IMPROVEMENT OF WATER QUALITY SENSORS FOR HYDRO QUALITY SYSTEM MONITORING DEVICE AT SUNGAI MELAKA

SAFURAA AGHNIA BINTI SHAMSUL

B092010024

BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY(BMID) WITH HONOURS

2024

Faculty of Industrial and Manufacturing Technology and Engineering

IMPROVEMENT OF WATER QUALITY SENSORS FOR HYDRO QUALITY SYSTEM MONITORING DEVICE AT SUNGAI MELAKA

Safuraa Aghnia Binti Shamsul

Bachelor of Manufacturing Engineering Technology(BMID) With Honours

2024

IMPROVEMENT OF WATER QUALITY SENSORS FOR HYDRO QUALITY SYSTEM MONITORING DEVICE AT SUNGAI MELAKA

SAFURAA AGHNIA BINTI SHAMSUL

A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Manufacturing Engineering Technology(BMID) With Honours

Faculty of Industrial and Manufacturing Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

DECLARATION

I declare that this Choose an item. entitled " Improvement of Water Quality Sensors' Development for Hydro Quality System Monitoring Device at Sungai Melaka " is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Safuraa Aghnia Binti Shamsul

Date : 31/1/2023

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor's Degree in Manufacturing Engineering Technology (Product Design) (BMID) with Honours.

Signature	:	
Supervisor Name	:	Mazran Bin Ahmad
Date	:	31/1/2024

TS. MAZRAN BIN AHMAD
Jurutera Pengajar
Jabatan Teknologi Kejuruteraan Pembuatan
Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan
Universiti Teknikal Malaysia Melaka

DEDICATION

This report is dedicated to everyone who supported me during my preparation of this report. My thanks to everyone , including my parents, supervisor, co-supervisor , comradein-arms, and people around me for the encouragement.

To My Parents,

Mr. Shamsul Bin Hj. Muen,

Mrs Azmah Binti Hj. Abd. Rahman

For my respected supervisor and co-supervisor,

Encik Mazran Bin Ahmad,

Ts. Dr. Nur Rashid Bin Mat Nuri @ Md Din

Thank you for support, sacrifie.

ABSTRACT

The Hydro Quality System (HydroQS) is a new system designed to monitor and evaluate river water quality. It measures pH level, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), turbidity, and ambient temperature. The five sensors used in the system are Arduino-based and can be connected and monitored through an application or online.However, there have been some problems with the HydroQS, such as inaccurate water quality data due to not calibrating the sensors, improper placement of sensors, and poor sensor functionality. These issues can lead to inaccurate water quality data, which can have serious consequences for poor decision-making about water management and public health.Water quality sensors are essential for environmental monitoring and ensuring that water resources meet safety and regulatory standards. In May 2019, the Melaka River experienced pollution, leading to black water and fish deaths. The Department of Environment (DOE) was directed to take water samples and fish carcasses to identify the cause. The results showed neutral pH levels at seven locations along the Melaka River, except for one location directly in front of the Melaka River barrier, which recorded 4.7 mg/l of dissolved oxygen.The HydroQS is a low-cost device that uses five sensors: pH value, temperature, turbidity, dissolved oxygen, and total dissolved solids. Solar panels will absorb sunlight to generate electricity, which will power the power bank. The device also incorporates IoT technology, allowing data to be delivered to the cloud using WiFi-linked sensors connected to the internet.The National Water Quality Standards (NWQS) classify water quality into five classes, with surface water quality being classified into six water use classes. The criteria help determine the sources of water quality problems, such as improperly treated water. The HydroQS device monitors freshwater quality by checking sensors' function and calibration. Data collected is compared with Department of Environment parameters. The device's pH, turbidity, temperature, DO, and TDS sensors are displayed on the Home Assistant Application. Calibration is performed to ensure accurate readings. After calibration, the experiment continues with field tests to verify the reliability of HydroQS water quality sensors.

ABSTRAK

Sistem Kualiti Hidro (HydroQS) ialah sistem baharu yang direka bentuk untuk memantau dan menilai kualiti air sungai. Ia mengukur tahap pH, Jumlah Pepejal Terlarut (TDS), Oksigen Terlarut (DO), kekeruhan, dan suhu ambien. Lima sensor yang digunakan dalam sistem adalah berasaskan Arduino dan boleh disambungkan serta dipantau melalui aplikasi atau dalam talian. Walau bagaimanapun, terdapat beberapa masalah dengan HydroQS, seperti data kualiti air yang tidak tepat kerana tidak menentukur sensor, penempatan yang tidak betul penderia, dan kefungsian penderia yang lemah. Isu-isu ini boleh membawa kepada data kualiti air yang tidak tepat, yang boleh membawa akibat yang serius untuk membuat keputusan yang lemah tentang pengurusan air dan kesihatan awam. Penderia kualiti air adalah penting untuk pemantauan alam sekitar dan memastikan sumber air memenuhi piawaian keselamatan dan kawal selia. Pada Mei 2019, Sungai Melaka mengalami pencemaran, menyebabkan air hitam dan kematian ikan. Jabatan Alam Sekitar (JAS) diarah mengambil sampel air dan bangkai ikan bagi mengenal pasti punca. Keputusan menunjukkan paras pH neutral di tujuh lokasi di sepanjang Sungai Melaka, kecuali satu lokasi betul-betul di hadapan penghalang Sungai Melaka, yang merekodkan 4.7 mg/l oksigen terlarut. HydroQS ialah peranti kos rendah yang menggunakan lima sensor: nilai pH, suhu, kekeruhan, oksigen terlarut, dan jumlah pepejal terlarut. Panel solar akan menyerap cahaya matahari untuk menjana elektrik, yang akan menjana kuasa bank kuasa. Peranti ini juga menggabungkan teknologi IoT, membolehkan data dihantar ke awan menggunakan penderia berkaitan WiFi yang disambungkan ke internet. Piawaian Kualiti Air Kebangsaan (NWQS) mengklasifikasikan kualiti air kepada lima kelas, dengan kualiti air permukaan dikelaskan kepada enam penggunaan air kelas. Kriteria membantu menentukan punca masalah kualiti air, seperti air yang tidak dirawat dengan betul. Peranti HydroQS memantau kualiti air tawar dengan memeriksa fungsi dan penentukuran sensor. Data yang dikumpul dibandingkan dengan parameter Jabatan Alam Sekitar. Penderia pH, kekeruhan, suhu, DO dan TDS peranti dipaparkan pada Aplikasi Pembantu Rumah. Penentukuran dilakukan untuk memastikan bacaan yang tepat. Selepas penentukuran, percubaan diteruskan dengan ujian lapangan untuk mengesahkan kebolehpercayaan penderia kualiti air HydroQS.

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my Sustainer, for everything I received since the beginning of my life. I would like to extend my appreciation to the University Technical Malaysia Melaka (UTeM) for providing the research platform.

My utmost appreciation goes to my main supervisor Encik Mazran bin Ahmad and also my co-supervisor Ts. Dr. Nur Rashid Bin Mat Nuri @ Md Din for all their support, advice, and inspiration. Their constant patience for guiding and providing priceless insights will forever be remembered. Also, to Ts. Mohd Idain Fahmy Bin Rosley who constantly supported my journey during the project.

Last but not least, from the bottom of my heart I express gratitude to my beloved parents, Shamsul Bin Hj. Muen and Azmah Binti Hj. Abd. Rahman, for all the encouragements and who have been the pillar of strength in all my endeavors, love and prayers. All my friends for their tolerance and understanding. Finally, thank you to all the individual(s) who had provided me with the assistance, support, and inspiration to embark on my study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

HydroQS	-	*Hydro Quality System*
DO	-	*Dissolved Oxygen*
TDS	-	*Total Dissolved Solid*
IoT	-	*Internet of Thing*
TMDL	-	*Total Maximum Daily Load*
DOE	-	*Department of Environment*
NTU	-	*Nephelometric Turbidity Unit*
Mg/L	-	*miligrams per litre*
WQI	-	*Water Quality Index*
NWQS	-	*National Water Quality Standards*
PPSPM	-	*Perbadanan Pembangunan Sungai Dan Pantai Melaka*
SLS	-	*Selective Laser Sintering*

CHAPTER 1

INTRODUCTION

1.1 Background

In the past, a new Hydro Quality System (HydroQS) system has been designed and developed to monitor and evaluate river water quality to implement the development of a new river monitoring system. This system measures river water quality in terms of pH level, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), turbidity, ambient temperature. At the same time, the use of the best type of sensor is also important to get good data. As part of that, there are several types of sensors that have been analyzed for use as Hydro Quality System devices.

The five sensors that will be used are based on Arduino and can be connected and monitored through an application or online using the device. There are many studies that have been carried out before on the water quality of Sungai Melaka by various parties. However, all the studies conducted were only monitored for a short period of time. This time, the results of this study will continue to make improvements to this Hydro Quality System.

1.2 Problem Statement

While this project was being caried out, there were some problems that arose. One of these problems is some of the water quality data that collected was not accurate due to not calibrate.This means that the sensors used to collect the water quality data were not calibrated correctly. Calibration is the process of adjusting a sensor so that it gives accurate readings. If a sensor is not calibrated correctly, its readings will be inaccurate, and the water quality data collected will be inaccurate as well.

Other than that, the placement of sensor was not suitable that can affect the reading of the water quality data. The placement of the sensor can also affect the accuracy of the water quality data. For example, if a sensor is placed in an area of the water body that is stagnant or polluted, the readings will not be representative of the water quality of the entire water body. Apart from that, the other problem is the sensor was not robust. Robustness refers to the ability of a sensor to withstand harsh environmental conditions. If a sensor is not robust, it may be damaged by factors such as temperature, pH, or salinity. This can damage the sensor and affect the accuracy of its readings. One of the sensors was not functioning well that cause the water quality data was not recorded. If a sensor is not functioning well, it will not be able to collect accurate water quality data. This can be due to a number of factors, such as a faulty sensor, a problem with the wiring, or a power outage.

All of these problems can lead to inaccurate water quality data. This can have serious consequences, as inaccurate water quality data can lead to poor decision-making about water management and public health. It is therefore important to ensure that water quality data is accurate. This can be done by using calibrated sensors, placing sensors in suitable locations, using robust sensors, and maintaining sensors properly. Figure 1.1 shows that the errors occured on data recorded which is turbidity sensor and pH sensor. The needle at turbidity meter points at red area as well as pH meter which means the river water was acidic whereas at that time, there is no pollution occur at the river.

Figure 1.1 Errors occured during real-time reading data of water quality sensors

Table 1.1 Comparison of previous data analysis with NWQS

Parameter	Range data n 24 hours	Range data from NWQS for clean water	Class of water
pH	8.7	6-9	IIA
Temperature(°C)	28.61-31.39	Normal + 2°C	IIA
Turbidity (NTU)	3.23-4.82	5-50 NTU	I
Dissolved Oxygen(mg/L)	4.26 – 10.79	>7 mg/L	IIA , I
Total Dissolved Solid(ppm)	513.79 – 622.41	<500 ppm	IIA

Table 1.1 shows that the data analysis of water quality sensors for previous project compared with National Water Quality Standards were not precise. At pH sensor, the value is only 8.7 and it should be have minimum and maximum value to ensure that the reading is reliable.

1.3 Research Objective

The main aim of this research is to monitor the water quality in the Melaka River,the following more particular objectives have been emphasized throughout the thesis:

a) To enhance the precision and reliability of water quality sensors in the Hydro Quality System.

b) To test the functionality of water quality sensors on Hydro Quality System at Sungai Melaka.

c) To interpret the data analysis of water quality sensors based on the guidance of National Water Quality Standards.

1.4 Scope of Research

The scope of this research are as follows:

- This project is to focus on the types of water quality sensors based on each parameters that will be used for the Hydro Quality System device.
- The water quality sensors are used to facilitate the Hydro Quality System to implement the data of water quality.
- This project is to focus on monitoring the water quality of the Melaka river in terms of parameters such as pH, turbidity, temperature , total dissolved solids and dissolved oxygen.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This project addresses the challenges associated with existing water quality monitoring technologies. Sungai Melaka, a vital waterway in the region, faces persistent threats from pollution sources, industrial discharges, and urban runoff. The project aims to enhance the capabilities of water quality sensors used in the Hydro Quality Monitoring device to tackle these challenges. The Hydro Quality System is a comprehensive water quality monitoring solution designed to assess the five types of parameters that influence the overall health of Sungai Melaka. This project seeks to improve the accuracy, sensitivity, and real-time capabilities of the sensors integrated into the monitoring device.

2.2 What are water quality sensors?

Water quality sensors are devices that designed to measure and monitor various parameters and characteristics of water to assess its quality. These sensors play an important role in environmental monitoring , ensuring that water resources meet safety and regulatory standards. Water quality sensors are used in various settings including rivers, lakes, ocean, drinking water supplies, industrial process, and wastewater treatment plants. In this project, there are five types of water quality sensors that will be used which are pH sensor, turbidity sensor, temperature sensor, total dissolved solids sensor and dissolved ovygen sensor.

2.3 River pollution in Melaka River

In the past middle of May 2019, there was an issue about Melaka River. It was polluted for about three kilometers(km) so that the water turned black, and the fish died (Zakinan, 2019). The country's Health and Anti-Disease EXCO, Low Chee Leong has directed to Department of Environment (DOE) to take water samples and fish carcasses to carry out a strategy to identify the cause, but this way will take a few days or more to get the result.

After getting the results, according to the DOE examination, the pH in the Malim region was neutral and slightly elevated to alkaline levels at seven places along the Melaka River, except for the location directly in front of the Melaka River barrier, which recorded 4.7 mg/l of dissolved oxygen. Meleka housing, Local Government, Environment and Green Technology Exco, Datuk Tey Kok Kiew said the changes in the color of the water that turns black and dirty can be caused by several factors including 'flushing' which when the action is carried out at the mouth of the Melaka River, there is a lot of mud or sediment in the riverbed rising to the surface and causing the change.

Figure 2.1 Melaka River turned to blackish colour and fish died

2.4 Past research method

Various methods have been taken to ensure the purity of river water. To monitor water quality in Melaka River prior to devices that utilize internet of things (IoT) technology, air samples were collected and sent to a laboratory for testing. Grab sampling was employed in research to collect river water samples. Polyethylene bottles are used to collect water samples to capture air bubbles.

