamination is due to these activities.

2.2.3 Non-Point Source Pollution

Non-point source pollution differs from point source pollution in that wastes are discharged from numerous locations. After accumulating from huge regions such as construction sites, urban streets, agriculture runoff, deforestation, and so on, polluted waste can flow on the land surface or from drainage system to adjacent streams or rivers. Most non-point sources can also occur during rainstorms, which can result in a huge flow rate that is difficult to treat (Peirce, 1998).

2.3 Water Quality Analysis

The Department of Environment (DOE) in Malaysia classifies rivers based on a water quality index (WQI). WQI uses a technique or model of computation to tie a set of water quality determinants to a common scale and combine them into a single value. Dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen (NH3-N), pH, and total suspended solids (TSS) are the six main factors used to calculate the WQI (TSS) (W.A.Amneera, 2013).

WQI is a dimensionless number that combines multiple water-quality factors into a single number by normalizing values to subjective rating curves. Factors to be included in WQI model could vary depending upon the designated water uses and local preferences. Some of these factors include DO, pH, BOD, COD, total coliform bacteria, temperature, and nutrients (nitrogen and phosphorus), etc. These parameters occur in different ranges and express in different units. The WQI takes the complex scientific information of these variables and synthesizes into a single number (Gorde & Jadhav, 2013)

2.4 Water Quality Parameter

Large amounts of sewage and industrial effluent are released into the lake as a result of population growth, industrialisation, and urbanisation, contributing considerably to the lake's pollution. Several authorities have undertaken water quality assessment studies on the Lake on a regular basis over the last two decades and have adopted pollution control measures to revitalise the lake (Gorde & Jadhav, 2013).

Water quality metrics give crucial information on health of water body. The characteristics used to test the quality of water whether it is acceptable for drinking water, leisure and aquatic life. These sections include specific characteristics about where it originates from and why it is important to monitor that have an impact on water quality in the ecosystem.

The formula for calculating the Water Quality Index (WQI) includes six components. pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammonia Nitrate (NH-3), and Total Suspended Solids (TSS) are the variables to consider the value of Water Quality Index (WQI). Aside from that, there are a number of characteristics that can be observed that aren't included in the Water Quality Index formula. Temperature, water velocity, water flowrate, river width and depth, alkalinity, turbidity, Oxygen Reduction Potential (ORP), Salinity, and Conductivity are just a few examples.

2.4.1 pH

The acidity of a solution of water is measured by its pH. Typically, the pH scale spans from 0 to 14. It is a logarithmic scale, not a linear scale. A solution with a pH of 6 is, for example, ten times more acidic than one with a pH of 7. With a pH of 7, pure water is neutral. Water with a pH of less than 7.0 is acidic, whereas water with a pH of more than 7.0 is basic or alkaline (Gorde & Jadhav, 2013). The activity of photosynthetic algae, which eats carbon dioxide dissolved in water, causes the pH concentration to rise. Overall, the pH range of 6.5 to 9 is primarily suitable for aquatic life. Because high and low pH may be detrimental in nature, it is critical to keep the aquatic ecology within this range (Al-Badaii et al., 2013).