2.4.1 Traditional method

The traditional technique of evaluating water quality is to collect samples of water manually and submit them to the laboratory for testing and analysis. It is based on physical, chemical, and biological factors that are combined into a single value that ranges from 0 to 100 and involves 4 processes: (1) parameter selection, (2) transformation of the raw data into common scale, (3) providing weights and (4) aggregation of sub-index values. This procedure is time intensive, wastes manpower and it is not cost effective (Satya Sai et al., 2021).

2.5 Hydro Quality System (HydroQS)

HydroQS is a low-cost device that monitors river water quality. This device comprises five sensors: pH value, temperature, turbidity, dissolved oxygen, and total dissolved solids. These sensors are used to collect data on how each parameter changes over time. Solar panels will absorb sunlight as an energy source to generate electricity, which will be used to power the power bank. The device also incorporates IoT, the most modern technology capable of sending data across a network while allowing for simple interaction. Data will be delivered to the cloud using sensors that are WiFi-linked to the cloud and directly connected to the Internet. Figure 2.2 show the overall body of HydroQS for previous project.

Figure 2.2 Overall design of HydroQS

2.6 Water Quality Index

WQI is a grading system that uses a single term to assess the overall quality of water (Pujar et al., 2020). It contributes to the selection of the best treatment strategy for the condition at hand (Pujar et al., 2020). The quality of a river has a significant impact on people's lives. River water pollution has become a major concern in Malaysia because of urbanization and modernization, affecting the quality of water sources.

According to the National Water Quality Standards (NWQS), the Department of the Environment (DOE) has classified the water quality index into five classes (Class I, II, III, IV, and V), as shown in Table 2.3. Surface water quality could be gradually improved and upgraded to a better water class based on the standard values of 72 parameters in six water use classes. The Malaysia NWQS is a water quality standard premised on useful applications. Water can be considered suitable for a specific use if it falls within the range defined for the designated classes, as defined in Table 2.2. Water for domestic use, fisheries and aquatic propagation, cattle drinking, recreation, and agriculture were all included. The criteria also help in determining the sources of water quality problems, such as improperly treated water (Zaideen et al., 2017).

Table 2.1 Excerpt of the National Water Quality Standards for Malaysia

PARAMETER	UNIT	CLASS					
		I	II A	II B	III	IV	V
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.3	0.9	2.7	>2.7
Biochemical Oxygen	mg/l	1	3	3	6	12	>12
Demand	mg/l	10	25	25	50	100	>100
Dissolved Oxygen	mg/l	7	5-7	5-7	3-5	<3	<1
pH	-	6.5-8.5	6-9	6-9	5-9	5-9	-
Color	TCU	15	150	150	-	-	-
Electrical conductivity*	µS/cm	1000	1000	-	-	6000	-
Floatable	-	N	N	N	-	-	-
Odour	-	N	N	N	-	-	-
Salinity	ppt	0.5	1	-	-	2	-
Taste	-	N	N	N	-	-	
Total Dissolved Solid	mg/l	500	1000	-	-	4000	-
Total Suspended Solid	mg/l	25	50	50	150	300	300
Temperature	°C	-	Normal+2°C	-	Normal+ 2°C	-	-
Turbidity	NTU	5	50	50	-	-	-
Faecal Coliform**	count/100ml	10	100	400	5000(20000)^a	5000(20000)^a	-
Total Coliform	count/100ml	100	5000	5000	50000	50000	>5000

Notes:
N : No visible floatable materials or debris, no objectional odour or no objectional taste
* : Related parameters, only one recommended for use
** : Geometric mean
a : Maximum not to be exceeded

Table 2.2 National Water Quality Standards clasification

Class	Uses
Class I	Conversation of natural environment Water supply I – Practically no treatment necessary. Fishery I – very sensitive aquatic species.
Class II A Class II B	Water supply II – Conventional treatment. Fishery II – Sensitive aquatic species. 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

2.7 Type of Water Quality Parameters

In industrial facilities, there are occasions when water needs to be treated to guarantee that the quality is at an appropriate level for a variety of essential operations. This study will focus on monitoring river water quality based on physical and chemical parameters in the saltwater area in Melaka River. There are five(5) parameters that will be focused to monitor periodically which are pH value, temperature, turbidity, dissolved oxygen(DO) and Total Dissolved Solid(TDS).

2.7.1 Physical Parameters

2.7.1.1 Turbidity

Turbidity is the cloudiness of water. It measures the rate at which light will pass through water. It is brought on by particulate matter suspended in water, such as clay, silt, organic matter, plankton, and other particles. Drinking water turbidity is unattractive aesthetically because it makes the water appear unappetizing.

The following statements sum up the effects of turbidity:

- It might raise the price of treating water for different purposes.
- The hazardous germs may find shelter in the particles, protecting them from cleaning operation.
- Materials in suspension can clog or harm fish gills, reducing the fish's growth rates, diminishing its resistance to illnesses, interfering with egg and larval maturation, and interfering with the effectiveness of fish capture techniques.
- Heavy metals like mercury, chromium, lead, and cadmium as well as many toxic organic pollutants like polychlorinated biphenyls (PCBs), polycyclic aromatic

hydrocarbons (PAHs), and numerous pesticides can all be adsorbed to suspended particles.

- Higher turbidity boosts water temperatures due to the fact that suspended particles absorb more solar heat, which reduces the amount of food that is readily available.

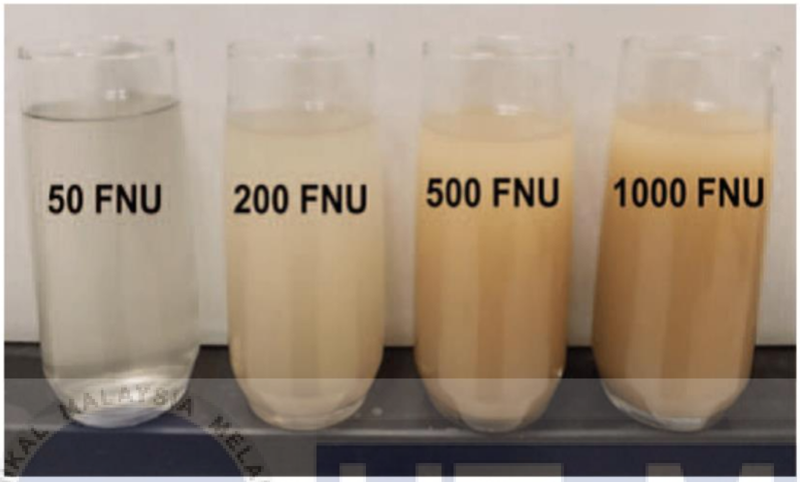


Figure 2.3 A set of water samples showing increasing turbidity(left to right), as well as changes color

2.7.1.2 Temperature

Temperature affects chemical reactions, odors, solubility, viscosity, and palatability (Rice et al.,2012). As a result, temperature affects the processes of sedimentation, chlorination, and biological oxygen demand (BOD) (Davis ML,2010). It also has an impact on how the dissolved heavy metals in water are bios orbed (Abbas et al.,2014). Most people believe that water tastes best when it is between 10-15°C in temperature (Omer et al.,2019).

Water temperature plays a significant role in affecting physical, chemical and biological processes in water bodies (including the flowing waters like rivers), and thus the 10 concentration of many variables (ANZECC 1992). High water temperature activates the rate of chemical reactions with effect to evaporation and volatilisation of substances from water. As water temperature increases, the solubility rate of gases in water such as Oxygen (O2) decreases. Moreover, the respiration rates of aquatic organisms increase in warm water which lead to greater consumption of O2 and increase the rate of decomposition (Chapman and Kimstach 1992). An abrupt change in water temperature can lead to greater destruction of aquatic life. On the other hand, excessively high water temperature may lead to the problem of unwanted growth of water plants and wastewater fungus (Metcalf and Eddy 1991). Surface water temperature can be influenced by factors such as geographical position, seasonality, diurnal period, circulation of air, quantity of cloud cover, depth of water and its flow rate. In general, the temperature of surface water varies within the range of 0°C to 30° C; however, abnormally high temperatures can arise from discharges of industrial effluent and sewage treatment plants (Chapman and Kimstach 1992).

2.7.1.3 Total Dissolved Solid (TDS)

In water, solids might be in suspension or in solution (Burton et al., 2003). By passing the water sample through a glass fiber filter, it is possible to distinguish between these two forms of solids . By definition, the dissolved solids flow through the filter with the water while the suspended solids are kept on top of the filter . The solids will remain as a residue if the filtered portion of the water sample is put in a tiny dish and allowed to evaporate. Total dissolved solids, or TDS, is the term most commonly used to describe this substance. 23 Water can be classified by the amount of TDS per liter as follows;

- Freshwater: 5000 mg/L TDS
- Brackish water: 1500-5000 mg/L TDS
- Saline water: >5000 mg/L TDS

2.7.2 Chemical Parameters

2.7.2.1 pH

One of the most crucial aspects of water quality is pH. It is described as the negative logarithm of the hydrogen ion concentration. The strength of an acidic or basic solution is represented by this dimensionless number. The pH level of water is a gauge of how acidic or basic it is. Both basic and acidic water contain greater quantities of hydrogen (H+) and hydroxyl (OH) ions than usual. According to Figure 2.5, a pH value of less than 5 denotes a very acidic substance, a pH value of 5 to 6 indicates a neutral substance, a pH value of 6 to 7 denotes a somewhat alkaline substance, and a pH value of 7 to 8 denotes an extremely basic or strongly alkaline substance (Vibhute, 2020). Clean water should have a pH between 7.0 and 8.0 (Praditya Nafis Muhammad et al., 2021).

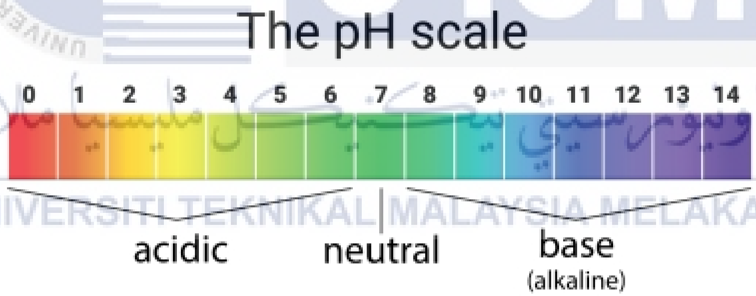


Figure 2.4 The pH scale

Impact of pH Level on Aquaculture

Rapid changes in water pH can have a significant impact on numerous different creatures. Fish, eggs, and fry have all evolved in water; they need a particular pH and perish if the pH shifts dramatically. In addition to dissolved carbon dioxide, other variables that affect pH include hardness and alkalinity. The possibility that additional elements like ammonia, heavy metals, cyanides, and hydrogen sulfide might be affected led to the hazardous effects. As indicated in Table 2.1, all these occurrences alter the pH level in aquaculture and influence fish health. Most freshwater fish can survive in a pH range of 7.5 to 8.5. However, marine fishes require a pH range of 7.5 to 8.5 to survive (Akhter et al., 2021).

Table 2.3 Impact of pH level in aquaculture

Value of pH	**Impact on Warm-Water Fish**
Less than 4.0	Reach to the point of acid death
4.0 to 5.0	Not productive
6.5 to 9.0	Fish production desirable range
9.0 to 11.0	Slow growth
Greater than 11.0	Reach to an alkaline death

2.7.2.2 Dissolved Oxygen (DO)

One of the most crucial indicators of the water quality in streams, rivers, and lakes is dissolved oxygen, or DO. It is an important indicator of water pollution. The water quality improves as the dissolved oxygen concentration increases. Water quality regulations set by the Department of the Environment (DOE) state that a river's water quality should be more than 7 mg/L. Oxygen is particularly sensitive to temperature and just slightly soluble in 25 water. For instance, the saturation concentration is 14.6 mg/L at 0°C and around 9 mg/L at 20°C. According to Che Osmi et al. (2018), less than 3 mg/L of DO is detrimental to aquatic life, while 5 mg/L is the optimum level. According to Krishnakumar et al. (2017), this parameter needs to be kept in water at a minimum concentration of 4 mg/l in order to support the growth of aquatic life and other planktonic populations. Wind and aeration cause amounts of dissolved oxygen. The DO level must be maintained within a specific range in order to maintain the stability of aquatic creatures and fish life.

2.8 Types of Water Quality Sensors

A sensor is a device that detects input of any kind from the physical world and reacts to it. Light, heat, motion, moisture, pressure, and a variety of other environmental phenomena can all be inputs. The most important characteristics of a sensor are precision, resolution, linearity, and speed (Satya Sai et al., 2021). The performance of sensors is optimized via calibration. The performance may be enhanced by minimizing structural flaws in the sensor outputs (Das & Jain, 2017). In monitoring water quality, the use of good sensors is one of the important factors for obtaining good data. The installation of sensors as devices used on HydroQS is done based on the appropriate type of water quality sensor. The following are the list of types of sensors based on the parameters focused:

2.8.1 pH Sensor

It is described as the negative log of the hydrogen ion concentration. The pH scale is logarithmic and ranges from 0 to 14. Measurements of hydrogen ion concentration are referred to as pH. With the help of a pH sensor, a bleach's tartness or alkalinity can be determined by measuring the density of hydrogen ions in the chemical. (Chowdury et al., 2019) As pH decreases, water becomes more acidic, and as H+ ion concentration increases, 26 water becomes more alkaline (Pujar et al., 2020). There are several types of pH sensors that are suitable for monitoring the quality of water. The choice of pH sensor depends on various factors such as the application, measurement requirements, budget, and environmental conditions.

2.8.2 Temperature sensor

Temperature is an important environmental and water quality parameter because it controls the types and amounts of aquatic life, limits the maximum dissolved oxygen concentration of the water, and affects the speed of chemical and biological reactions. Temperature sensors find widespread use in various applications, ranging from industrial processes and environmental monitoring to consumer electronics and healthcare.