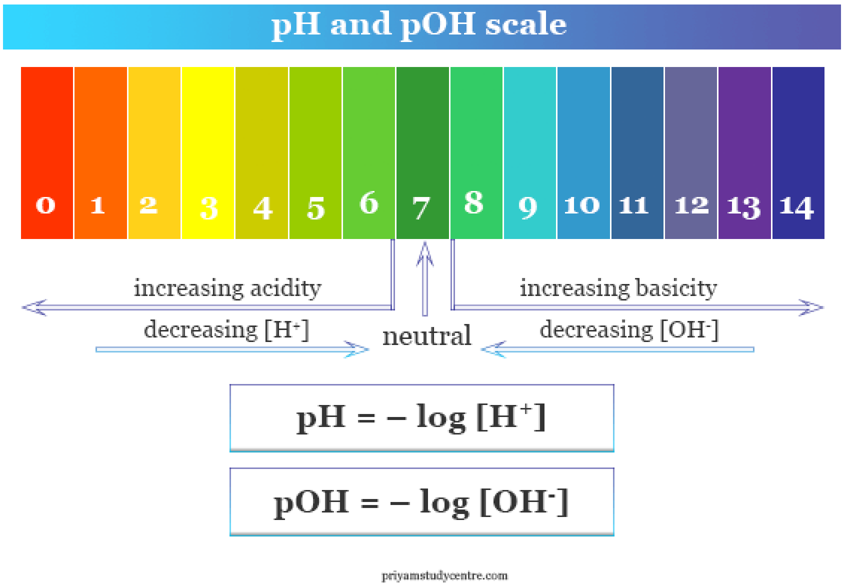

Figure 2.2 The logarithmic scale of pH (Learning Chemistry)

The logarithmic scale of pH means that as pH increases, the H+ concentration will decrease by a power of 10. Thus, at a pH of 0, H+ has a concentration of 1 M. At a pH of 7, this decreases to 0.0000001 M. At a pH of 14, there is only 0.00000000000001 M H+.

2.4.1(a) Alkalinity

The total amount of components in water that tend to raise the pH to the alkaline side of neutrality is known as alkalinity. It is generally reported as milligrammes per litre as calcium carbonate (mg/L as CaCO3) and is determined by titration with standardised acid to a pH of 4.5. Because pH has a direct influence on organisms as well as an indirect effect on the toxicity of some other contaminants in the water, alkalinity is a measure of the water's buffering capacity (ability to tolerate variations in pH). Carbonates, bicarbonates, phosphates, and hydroxides are all common alkalinity-increasing elements found in water (Gorde & Jadhav, 2013).

2.4.1(b) Acidity

The capacity of a water or solution to neutralize an alkali is measured in acidity. In layman's terms, pH is a measurement of an aqueous solution's acidity or basicity. Acidic solutions have a pH less than 7, while basic or alkaline solutions have a pH more than 7. Acidic water is said to have antibacterial properties, making it useful for skin, hair, and cleaning produce. It can, however, have a number of unfavorable and sometimes deadly side effects (Gorde & Jadhav, 2013)

Acidic water has a pH of 6.5 or below, as opposed to alkaline water, which has a pH greater than 7. Low pH water can be caused by a variety of factors, including natural factors such as acid rain. Acids can be produced by soil bacteria, tree roots, and some rock formations, causing neighboring water to become acidic. Low pH water is frequently found around mining sites, chemical dumps, power stations, confined animal feeding facilities, and landfills, and is generally caused by industrial pollution.

Many species are physiologically stressed by pH fluctuations or prolonged pH outside of this range, which can result in diminished reproduction, growth, disease, or death. This may eventually result in a loss of biological diversity in streams. Even slight variations in pH can modify the composition of a stream's community. This is due to the fact that pH changes the chemical state of many contaminants (such as copper and ammonia), affecting their solubility, transport, and bioavailability. Metal and nutrient toxicity in aquatic plants and animals may be increased as a result of this.

Figure 2.3 Acidic Stream due to Mine Drainage (US EPA)

2.4.2 Dissolved Oxygen

The dissolved gaseous form of oxygen is known as D.O. It is required for fish and other aquatic species to breathe. D.O. enters water through diffusion from the \atmosphere and as a by- product of photosynthesis by algae and plants. To maintain 100 percent D.O. saturation, the concentration of D.O. in epilimnetic fluids constantly equilibrates with the concentration of atmospheric oxygen. When the rate of photosynthesis exceeds the rate of oxygen diffusion to the atmosphere, excessive algal growth can over-saturate (more than 100 percent saturation) the water with D.O. Because there is no mechanism to replenish oxygen depleted by respiration and decomposition, hypolimnetic D.O. concentrations are often low. To live, fish require at least 3-5 mg/L of D.O (Gorde & Jadhav, 2013)

2.4.3 Biochemical Oxygen Demand (BOD)

The quantity of oxygen required by bacteria and other microorganisms when decomposing organic matter under aerobic (oxygen present) conditions at a specific temperature is referred to as biochemical oxygen demand (BOD). The BOD concentration continuously increases because of natural plant decaying process and other contributors that increase the total nutrient in water bodies such as fertilizer, construction effluent, animal farm, and septic system. BOD concentration is directly associated with DO concentrations. High value of BOD shows decline in DO (Gorde & Jadhav, 2013).