2.8.3 Turbidity Sensors

A turbidity sensor is a device used to measure the cloudiness or haziness of a fluid caused by large particles or suspended solids. Turbidity is an important parameter in water quality monitoring, as it can indicate the presence of impurities, sediments, or other contaminants in water. The level of turbidity in water can affect its clarity and overall quality.

Turbidity sensors work by emitting light into a water sample and then measuring the amount of light that is scattered or absorbed by particles in the water. The presence of suspended solids or particles in the water causes the light to scatter, and the turbidity sensor detects this scattering of light to quantify the turbidity.

2.8.4 Dissolved Oxygen Sensor

A dissolved oxygen (DO) sensor is a device used to measure the concentration of oxygen dissolved in a liquid, typically water. Monitoring dissolved oxygen levels is crucial in various environmental, industrial, and biological applications, especially in aquatic ecosystems. The amount of dissolved oxygen in water is an important indicator of water quality and is essential for the survival of aquatic organisms.

2.8.5 Total Dissolved Solid (TDS) Sensor

The function of Analog TDS Sensor used in this study is to measure the value of Total Dissolved Solids (TDS) in water. The use of the TDS sensor is a professional instrument because this sensor has high accuracy in the process of measuring and sending data directly to the controller system. The TDS sensor probe has the advantage of being waterproof and can be used in water for a long time.

CHAPTER 3

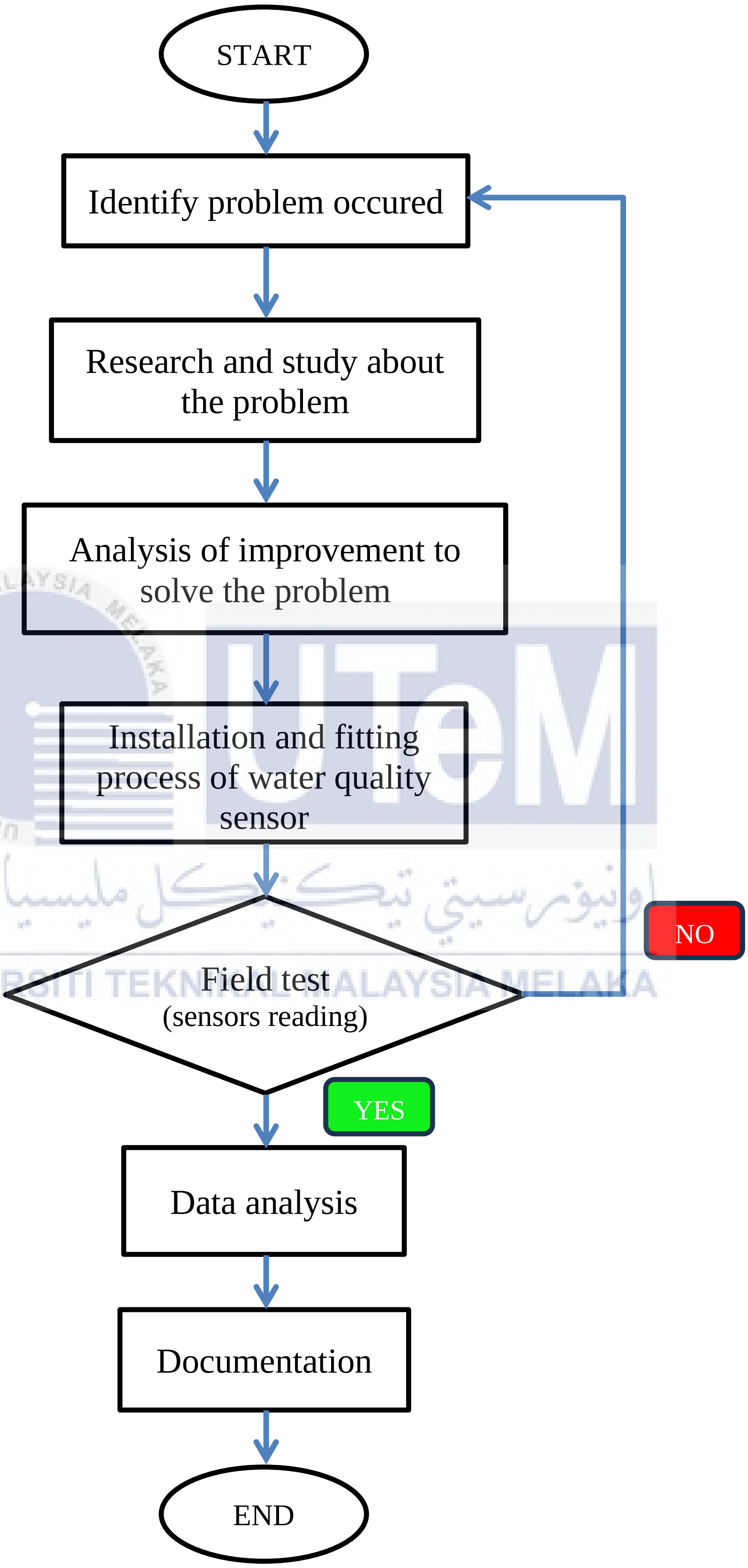
METHODOLOGY

3.1 Introduction

The methodology refers to the procedure for conducting an analysis. It is a strategy for achieving objectives through planning, data collection, research, and analysis to demonstrate the validity of the study. The methodical nature of the research will increase as a result of the methodology, and the goals-oriented nature of the scientific approach will increase. This study will provide an overview of the entire procedure, including sample collection, field research, and data analysis.

In general, precision and reliability are considered the two conflicting requirements of any water quality sensors model for monitoring water quality at any environment. Here, precision refers to how consistent results are, when measurements are repeated. Precise values differ from each other because of random error, which is a form of observational error(Helmenstine, 2020). Reliability is the degree which a measurement instrument gives the same results each time that it is used, assuming that the underlying thing being measured does not change. (Crossman, 2019).

3.2 Project Planning



3.3 Project method

When a project title is given, problem areas are discovered. Objectives, scopes, and plans include a clear description of how to solve problems with research. The internet, journals, and papers served as the sole sources of data for this study. The process of data analysis is based on recommendations issued by the Department of Environment Malaysia. It is an answer to this investigation or undertaking.

3.3.1 Specification of water quality sensors including model, manufacturer brand and cost.

i. pH sensor

It is described as the negative log of the hydrogen ion concentration. The pH scale is logarithmic and ranges from 0 to 14. Measurements of hydrogen ion concentration are referred to as pH. With the help of a pH sensor, a bleach's tartness or alkalinity can be determined by measuring the density of hydrogen ions in the chemical. (Chowdury et al., 2019). As pH decreases, water becomes more acidic, and as H+ ion concentration increases, water becomes more alkaline (Pujar et al., 2020). There are several types of pH sensors that are suitable for monitoring the quality of water. The choice of pH sensor depends on various factors such as the application, measurement requirements, budget, and environmental conditions. The model of pH sensor used on the HydroQS device is the industrial type of pH sensor, H-101 model manufactured by DfRobot Company, as shown in Figure.

Figure 3.1 H-101 pH DfRobot sensor

Table 3.1 The specifications of the pH sensor

Model	H-101
Manufacturer brand	DfRobot
Cost (MYR)	268.42
Probe Type	Industrial Grade
Detection Range	0~14
Temperature Range	: 0~60°C
Accuracy	± 0.1pH (25 °C)
Response Time	<1min
Probe Life	7*24hours >0.5 years (depend on the water quality)
Supply Voltage	3.3~5.5V
Output Voltage	0~3.0V
Probe Connector	BNC
Signal Connector	PH2.0-3P
Measurement Accuracy	±0.1@25℃
Dimension	42mm*32mm/1.66*1.26in

ii. Temperature sensor

Temperature sensors provide more accurate readings when compared to the use of mercury thermistors to take current temperature readings. The temperature sensor used on the HydroQS device measures river water temperature. The temperature sensor can measure the temperature value with an accuracy of 0.1. The model for this temperature sensor is DS18B20, as shown in Figure 3.7 and the specification of the temperature sensors shown in Table 3.2.

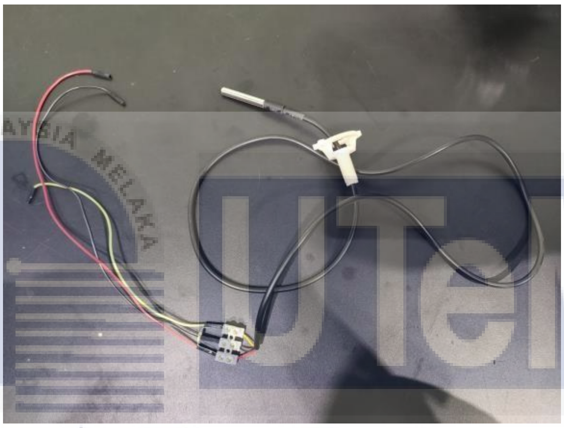


Figure 3.2 Temperature sensor for Arduino

Table 3.2 Specification of DfRobot temperature sensor

Model	DS18B20
Manufacturer brannd	DfRobot
Cost(MYR)	86.57
Temperature sensor supply voltage	3.0V ~ 5.5V
Temperature sensor resolution	9 to 12 adjustable resolution
Temperature range	-55°C ~ +125°C
Temperature Sensor Output Lead	Yellow(DATA) Red(VCC) and Black(GND)
Adapter Cables	DATA, VCC, BLK,
Suitable platform	for Arduino and Raspberry Pi
Cable Diameter	$4mm$ (0.16)
Length	$95cm$

iii. Turbidity sensor

The turbidity sensor used on this HydroQS device measures the turbidity value to monitor water quality. The ability of this sensor is that it can detect particles suspended in water by measuring the transmittance of light and the rate of scattering that varies with the number of total suspended solids (TSS) in the water. The turbidity rate will increase as the TSS increases. The sensor used in this study is a type of Arduino turbidity sensor F2A09 produced by DfRobot Company which has two analog and digital signal outputs, as shown in Figure 3.8 below.

Figure 3.3 Arduino turbidity sensor

The specifications of DfRobot turbidity sensor are shown in Table 3.3 below which consists of model, cost, response time and other details.

Table 3.3 Specification detail for Turbidity sensor

Model	Arduino turbidity sensor F2A09
Manufacturer brand	DfRobot
Cost(MYR)	46.70
Operating Voltage	5V DC
Operating Current	40mA (MAX)
Response Time	<500ms
Insulation Resistance	100M (Min)
Output Method	Analog
Analog output	0-4.5V
Digital Output	High/Low level signal (can adjust the threshold value by adjusting the potentiometer)
Operating Temperature	5℃~90 ℃
Storage Temperature	-10℃~90℃
Weight	30g
Adapter Dimensions	38mm*28mm*10mm/1.5inches *1.1inches*0.4inches

iv. Dissolved oxygen sensor

DfRobot's Analog Dissolved Oxygen sensor kit can easily connect with other microcontrollers. The sensor used on the HydroQS device to measure the amount of oxygen dissolved in the water is shown in Figure 3.9 below. The specifications for the dissolved oxygen sensor shown in Table 3.3 below are very suitable for use in this study's water quality monitoring system.

Figure 3.4 Dissolved oxygen sensor by DfRobot

Table 3.4 Dissolved oxygen sensor by DfRobot specification details

Model	SEN0237-A
Manufacturer brand	DfRobot
Cost (MYR)	797.20
Probe type	Galvanic Probe
Detection Range	0~20 mg/L
Temperature Range	0~40 ℃
Response Time	Up to 98% full response, within 90 seconds (25℃)
Pressure Range	0~50 PSI
Electrode Service Life	1 year (normal use)

Maintenance Period	• Membrane Cap Replacement Period:
	  ○ 1~2 months (in muddy water);
	  ○ 4~5 months (in clean water)
	• Filling Solution Replacement Period: Once every month

Cable Length	2 meters
Probe Connector	BNC
Supply Voltage	3.3~5.5V
Output Signal	0~3.0V
Cable Connector	BNC
Signal Connector	Gravity Analog Interface (PH2.0-3P)
Dimension	42mm * 32mm/1.65 * 1.26 inches

v. Total dissolved solid sensor

The function of Analog TDS Sensor used in this study is to measure the value of Total Dissolved Solids (TDS) in water. The use of the TDS sensor, as shown in Figure 3.10, is a professional instrument because this sensor has high accuracy in the process of measuring and sending data directly to the controller system. The TDS sensor probe has the advantage of being waterproof and can be used in water for a long time. The specifications for the Analog TDS sensor used in the water quality monitoring study are shown in Table 3.4.

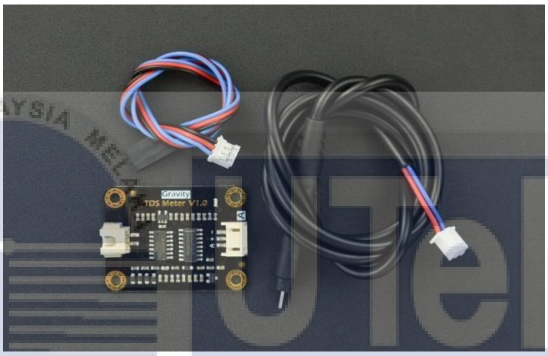


Figure 3.5 Analog TDS Sensor for Arduino

Table 3.5 Analog TDS Sensor specification

Model	TDS sensor for Arduino
Manufacturer brand	DfRobot
Cost(MYR)	90.00
Input Voltage	3.3V to 5.5V DC
Output Voltage	0V to 2.3V DC
Current Consumption	3mA to 6mA
TDS Measuring Range	0 to 1000ppm
TDS Measuring Accuracy	±10% F.S (25°C)
Module: MCU Interfacing Port	PH2.0-3P
Module: Probe Interfacing Port	XH2.54-2P
Probe: No. of Needles	2
Probe: Length	830mm
Probe: Connection Interface	XH2.54-2P
Probe: Colour	Black
Probe: Waterproof Rating	IP67

3.3.2 HydroQS structure design and placement

This section will describe the position of water quality sensors and other electronic components in a HydroQS body. Figure 3.6 illustrates the location where the water quality sensors and other electronic items such as, Arduino boards and battery are placed in the HydroQS body. All sensors will be on the lower part of the HydroQS body to ensure the sensors are in contact with the water surface and data can be intepret.