BOD has a substantial impact on the amount of DO in rivers and streams. Temperature, pH, the life duration of microorganisms, and the kind of organic and inorganic substances in the water can all be affected by the consumption of oxygen. BOD is an essential water quality indicator because it gives an index for determining the environmental impact of discharged wastewater. The higher the BOD, the faster the oxygen in the stream is reduced, posing a hazard to aquatic life. High BOD has the same effects as low DO, causing aquatic creatures to get stressed, suffocate, and perish (Abdul Rani A. Baginda & Zaki Zainudin, 2009).

The same variables that impact dissolved oxygen also affect BOD. The (APHA, 1999) states that measurement calls for collecting two measurements. The quantity of dissolved oxygen in one is measured right away and is regarded as the initial amount, while the amount of dissolved oxygen in the second is measured after it has been incubated in the lab for five days and is regarded as the final amount. This is an indicator of how much oxygen was used by microbes to break down the organic material in the sample while it was incubating. Since microorganisms are frequently utilised to remediate organic waste, BOD is also widely used in wastewater treatment.

2.4.4 Chemical Oxygen Demand (COD)

The chemical oxygen demand is a measure of the quantity of oxygen that can be consumed by reactions in a measured solution in environmental chemistry. It's usually measured in mass of oxygen used per volume of solution, which is measured in milligrammes per litre in SI units. Generally, the lower COD level indicates a low level of pollution, while \sthe high level of COD points out the high level of pollution of water in the study area.

Furthermore, widespread use of chemical and organic fertilisers, as well as sewage discharge, impact COD levels, with high COD indicating a degradation in water quality related to municipal effluent discharge (Al-Badaii et al., 2013). Domestic waste also contributes to high COD content and can bring harmful effects to living things. Moreover, statistically significant differences of COD were found between stations (Kruskal Wallis, $\rho < 0.05$). In contrast, the range values of COD concentration from this study (16 - 86 mg/L) were high compared to the ones reported by Al-Badaii et al. (2013) at Sungai Semenyih with the range of 0.32 to 4.56 mg/L (Maliki Abdullah et al., 2020).

2.4.5 Ammonia-Nitrogen (NH3-N)

Ammonia is produced by the microbial breakdown of nitrogenous molecules in organic materials in water bodies. Ammonia is also excreted by fish and other aquatic species. Some industrial activities, as well as home sewage and animal slurry, can dump ammonia straight into water bodies. Ammonia can also be released into the environment as a result of the breakdown of organic waste that has been discharged (Qannaf Aziz Zaid et al., 2019).

Water with a high ammonia content can be hazardous to aquatic life. Algae and weeds grow quickly when fertilised with nitrogen, which is a good fertiliser. Algae and weed growth can lower water oxygen levels and dissolved oxygen concentrations, endangering aquatic life. Problems with the taste and odour of river water are brought on by an overabundance of ammonia in the streams (Peirce, 1998).