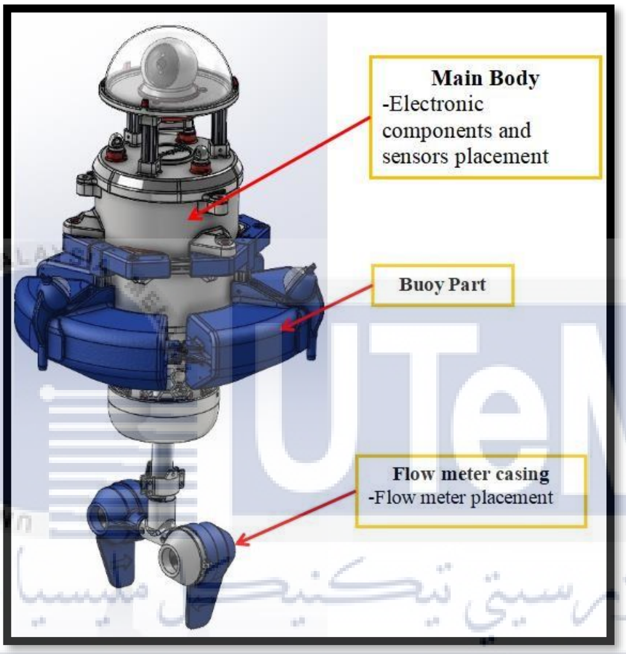


Figure 3.6 HydroQS sensors and electronic components placement

Figure 3.7 shows the buoy design structure used on the HydroQS device. There are standard parts and also custom parts that are used in the creation of the buoy.

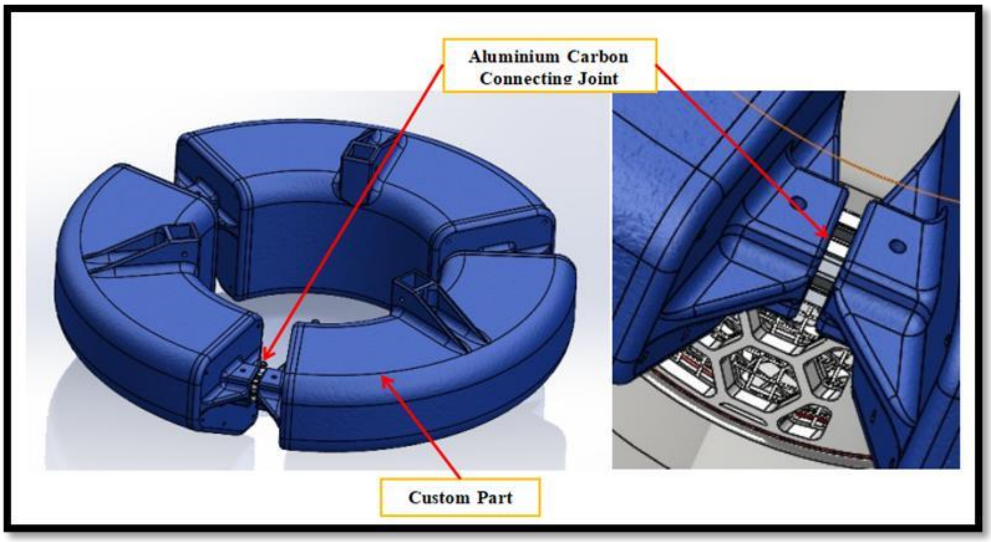


Figure 3.7 HydroQS Buoy structure design

Figure 3.8 shows the part of water quality sensors placed at the bottom of the main body with labels.

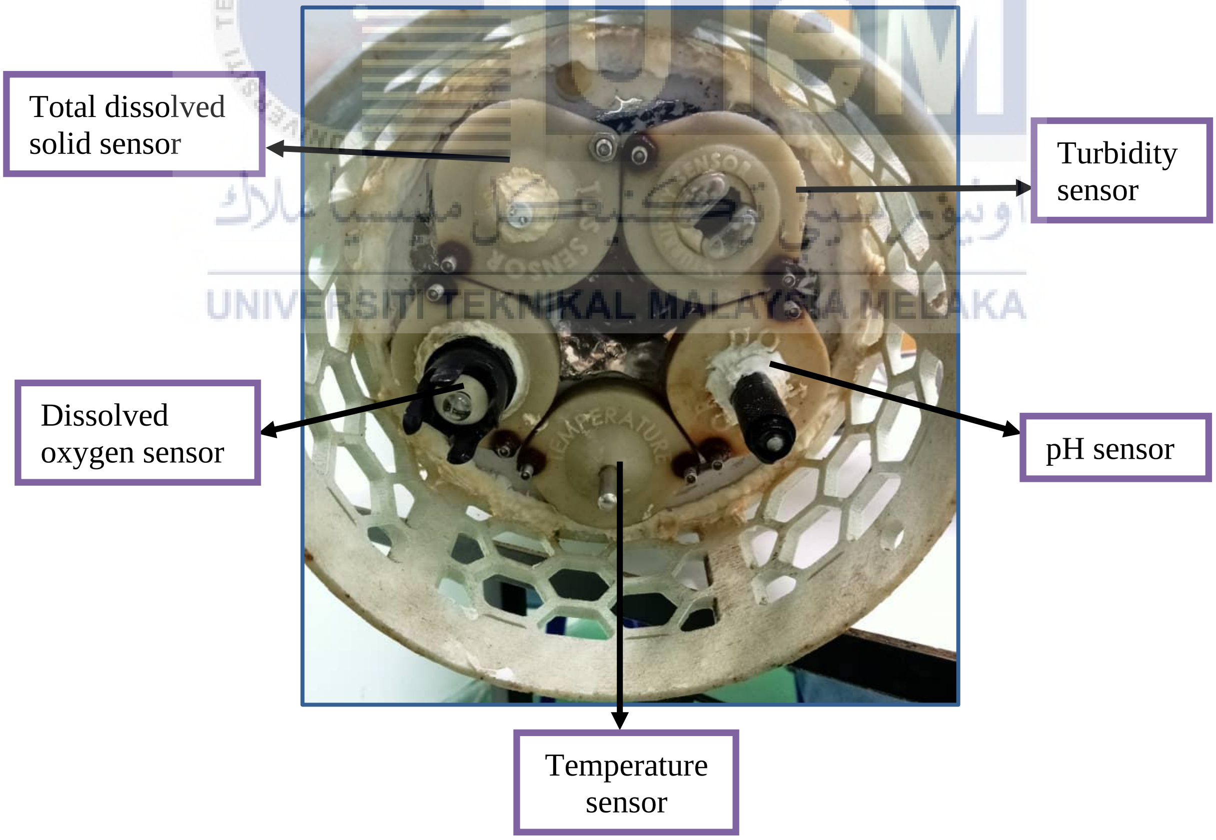
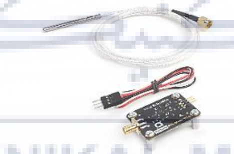


Figure 3.8 Placement of water quality sensors

The purpose of morphological chart is to determine and decide the best and low cost sensors. The factors that has been considered are costing, durability and accuracy. Table 3.6 shows the types of watwr quality sensors that has been choose with different type of manufacturer brand.

Table 3.6 Morphological chart for water quality sensors

Function/sensors	Option 1	Option 2	Option 3	Option 4
pH sensor	**GAOHOU**  Cost(MYR): 148.61 Lifespan: 3 years Accuracy:± 0.25	**McMaster-Carr**  Cost(MYR): 341.67 Lifespan: 3 years + Accuracy: ± 0.1	**Vernier**  Cost(MYR): 636.43 Lifespan: 3 years Accuracy: ± 0.2	**AtlastScientific**  Cost(MYR): 1,486.51 Lifespan: 4 Years+ Accuracy:+/- 0.002
Temperature sensor	**Vernier**  Cost(MYR): 278.73 Lifespan: 4 years+ Accuracy: ±0.01	**AtlasScientific**  Cost(MYR): 139.32 Lifespan: 3 years Accuracy: ± 0.5	**Twidec**  Cost(MYR): 60.35 Lifespan: 15 years Accuracy: ± 0.05	**The Connected Shop**  Cost(MYR): 448.00 Lifespan: 3 years+ Accuracy: ± 0.1

Turbidity sensor	**KEYES**  Cost(MYR): 58.25 Lifespan: 3 years + Accuracy: ±0.05	**Homemaxs**  Cost(MYR): 60.30 Lifespan: 3 years Accuracy: ±0.1	**Seeed**  Cost(MYR): 111.872 Lifespan: 3 years Accuracy: ±0.1	**Zwinsoft**  Cost(MYR): 10,298.78 Lifespan: 10years+(infrared light) Accuracy: ±0.02
Dissolved oxygen sensor	**AtlasScientific**  Cost(MYR): 1,133.46 Lifespan: 4 years + Accuracy: ±0.02	**HFDR**  Cost(MYR): 1,096.26 Lifespan: 4 years Accuracy: ±0.5	**AtlasScientific**  Cost(MYR): 696.25 Lifespan: 4 years + Accuracy: ±0.02	**DfRobot**  Cost(MYR): 784.50 Lifespan: 1 year(electrode)(normal use) Accuracy: ±0.1

Total dissolved solid sensor	Qinlorgo	Seeed	CQRobot	Winyuyby
	 Cost(MYR): 68.10 Lifespan: 4 years after calibration Accuracy: ±0.1	 Cost(MYR): 66.38 Lifespan: 4 years Accuracy: ±0.3	 Cost(MYR): 37.09 Lifespan: 3 years Accuracy: ±0.2	 Cost(MYR): 47.12 Lifespan: 4years after calibration Accuracy: ±0.1

Based on observation, the water quality sensors were chosen and decided using morphological chart based on factors such as cost, lifespan, and accuracy. The longer the lifespan, the higher reliability of the sensors while the lower value of accuracy measurement, the higher accuracy of sensors reading.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This section will show how the HydroQS device works in monitoring freshwater quality. In addition, all data recorded by the HydroQS device will be stated in this title based on the analysis made. There is main processes before obtaining data using this device, which is checking sensors' function ability with calibration process. The data parameters collected using this device will be used as analysis to be compared with the parameters issued by the Department of Environment (DOE).

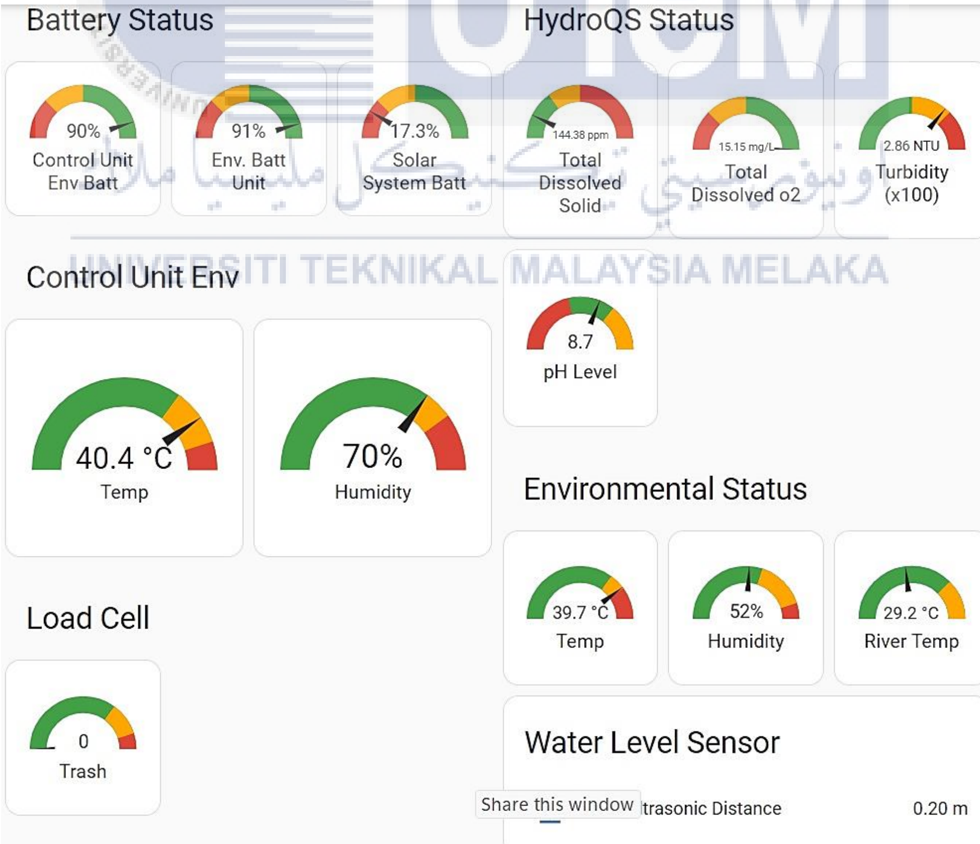


Figure 4.1 Home Assistant Applicaion result display

Based on the screen display on Home Assistant Application in Figure 4.1 above and Table 4.1 below, the sensor's pH reading shows a value of 8.70. The turbidity sensor reading is 2.86 NTU. In contrast, the reading for temperature sensor is 29.2 Celsius. The Dissolved Oxygen (DO) sensor reading is 15.15 mg/l while the reading value for Total Dissolved Solid (TDS) sensor is 144.38 ppm. Before conducting a test, to ensure that the water quality sensors are working effectively, the sensor calibration process should be performed to ensure the readings taken are accurate. Table 4.1 and Table 4.2 show the difference between calibration reading data and testing reading data.

After calibration and confirming all the sensors is functioning, the experiment continued with field test to check the reliability of HydroQS water quality sensors. Figure 4.2 shows the field test was held at Sungai Melaka.

Figure 4.2 Field test at Sungai Melaka

Table 4.1 Sensors function ability check result display(calibration result)

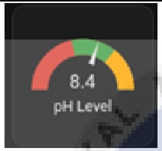
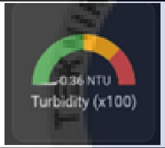
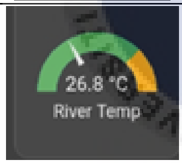
Types of sensors	Display results from the application (Calibration result)	Full display on Home Assistant application
pH sensor		
Turbidity Sensor		
Temperature Sensor		
Dissolved Oxygen Sensor		
Total Dissolved Solid Sensor		

Table 4.2 Reading data for water quality sensors during field test.

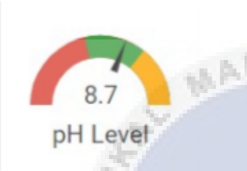
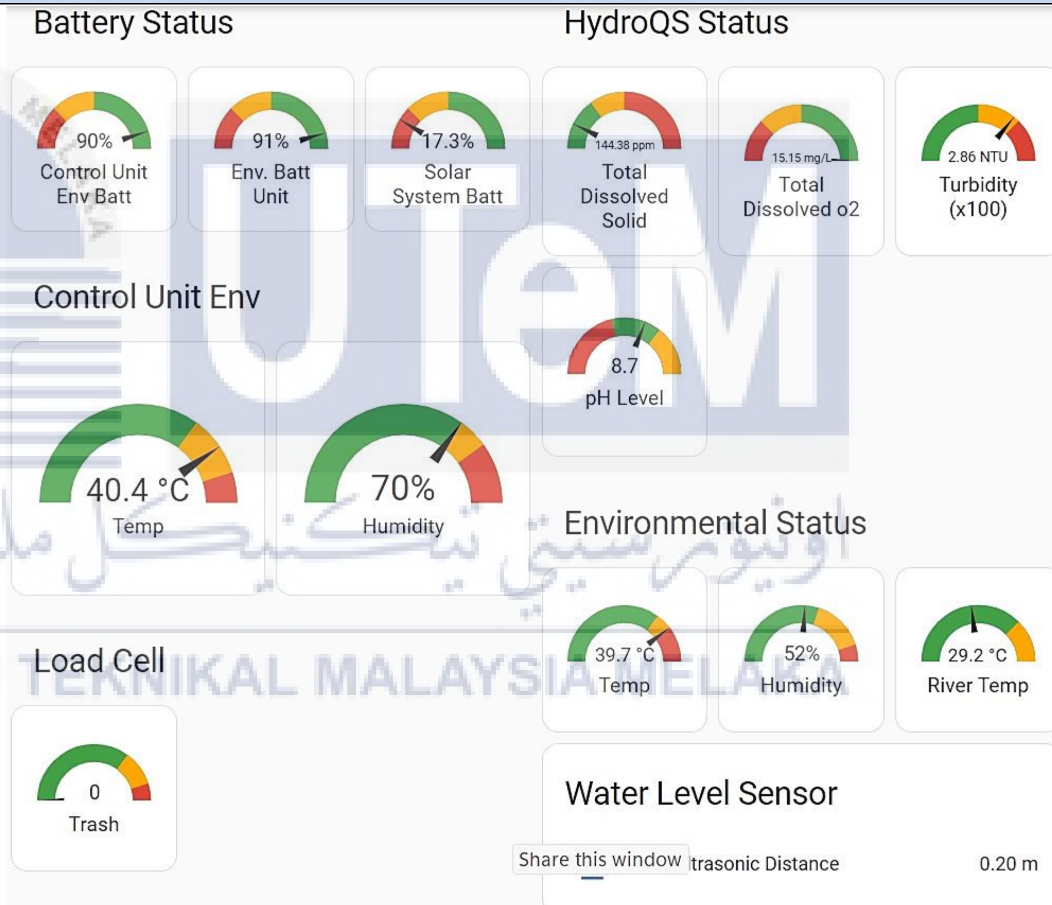
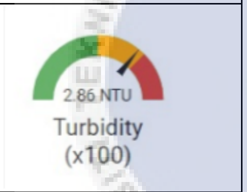
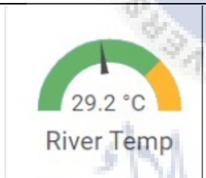
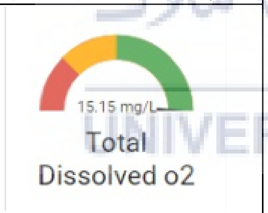
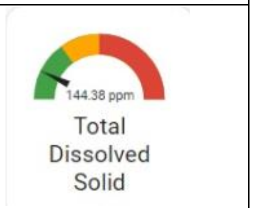
<table>
<tr><th>Types of sensors</th><th>Display results from the application (Field test result)</th><th>Full display on Home Assistant application</th></tr>
<tr><td>pH sensor</td><td>
</td><td rowspan="5">
</td></tr>
<tr><td>Turbidity Sensor</td><td>
</td></tr>
<tr><td>Temperature Sensor</td><td>
</td></tr>
<tr><td>Dissolved Oxygen Sensor</td><td>
</td></tr>
<tr><td>Total Dissolved Solid Sensor</td><td>
</td></tr>
</table>

Table 4.3 shows the difference and error between field test reading data taken and calibration reading data.

Table 4.3 Water quality sensors' percentage error during calibration and field test

Parameter	**Calibration reading data (using special tools & solution)**	**Field reading data**
pH	8.40	8.70
Percentage Error	$\left\lvert \frac{8.28-8.70}{8.70} \right\rvert \times 100\% = 4.83\%$	
Turbidity	0.36 NTU	2.86 NTU
Percentage Error	$\left\lvert \frac{0.36-2.85}{2.86} \right\rvert \times 100\% = 87.41\%$	
Temperature	26.8℃	29.2℃
Percentage Error	$\left\lvert \frac{26.8-29.2}{29.2} \right\rvert \times 100\% = 8.23\%$	
Dissolved Oxygen	7.62 mg/L	15.15 mg/L
Percentage Error	$\left\lvert \frac{7.62-15.15}{15.15} \right\rvert \times 100\% = 49.70\%$	
Total Dissolved Solid	78.81 ppm	144.38 ppm
Percentage Error	$\left\lvert \frac{78.81-144.38}{144.38} \right\rvert \times 100\% = 45.41\%$	

4.2 Comparison of sensors costing

After analyzing the specification details and choosing the suitable sensors in methodology, there are comparisons that have been made between the previous project total cost for sensors and the current project, which are shown in Table 4.4.

Table 4.4 Comparison of sensors costing

Sensors	Total Cost for previous project (MYR)	Total cost for current project (MYR)
pH	286.42	341.67
Temperature	86.57	60.35
Turbidity	46.70	58.25
Dissolved Oxygen	797.20	696.25
Total Dissolved Solid	90.00	47.12
Total Cost (MYR)	**1306.89**	**1203.64**

4.2.1 Percentage difference of total cost

$$\frac{1306.89 - 1203.64}{\left[\frac{1306.89 + 1203.64}{2}\right]} x\ 100\% = 8.23\%$$

Based on the table above, the total cost of water quality sensors for the current project is 8.23% lesser than previous project.

4.3 Field test

4.3.1 Data analysis of water quality sensors in 24 hours

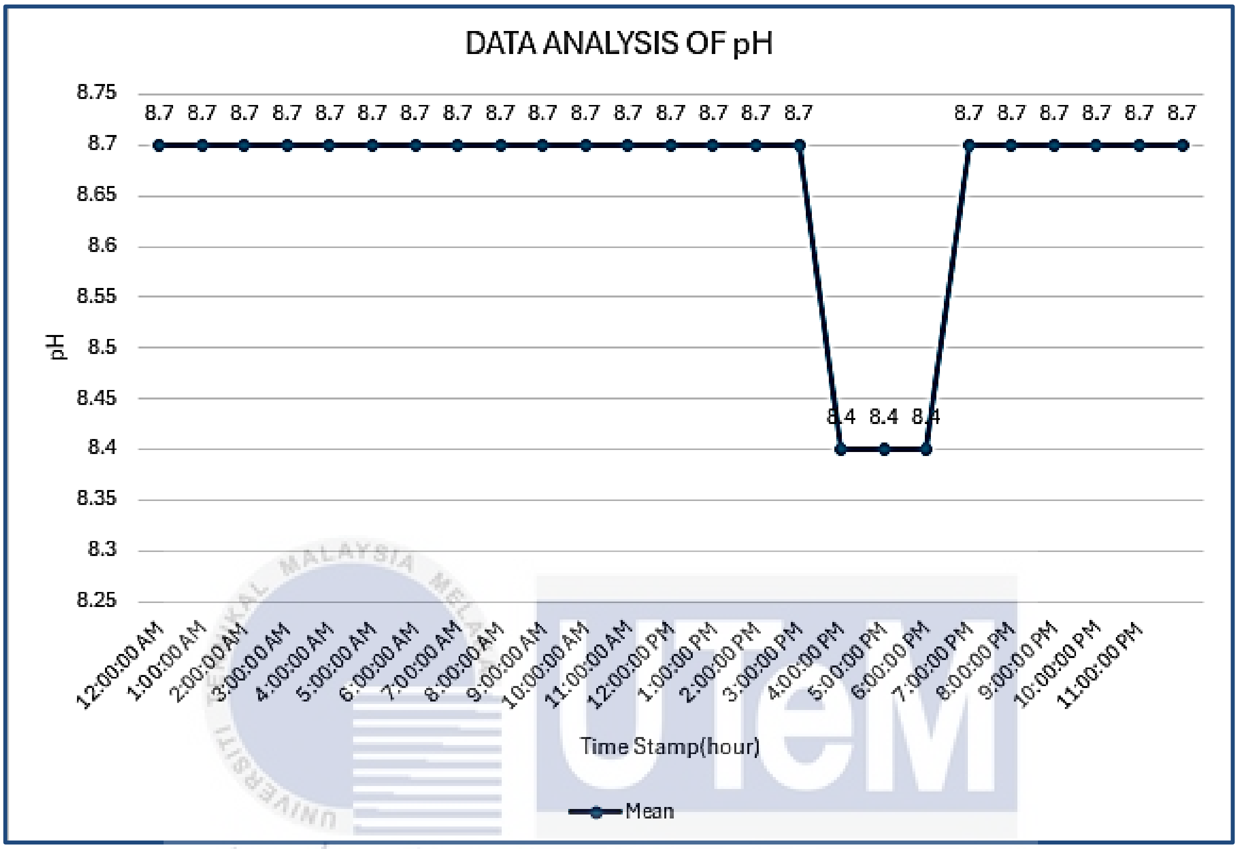


Figure 4.3 Real-time reading data pH value for 24 hours

Based on the graph, the range value of pH recorded is at 8.4 to 8.7 in 24 hours. According to NWQS , the value in range >7 pH which in Class I stated that the water supply is conservation of natural environment. This could imply that the water source is relatively clean and doesn't require extensive treatment. It's essential to ensure that such sources remain unpolluted to maintain water quality. Monitoring and preventing pollution, as well as protecting watersheds, are crucial steps in conserving clean water sources.While not as delicate as species in Fishery I, the sensitivity of aquatic species suggests that the ecosystem is delicate and easily disrupted. Conservation efforts should focus on protecting the habitat, maintaining water quality.

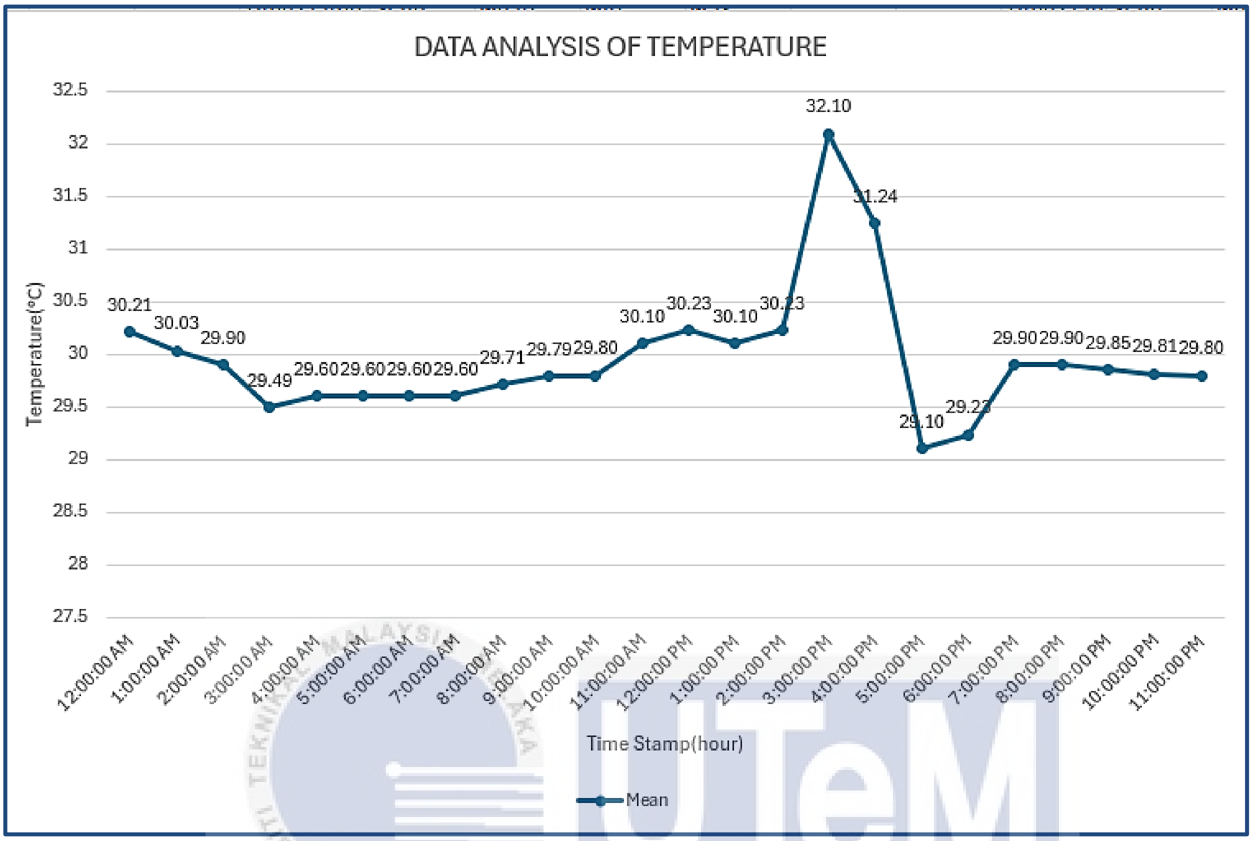


Figure 4.4 Real-time reading data temperature value for 24 hours

This graph shows that the maximum value of temperature sensor reach at 32.10 Celsius then it drops drastically to 29.10 but then, its continue maintain at range 29 Celcius.