2.4.6 Total Suspended Solid (TSS)

The number of particles present in the water is measured by total suspended solids (TSS). It is made up of both biological and inorganic particles. One of the numerous reasons why water quality decline leads to aesthetic issues is a high concentration of TSS. The rise in TSS not only raises the expense of water treatment, but it also has certain ecological consequences for aquatic habitats (Thy et al., 2015)

All streams carry some SS under natural conditions. However, if concentrations are enhanced through, for example, anthropogenic perturbations, this can lead to alterations to the physical, chemical, and biological properties of the water body. A high total solids content in drinking water will make it unappealing and may have an unfavourable impact on persons who are not accustomed to drinking such water. The effectiveness of water treatment plants, as well as the functioning of industrial operations that utilise raw water, can be harmed by too high or too low total solids levels. The assessment of Total Suspended Solids (TSS) is critical in determining the best treatment strategy (Md et al., 2019)

2.4.7 Turbidity

The presence of suspended particles, such as clay, silt, and sand, from inorganic materials and organic matter, such as algae and/or plankton, can create turbidity. Water turbidity is also influenced by the presence of dissolved organic matter, luminous dissolved organic matter, and other colours. Because turbidity is a result of particle shape, size, and composition, two fluids with the same turbidity may not necessarily contain the same suspended solids content (Md et al., 2019)

Although there is no uniform linkage between turbidity and TSS, there are several studies that demonstrate that turbidity is linked to suspended sediments. The density, size, and form of particles, as well as the colour of the water, are known to influence the final link between TSS and turbidity. However, if a strong relationship between TSS and turbidity can be established, turbidity can be used as a proxy for suspended solids and pollution concentrations within a basin. This was observed by Nasrabadi et al (Nasrabadi et al., 2016).

2.4.8 Oxygen Reduction Potential (ORP)

The ability of a lake or river to cleanse itself or break down waste products such as pollutants and dead plants and animals is measured by its oxidation-reduction potential (ORP). When the ORP score is high, the water contains a lot of oxygen. Bacteria that breakdown dead tissue and pollutants will be able to perform more efficiently as a result.

The higher the ORP value, the healthier the lake or river is in general. Even in healthy lakes and rivers, however, as you move closer to the bottom sediments, there is less oxygen (and thus lower ORP values). This is because numerous bacteria in the sediments are working hard to breakdown dead tissue, and they consume a lot of the oxygen available. In fact, oxygen quickly depletes in the bottom muck (typically within a millimetre or two), and ORP rapidly decreases. ORP is tested in addition to dissolved oxygen because it can give scientists more information about the water quality and, if pollution is present, the degree of pollution. Other elements, such as oxygen (in terms of chemistry), can also function and contribute to increased ORP (Nkotagu & Athuman, 2007).

Biochemical Reactions and Corresponding ORP Values

Biochemical Reaction	ORP, mV
Nitrification	+100 to +350
cBOD degradation with free molecular oxygen	+50 to +250
Biological phosphorus removal	+25 to +250
Denitrification	+50 to -50
Sulfide (H_2S) formation	-50 to -250
Biological phosphorus release	-100 to -250
Acid formation (fermentation)	-100 to -225
Methane production	-175 to -400

Figure 2.4 Biochemical Reactions and Corresponding ORP Values (Arduino Cloud)

2.4.9 Salinity

According to United State Geological Survey (USGS), saline water includes large levels (referred to as "concentrations") of dissolved salts, the most common of which being sodium chloride, which we all know (NaCl). The concentration in this context is the amount of salt in water (by weight), given in "parts per million" (ppm). If dissolved salts are present in water at a concentration of 10,000 parts per million (ppm), dissolved salts account for one percent of the water's weight (10,000 divided by 1,000,000).

According to US EPA, water salinity is important because it contributes significantly to conductivity and influences many aspects of natural water chemistry and biological processes. The physical qualities of water, such as density and heat capacity, are governed by salinity, together with temperature and pressure.

organization's (FAO) recommendation[3]

Water class	Electrical conductivity/$dS \cdot m^{-1}$	Salt concentration /$mg \cdot L^{-1}$	Type of water
Non-saline	< 0.7	< 500	Drinking and irrigation water
Slightly saline	0.7-2	500-1500	Irrigation water
Moderately saline	2-10	1500-7000	Primary drainage water and groundwater
Highly saline	10-25	7000-15 000	Secondary drainage water and groundwater
Very Highly saline	25-45	15 000-35 000	Very saline groundwater
Brine	> 45	> 35 000	Seawater

Figure 2.5 Classification of Water Salinity (Research Gate)

We are all more aware of the necessity to save freshwater in today's environment. With the ever-increasing need for water from ever-increasing populations around the world, it makes sense to try to find new uses for the copious saltwater supplies found primarily in the oceans. As these pie charts of the nation's water use indicate, salty water accounted for nearly 16% of all water utilized in the United States in 2015. The thermoelectric-power business used practically all saline withdrawals (almost 97 percent) to cool electricity-generating equipment, as shown in the second graph. For mining and industrial uses, about 3% of the nation's saline water was consumed.