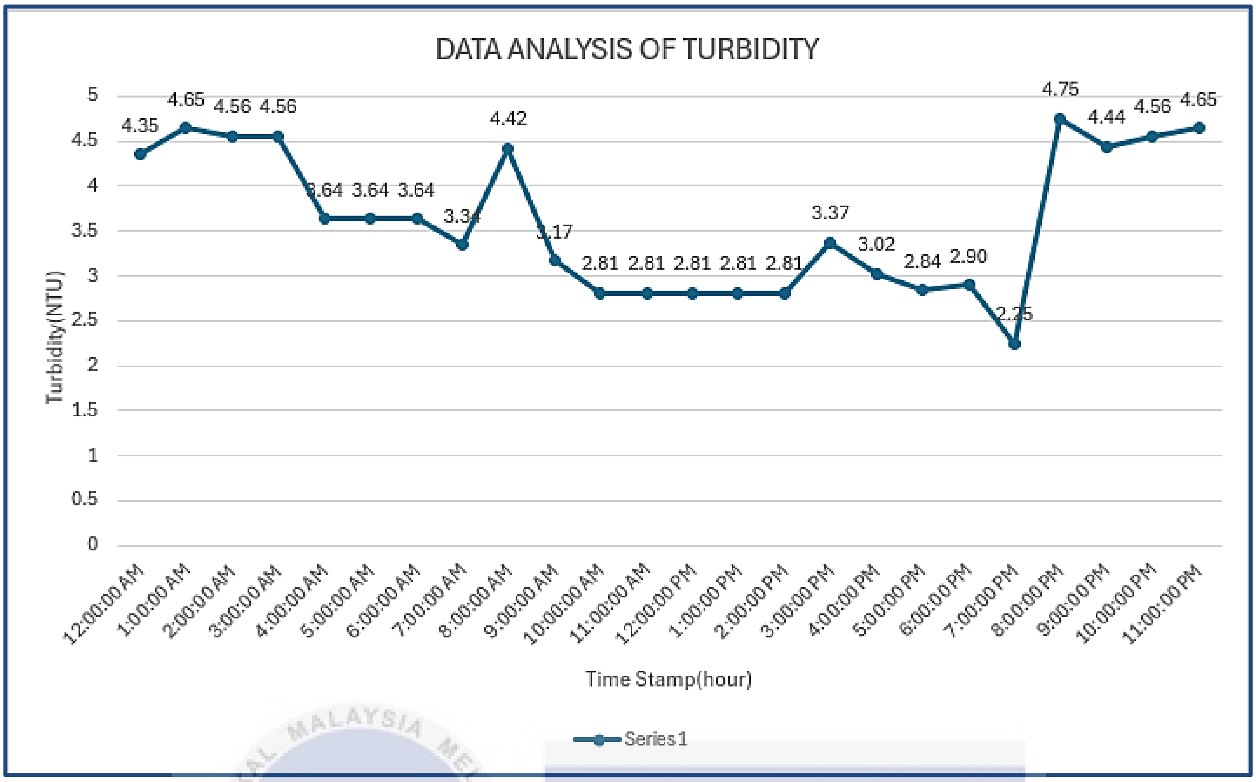


Figure 4.5 Real-time reading data turbidity value for 24 hours

Based on the graph, the reading of turbidity sensor was not stable but the value still in good condition which is below range 5mg/L according to NWQS. It is in Class I which indicates that the water quality is considered excellent and suitable for supporting sensitive ecosystems. It should meet strict environmental standards and be free from major pollution or disturbances.

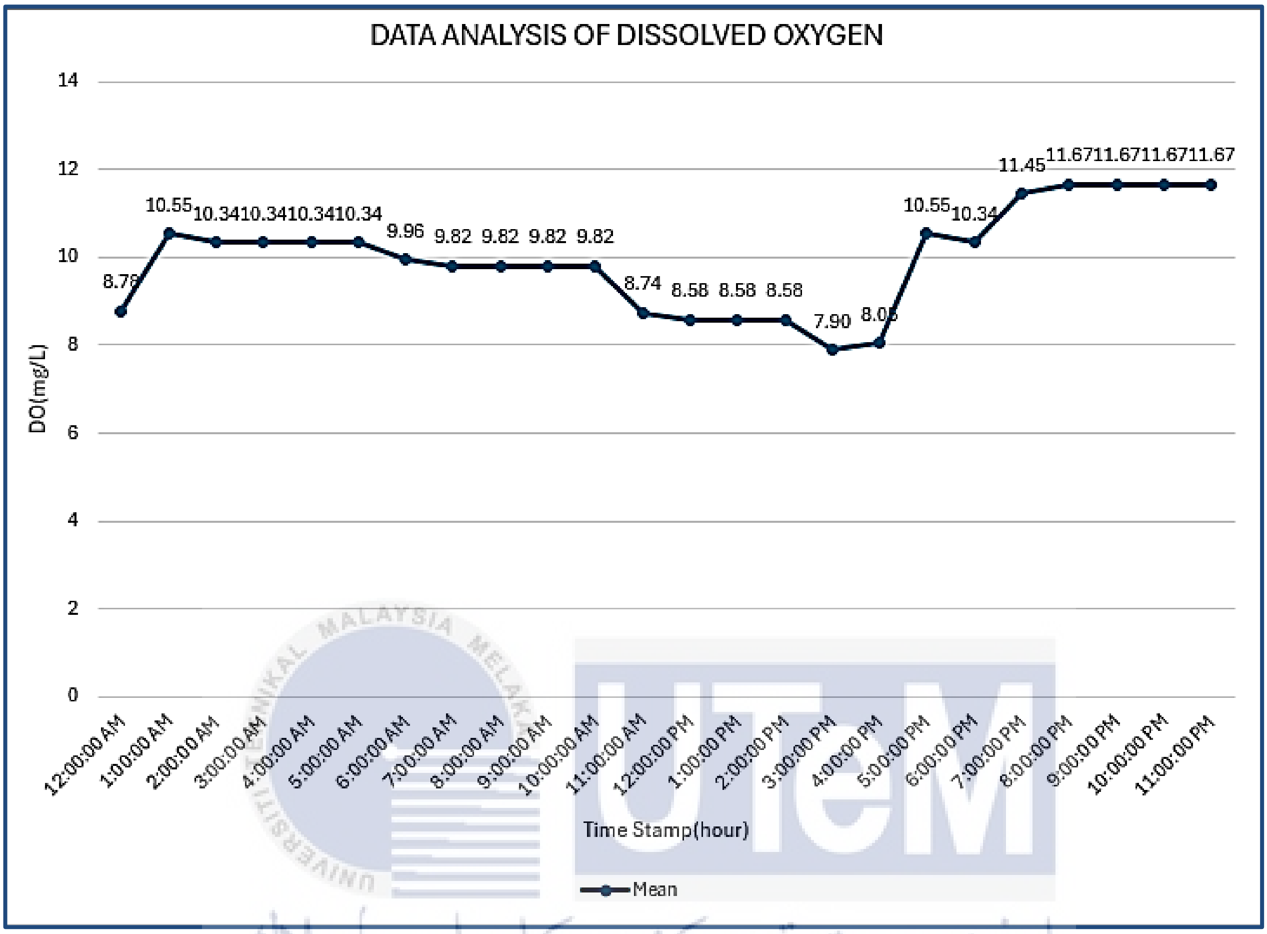


Figure 4.6 Real-time reading data dissolved oxygen value for 24 hours

Based on the reading of the Dissolved Oxygen value graph recorded in 24 hours, the maximum value is 11.67 mg/L at 11.00 p.m which is >7 mg/L. According to National Water Quality Standards(NWQS) which is in Class I stated that the the water source is relatively clean and doesn't require extensive treatment. It's essential to ensure that such sources remain unpolluted to maintain water quality. Monitoring and preventing pollution, as well as protecting watersheds, are crucial steps in conserving clean water sources.

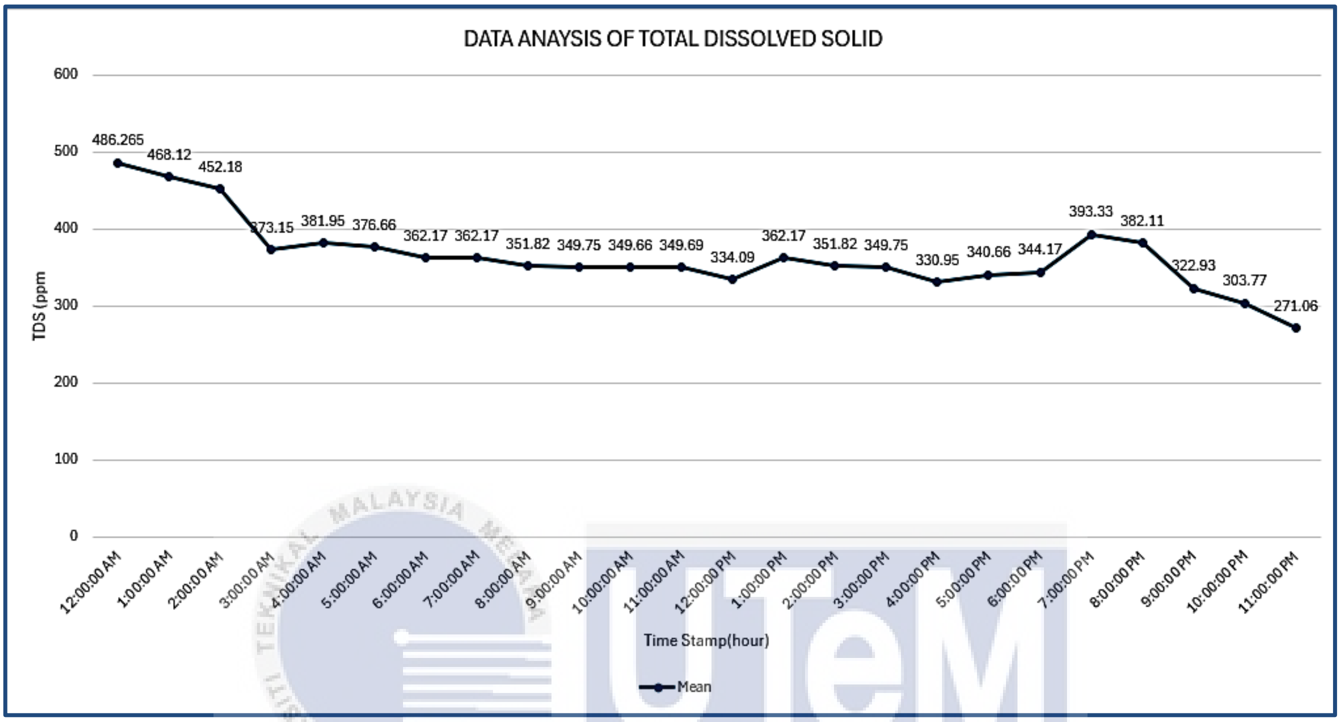


Figure 4.7 Real-time reading data total dissolved solid value for 24 hours

Based on the reading graph for the value of Total Dissolved solid for 24 hours, the maximum reading recorded was 486.27 ppm which is <500, where this reading is in Class I acording to National Water Quality Standards(NWQS) which state that the water supply does not require the conventional treatment.

4.4 Result Comparison with NWQS

Table 4.5 Comparion of water quality data with NWQS

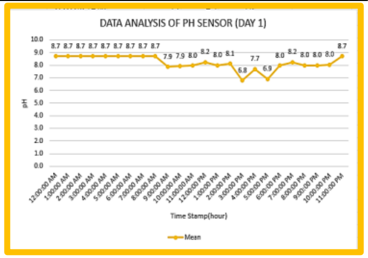
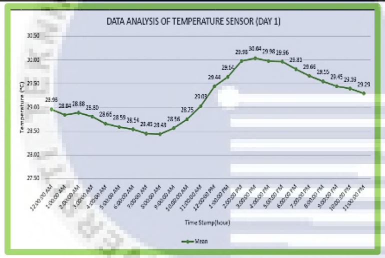
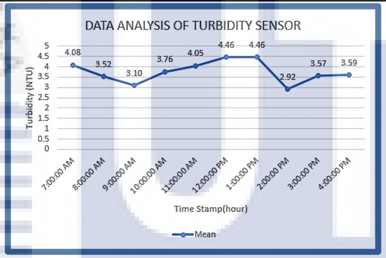
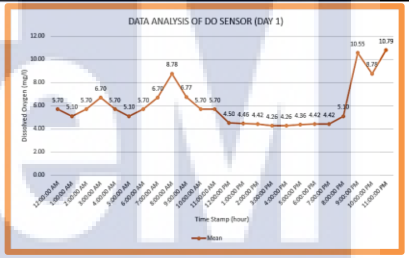
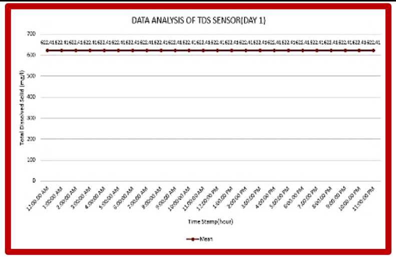
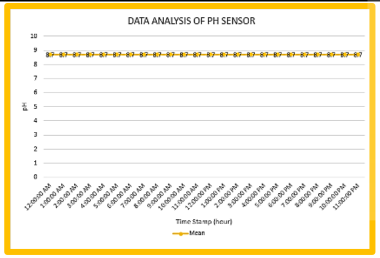
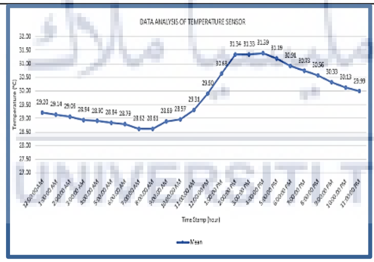
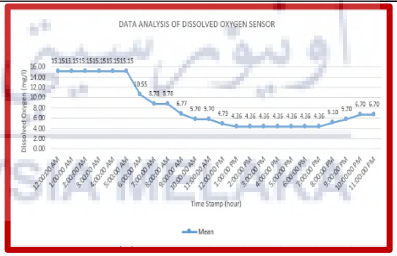
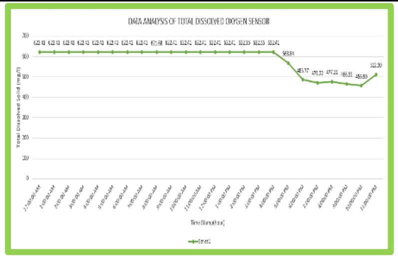
Parameters	Range data in 24 hours	Range data from NWQS for clean water	Class
pH	8.4-8.7	>7	I
Temperature(°C)	29.1- 32.1	Normal + 2°C	IIA
Turbidity(NTU)	2.25-4.75	5-50 NTU	I
Dissolved Oxygen(mg/L)	7.9-11.67	>7 mg/L	I
Total Dissolved Solid(ppm)	271.06 – 486.27	<500 ppm	I