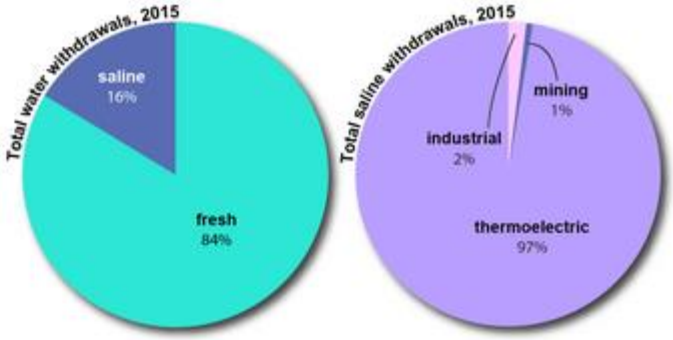

Figure 2.6 Saline water withdrawals in the United States, by category of use, for 2015 (USGS)

2.4.10 Conductivity

According to Fondriest Environment, the ability of water to carry electrical current is measured by its conductivity. This ability is proportional to the ion concentration in the water. Dissolved salts and inorganic elements such as alkalis, chlorides, sulfides, and carbonate compounds provide these conductive ions. Electrolytes are chemical compounds that dissolve into ions. The conductivity of water increases as the number of ions present increases. Similarly, the less ions in the water, the less conductive it becomes. Because of its poor (if not non-existent) conductivity, distilled or deionized water can behave as an insulator. The conductivity of sea water, on the other hand, is extremely high.

Because of their positive and negative charges, ions carry electricity. Electrolytes break into positively charged (cation) and negatively charged (anion) particles when they dissolve in water. The concentrations of each positive and negative charge remain equal as the dissolved compounds split in water. This indicates that while water's conductivity rises with the addition of ions, it stays electrically neutral.

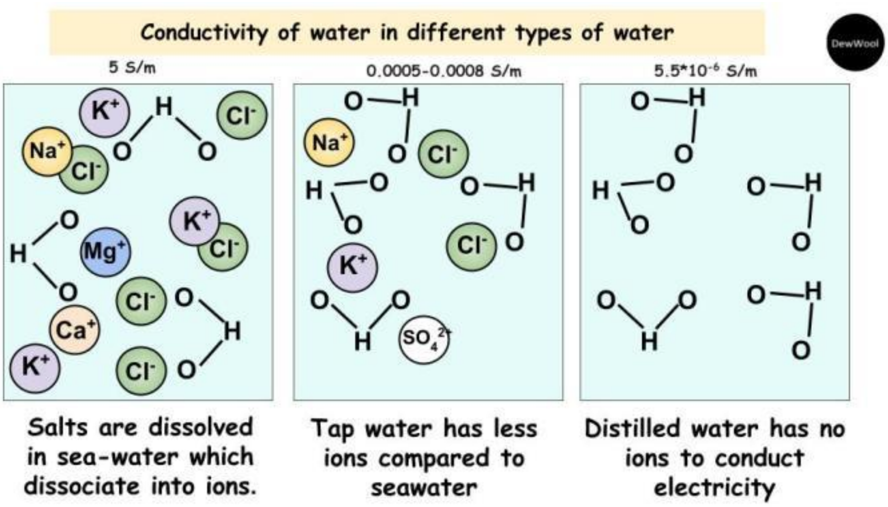

Figure 2.7 Conductivity of Water in Different Types of Water (Atlas Scientific)

2.5 Heavy Metals

Heavy metal is defined as a metal with a high density or relative atomic weight. As harmful activities are present along the Pengkalan Hulu River, heavy metals may be present in the water. Cadmium (Cd), Copper (Cu), Lead (Pb), Zinc (Zn), Magnesium (Mg), Manganese (Mn), Ferum (Fe), and Arsenic (As) have all been widely used in industry, whether in mining or chemical processes(Ulfa et al., 2014). This parameter has contributed to the increase of contamination of water in Malaysia.