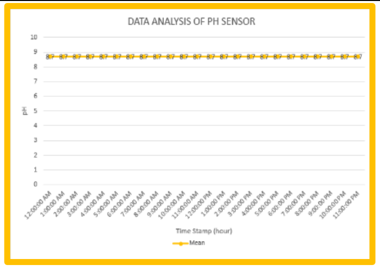
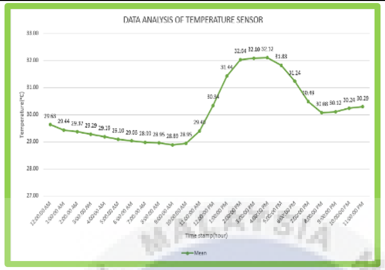
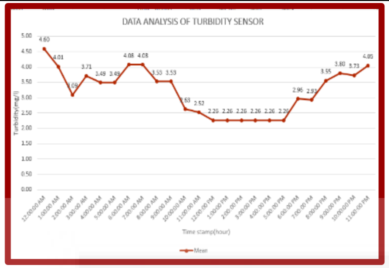
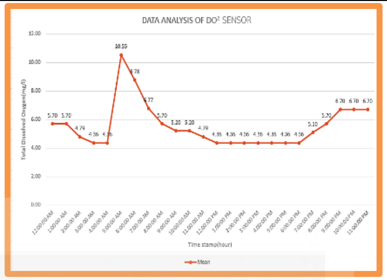
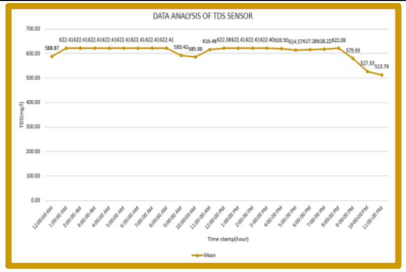
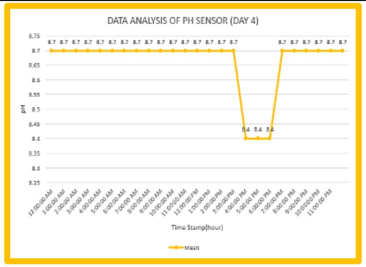
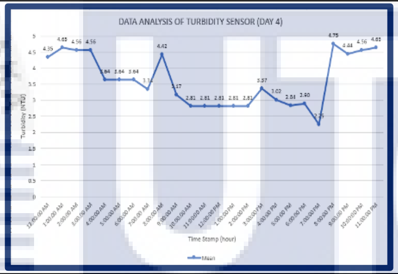
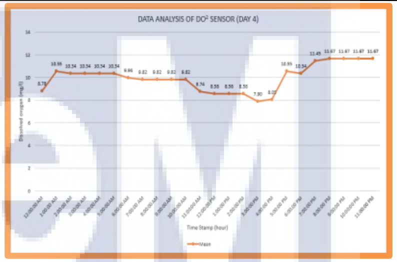
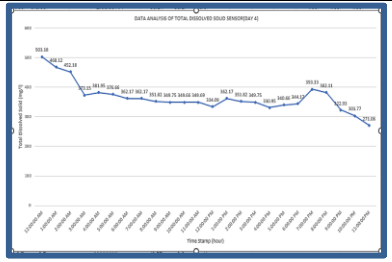
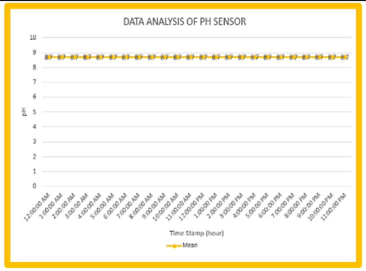
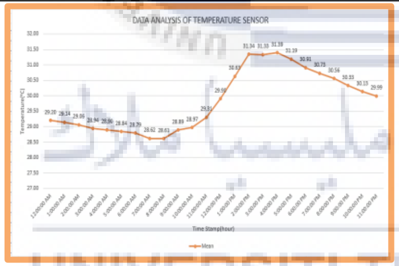
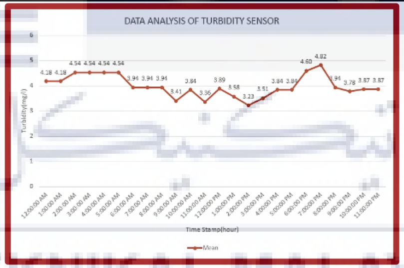
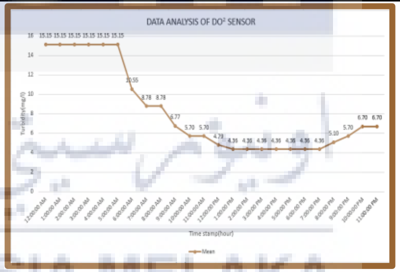
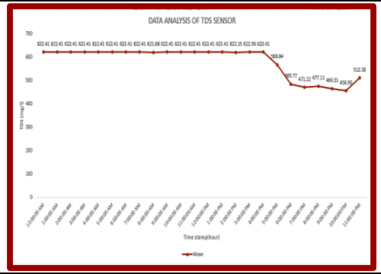
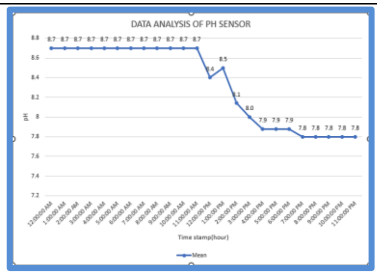
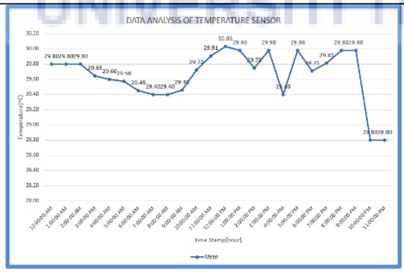
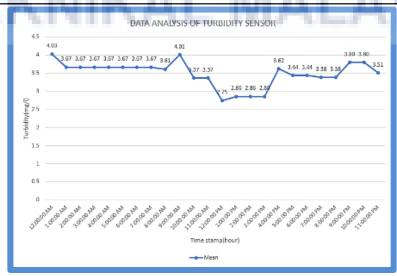
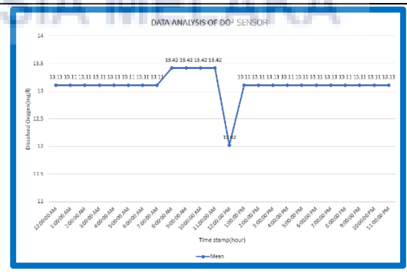
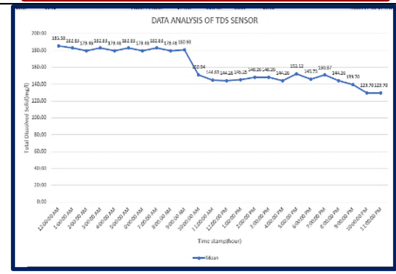
Table 4.5 shows the comparison of water quality data taken during field test with NWQS data. According to NWQS, all of the data except for temperature fall to Class I which is water supply I – Conservation of natural environment, Fishery I which is very sensitive aquatic species. The sensitivity of aquatic species suggests that the ecosystem is delicate and easily disrupted. Conservation efforts should focus on protecting the habitat, maintaining water quality, and implementing sustainable fishing practices. While temperature is in Class IIA which means it requires conventional treatment. However, the temperature of the river water is something that cannot be controlled because it is dependent on the provisions of the weather.

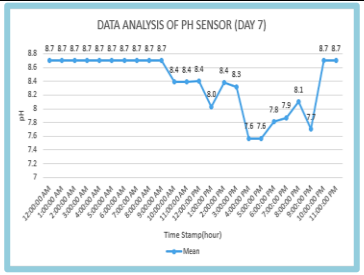
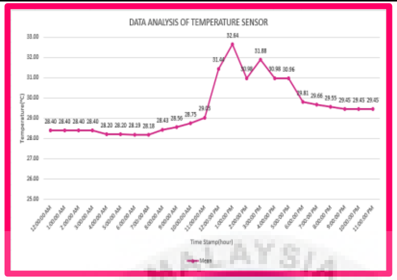
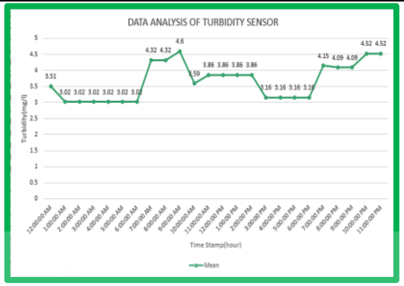
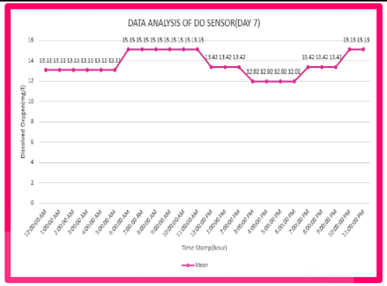
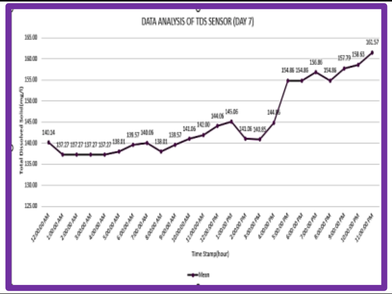
4.4.1 Data analysis of water quality sensors in one week

The data analysis of water quality sensors was generated from the Home Assistant Application as shown in Table 4.4.

Table 4.6 Data analysis of water quality sensors in one week

	Data analysis of sensors reading in one week				
	pH	Temperature	Turbidity	Dissolved oxygen	Total dissolved solid
Day 1					
Day 2					

Day 3					
Day 4					
Day 5					
Day 6					

Day 7					

Based on the data analysis of one-week sensors' reading in the Table 4.6, the average data was calculated and were compared with NWQS data as shown in Table 4.7. Overall data were in Class I same as comparison of data for 24 hours in Table 4.5.

Table 4.7 Comparison of average data of water quality sensors in one week with NWQS

Parameters	Average data in one week	Range data in NWQS for clean water	Class
pH	8.5	>7 mg/L	I
Temperature	29.72	Normal+ 2°C	IIA
Turbidity	3.65	5-50 NTU	I
Dissolved oxygen	9.20	>7 mg/L	I
Total dissolved solid	438.15	<500 ppm	I

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The improvement of water quality sensors for the development of Hydro Quality System Monitoring Device at Sungai Melaka is a crucial initiative in ensuring the sustainablility and health of the river ecosystem. Sungai Melaka plays a pivotial role in the environment, social, and economic fabric of th eregion. The successful implementation of advanced water quality sensors will enable the real-time monitoring, early detection of pollutants, and informed decision-making for effective water management.

Through the study of this project, the objectives of enhancing precision and reliability, testing the functionality of water quality sensors within the Hydro Quality System and interpret data analysis of water quality sensors based on guidance of NWQS have been addressed with dedication and technical expertise. The efforts to enhance the precision and reliability of water quality sensors represent a commitment to data accuracy and the production of reliable information for hydro quality monitoring. This improvement is vital for making informed decisions related to water management and environmental conservation.

5.2 Recommendations

HydroQS features can still be upgraded to provide optimal and maximum water quality monitoring. One of the enhancements that can be made is automatic calibration, which eliminates the need for periodic monitoring. This helps to save time and money during the study term. Furthermore, one possible enhancement that can be done is to extend the main body of the HydroQS to provide a more orderly arrangement of electronic components without interfering with electronic functionality. This is because the small space of the electrical enclosure makes it difficult to keep electronic components.

REFERENCES

Chapman, D. and Kimstach, V. (1992) Selection of Water Quality Variables. In: Chapman, D., Ed., Water Quality Assessments, Chapman and Hall, London, 51-119.

Malacca River Is Polluted, Nurul Fhatihah Zakinan. May 20,2019. https://www.bharian.com.my/berita/wilayah/2019/05/566031/sungai-melaka-tercemar

Rice, E. W., Bridgewater, L., & American Public Health Association (Eds.). (2012). *Standard methods for the examination of water and wastewater* (Vol. 10). Washington, DC: American public health association.

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

Abbas, S. H., Ismail, I. M., Mostafa, T. M., & Sulaymon, A. H. (2014). Biosorption of heavy metals: a review. *J Chem Sci Technol*, *3*(4), 74-102.

Tchobanoglous G, Peavy HS, Rowe DR. Environmental Engineering. New York: McGraw-Hill Interamericana; 1985

Omer, N. H. (2019). Water quality parameters. *Water quality-science, assessments and policy*, *18*, 1-34.

Osmi, S. A. C., Ishak, W. F. W., Azman, M. A., Ismail, A. S., & Samah, N. A. (2018, June). Development of water quality modelling using InfoWork river simulation in Malacca River, Malaysia and contribution towards Total Maximum Daily Load approach. In *IOP Conference Series: Earth and Environmental Science* (Vol. 169, No. 1, p. 012073). IOP Publishing.

Pujar, P. M., Kenchannavar, H. H., Kulkarni, R. M., & Kulkarni, U. P. (2020). Real-time water quality monitoring through Internet of Things and ANOVA-based analysis: a case study on river Krishna. *Applied Water Science*, 10(1), 1-16.