Cadmium (Cd), Copper (Cu), Lead (Pb), Zinc (Zn), Magnesium (Mg), Manganese (Mn), Ferum (Fe), and Arsenic are all essential heavy metals that contribute to water contamination (As). Some of these metals, including as Cu, Fe, Mg, Cr, and Zn, are necessary as nutrients in some biological processes but become poisonous at excessive concentrations(Peirce, 1998). Heavy metals may enter the water as a result of natural processes such as rain. The presence of excessive metal concentrations will degrade the quality of river water.

Table 2.1 Source of Heavy Metals

Metals	Source
Arsenic (As)	Pesticides, fungicides, metal smelters
Cadmium (Cd)	Welding, electroplating, pesticides, fertilisers, batteries, nuclear fission plant
Chromium (Cr)	Mining, electroplating, textile, tannery industries
Copper (Cu)	Electroplating, pesticides, mining
Lead (Pb)	Paint, pesticides, batteries, automobile emission, mining, burning of coal
Manganese (Mn)	Welding, fuel addition, ferromanganese production
Nickel (Ni)	Electroplating, zinc base casting, battery industries
Zinc (Zn)	Refineries, brass manufacture, metal plating, immersion of painted idols

2.6 Ministry of Health (MOH) Malaysia Standard

The Ministry of Health, abbreviated as MOH, is the Malaysian government ministry in charge of the country's health system. In other words, Malaysia's Ministry of Health is in charge of the country's health and disability system, as well as its management and development. It directs changes that enable Malaysians live longer, healthier, and more self-sufficient lives. The Ministry of Health guarantees that the health system is meeting the Government's aims and that health-care organizations are well-governed and financially healthy.

2.6.1 Interim National Water Quality Standard (INWQS) Malaysia

The National Water Quality Standards are used to classify the level of contamination of surface water based on standards of a certain water class in order to enhance water quality to a higher water class. INWQS defines its various useful applications. As long as the water quality is within the range provided for the designated classes, it is regarded appropriate for a certain usage. The INWQS sets the minimum water quality required to support aquatic life, with increasing degrees of sensitivity from Class I to Class III.

Due of its economic worth, fish is utilized as an indicator. When a fish becomes contaminated, it is able to classify the level of contamination in the water and must treat it effectively. For example, for a Class III rather than a Class II, more modern treatment techniques are necessary. Class IV water sources can still be used for irrigation; however, Class V water sources are thought to be of little utility.

Seasonal flow fluctuations because of precipitation also have an impact on water quality. During the dry season, water quality may remain relatively stable with some changes if there are no major external disturbances or drought. During the rainy season, the likelihood of precipitation creation is higher, and the quality of the water has the ability to improve or be temporarily delayed, depending on the input that enters rivers and streams.

Table 2.2 Interim National Water Quality Index Classifications (water classes and uses)

Classes	Index	Uses
Class I	< 92.7	Conservation of natural environment. Water Supply I – Practically no treatment necessary. Fishery I – Very sensitive aquatic species.
Class II- A Class II- B	76.5 – 92.7	Water Supply II – Conventional treatment. Fishery II – Sensitive aquatic species. Recreational use body contact.
Class III	51.9 – 76.5	Water Supply III – Extensive treatment required. Fishery III – Common, of economic value and tolerant Species; livestock drinking.
Class IV	31.0 – 51.9	Irrigation
Class V	< 31.0	None of the above