Ramadhan, A. J., Ali, A. M., & Kareem, H. K. (2020). Smart water-quality monitoring system based on enabled real-time internet of things. *Journal of Engineering Science and Technology, 15*(6), 3514-3527.

Salam, M. A., Paul, S. C., Shaari, F. I., Rak, A. E., Ahmad, R. B., & Kadir, W. R. (2019). Geostatistical distribution and contamination status of heavy metals in the sediment of Perak River, Malaysia. *Hydrology*, 6(2), 30.

Metcalf and Eddy, Inc. (1991) Wastewater Engineering: Treatment, Disposal, and Reuse. 3rd Edition, McGraw-Hill, Inc., Singapore.

Analog TDS Sensor for Arduino | Total Dissolved Solids Sensor. (n.d.). DIYElectronics. https://www.diyelectronics.co.za/store/liquid/2251-analog-tds-sensor-for-arduino.html

Helmenstine, A. M., PhD. (2020, November 2). *What is the difference between accuracy and precision?* ThoughtCo. https://www.thoughtco.com/difference-between-accuracy-and-precision-609328

Crossman, A. (2019, July 22). *The meaning of reliability in sociology*. ThoughtCo. https://www.thoughtco.com/reliability-definition-3026520

Amazon.com: GAOHOU PH0-14 Value Detect Sensor Module + PH Electrode Probe BNC for Arduino : Industrial & Scientific. (n.d.). https://www.amazon.com/GAOHOU-PH0-14-Detect-Electrode-Arduino/dp/B0799BXMVJ

CalculatorSoup, L. (2023, August 17). *Percentage difference Calculator*. CalculatorSoup. https://www.calculatorsoup.com/calculators/algebra/percent-difference-calculator.php

Table 1 .2: INWQS Class Definitions Class Definition. (n.d.). ResearchGate. https://www.researchgate.net/figure/2-INWQS-Class-Definitions-Class-Definition_tbl1_271019943

Morphological charts. (n.d.). https://www.ifm.eng.cam.ac.uk/research/dmg/tools-and-techniques/morphological-charts/

De Camargo, E. T., Spanhol, F. A., Slongo, J. S., Da Silva, M. V. R., Pazinato, J., De Lima Lobo, A. V., Coutinho, F. R., Pfrimer, F. W. D., Lindino, C. A., Oyamada, M. S., & Martins, L. D. (2023). Low-Cost water Quality Sensors for IoT: A Systematic review. *Sensors*, *23*(9), 4424. https://doi.org/10.3390/s23094424

Water quality Monitoring | Collect water quality data. (n.d.). In-Situ LLC. https://in-situ.com/us/products/water-quality

GravityTM Analog Dissolved Oxygen Kit | Atlas Scientific. (2023, October 26). Atlas Scientific. https://atlas-scientific.com/kits/gravity-analog-do-kit/

dfrobot.com. (n.d.). *Gravity: analog pH Sensor / Meter Pro Kit for Arduino*. https://www.dfrobot.com/product-1110.html

APPENDICES

APPENDIX A

NATIONAL WATER QUALITY STANDARDS FOR MALAYSIA

PARAMETER	UNIT	CLASS				
		I	IIA/IIB	III#	IV	V
A l	mg/l		-	(0.06)	0.5	↑
As	mg/l		0.05	0.4 (0.05)	0.1	
Ba	mg/l		1	-	-	
Cd	mg/l		0.01	0.01* (0.001)	0.01	
Cr (VI)	mg/l		0.05	1.4 (0.05)	0.1	
Cr (III)	mg/l		-	2.5	-	
Cu	mg/l		0.02	-	0.2	
Hardness	mg/l		250	-	-	
Ca	mg/l		-	-	-	
Mg	mg/l		-	-	-	
Na	mg/l		-	-	3 SAR	
K	mg/l		-	-	-	V
Fe	mg/l		1	1	1 (Leaf) 5 (Others)	OV
Pb	mg/l		0.05	0.02* (0.01)	5	E
Mn	mg/l		0.1	0.1	0.2	R A
Hg	mg/l		0.001	0.004 (0.0001)	0.002	EL
Ni	mg/l		0.05	0.9*	0.2	EV
Se	mg/l		0.01	0.25 (0.04)	0.02	I
Ag	mg/l		0.05	0.0002	-	
Sn	mg/l		-	0.004	-	
U	mg/l		-	-	-	
Zn	mg/l		5	0.4*	2	
B	mg/l		1	(3.4)	0.8	
Cl	mg/l		200	-	80	
Cl_2	mg/l		-	(0.02)	-	
CN	mg/l		0.02	0.06 (0.02)	-	
F	mg/l		1.5	10	1	
NO_2	mg/l		0.4	0.4 (0.03)	-	
NO_3	mg/l		7	-	5	
P	mg/l		0.2	0.1	-	↓
Silica	mg/l		50	-	-	
SO_4	mg/l		250	-	-	
S	mg/l		0.05	(0.001)	-	
CO_2	mg/l		-	-	-	
Gross-α	Bq/l		0.1	-	-	
Gross-β	Bq/l		1	-	-	
Ra-226	Bq/l		< 0.1	-	-	
Sr-90	Bq/l		< 1	-	-	
CCE	mg/l		500	-	-	-
MBAS/BAS	mg/l		500	5000 (200)	-	-

O & G (Mineral)	mg/l		40; N	N	-	-
O & G (Emulsified Edible)	mg/l		7000; N	N	-	-
PCB	mg/l		0.1	6 (0.05)	-	-
Phenol	mg/l		10	-	-	-
Aldrin/Dieldrin	mg/l		0.02	0.2 (0.01)	-	-
BHC	mg/l		2	9 (0.1)	-	-
Chlordane	mg/l		0.08	2 (0.02)	-	-
t-DDT	mg/l		0.1	(1)	-	-
Endosulfan	mg/l		10	-	-	-
Heptachlor/Epoxide	mg/l		0.05	0.9 (0.06)	-	-
Lindane	mg/l		2	3 (0.4)	-	-
2,4-D	mg/l		70	450	-	-
2,4,5-T	mg/l		10	160	-	-
2,4,5-TP	mg/l		4	850	-	-
Paraquat	mg/l		10	1800	-	-
		TU RA L LEV EL OR AB SE NT A N				

Notes :
* = At hardness 50 mg/l CaCO
\# = Maximum (unbracketed) and 24-hour average (bracketed) concentrations$_{3}$
N = Free from visible film sheen, discolouration and deposits

APPENDIX B

NATIONAL WATER QUALITY STANDARDS FOR MALAYSIA

PARAMETER	UNIT	CLASS					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.3	0.9	2.7	> 2.7
Biochemical Oxygen Demand	mg/l	1	3	3	6	12	> 12
Chemical Oxygen Demand	mg/l	10	25	25	50	100	> 100
Dissolved Oxygen	mg/l	7	5 - 7	5 - 7	3 - 5	< 3	< 1
pH	-	6.5 - 8.5	6 - 9	6 - 9	5 - 9	5 - 9	-
Colour	TCU	15	150	150	-	-	-
Electrical Conductivity*	µS/cm	1000	1000	-	-	6000	-
Floatables	-	N	N	N	-	-	-
Odour	-	N	N	N	-	-	-
Salinity	%	0.5	1	-	-	2	-
Taste	-	N	N	N	-	-	-
Total Dissolved Solid	mg/l	500	1000	-	-	4000	-
Total Suspended Solid	mg/l	25	50	50	150	300	300
Temperature	°C	-	Normal + 2 °C	-	Normal + 2 °C	-	-
Turbidity	NTU	5	50	50	-	-	-
Faecal Coliform**	count/100 ml	10	100	400	5000 (20000)[a]	5000 (20000)[a]	-
Total Coliform	count/100 ml	100	5000	5000	50000	50000	> 50000

Notes :

N : No visible floatable materials or debris, no objectional odour or no objectional taste

* : Related parameters, only one recommended for use

** : Geometric mean a :

Maximum not to be exceeded

APPENDIX C

WATER CLASSES AND USES

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

APPENDIX D

DOE WATER QUALITY CLASSIFICATION BASED ON WATER QUALITY INDEX

SUB INDEX & WATER QUALITY INDEX	INDEX RANGE		
	CLEAN	SLIGHTLY POLLUTED	POLLUTED
Biochemical Oxygen Demand (BOD)	91 - 100	80 - 90	0 - 79
Ammoniacal Nitrogen (NH_3-N)	92 - 100	71 - 91	0 - 70
Suspended Solids (SS)	76 - 100	70 - 75	0 - 69
Water Quality Index (WQI)	81 - 100	60 - 80	0 - 59

APPENDIX E

DOE WATER QUALITY INDEX CLASSIFICATION

PARAMETER	UNIT	CLASS				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	< 0.1	0.1 – 0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
Biochemical Oxygen Demand	mg/l	< 1	1 – 3	3 – 6	6 – 12	> 12
Chemical Oxygen Demand	mg/l	< 10	10 – 25	25 – 50	50 – 100	> 100
Dissolved Oxygen	mg/l	> 7	5 – 7	3 – 5	1 – 3	< 1
pH	-	> 7.0	6.0 – 7.0	5.0 – 6.0	< 5.0	> 5.0
Total Suspended Solid	mg/l	< 25	25 – 50	50 – 150	150 – 300	> 300
Water Quality Index (WQI)		> 92.7	76.5 – 92.7	51.9 – 76.5	31.0 – 51.9	< 31.0

APPENDIX F Reading data of each parameter within time in one week

Date	Time	pH	Temperature	Turbidity	DO	TDS
2/12/2023	12:00:00 AM	8.7	28.96	-	5.7	622.41
	1:00:00 AM	8.7	28.84	-	5.1	622.41
	2:00:00 AM	8.7	28.88	-	5.7	622.41
	3:00:00 AM	8.7	28.80	-	6.7	622.41
	4:00:00 AM	8.7	28.66	-	5.7	622.41
	5:00:00 AM	8.7	28.59	-	5.1	622.41
	6:00:00 AM	8.7	28.54	-	5.7	622.41
	7:00:00 AM	8.7	28.45	1.91	6.7	622.41
	8:00:00 AM	8.7	28.43	3.58	8.8	622.41
	9:00:00 AM	7.9	28.56	3.31	6.8	622.41
	10:00:00 AM	7.9	28.75	3.43	5.7	622.41
	11:00:00 AM	8.0	29.03	3.43	5.7	622.41
	12:00:00 PM	8.2	29.44	3.37	4.5	622.41
	1:00:00 PM	8.0	29.64	3.37	4.5	622.41
	2:00:00 PM	8.1	29.98	4.08	4.4	622.41
	3:00:00 PM	6.8	30.04	3.52	4.3	622.41
	4:00:00 PM	7.7	29.98	3.10	4.3	622.41
	5:00:00 PM	6.9	29.96	3.76	4.4	622.41
	6:00:00 PM	8.0	29.81	4.05	4.4	622.41

	7:00:00 PM	8.2	29.66	4.46	4.4	622.41
	8:00:00 PM	8.0	29.55	4.46	5.1	622.41
	9:00:00 PM	8.0	29.45	2.92	10.6	622.41
	10:00:00 PM	8.0	29.39	3.57	8.8	622.41
	11:00:00 PM	8.7	29.29	3.59	10.8	622.41
3/12/2023	12:00:00 AM	8.7	29.20	4.18	15.15	622.41
	1:00:00 AM	8.7	29.14	4.18	15.15	622.41
	2:00:00 AM	8.7	29.06	4.54	15.15	622.41
	3:00:00 AM	8.7	28.94	4.54	15.15	622.41
	4:00:00 AM	8.7	28.90	4.54	15.15	622.41
	5:00:00 AM	8.7	28.84	4.54	15.15	622.41
	6:00:00 AM	8.7	28.79	3.94	10.55	622.41
	7:00:00 AM	8.7	28.62	3.94	8.78	622.41
	8:00:00 AM	8.7	28.61	3.94	8.78	621.68
	9:00:00 AM	8.7	28.89	3.41	6.77	622.41
	10:00:00 AM	8.7	28.97	3.84	5.70	622.41
	11:00:00 AM	8.7	29.31	3.36	5.70	622.41
	12:00:00 PM	8.7	29.90	3.89	4.79	622.41
	1:00:00 PM	8.7	30.63	3.58	4.36	622.41
	2:00:00 PM	8.7	31.34	3.23	4.36	622.15
	3:00:00 PM	8.7	31.33	3.51	4.36	622.36
	4:00:00 PM	8.7	31.39	3.84	4.36	622.41
	5:00:00 PM	8.7	31.19	3.84	4.36	568.84
	6:00:00 PM	8.7	30.91	4.60	4.36	485.77
	7:00:00 PM	8.7	30.73	4.82	4.36	471.22
	8:00:00 PM	8.7	30.56	3.94	5.10	477.11
	9:00:00 PM	8.7	30.33	3.78	5.70	466.31
	10:00:00 PM	8.7	30.13	3.87	6.70	456.90
	11:00:00 PM	8.7	29.99	3.87	6.70	512.30
4/12/2023	12:00:00 AM	8.7	29.63	4.60	5.70	588.87
	1:00:00 AM	8.7	29.44	4.01	5.70	622.41
	2:00:00 AM	8.7	29.37	3.09	4.79	622.41
	3:00:00 AM	8.7	29.29	3.71	4.36	622.41
	4:00:00 AM	8.7	29.19	3.49	4.36	622.41
	5:00:00 AM	8.7	29.10	3.49	10.55	622.41
	6:00:00 AM	8.7	29.03	4.08	8.78	622.41
	7:00:00 AM	8.7	28.99	4.08	6.77	622.41
	8:00:00 AM	8.7	28.95	3.53	5.70	622.41
	9:00:00 AM	8.7	28.89	3.53	5.20	593.42
	10:00:00 AM	8.7	28.95	2.63	5.20	585.99
	11:00:00 AM	8.7	29.40	2.52	4.79	616.46
	12:00:00 PM	8.7	30.34	2.26	4.36	622.38
	1:00:00 PM	8.7	31.44	2.26	4.36	622.41
	2:00:00 PM	8.7	32.04	2.26	4.36	622.41

	3:00:00 PM	8.7	32.10	2.26	4.36	622.40
	4:00:00 PM	8.7	32.12	2.26	4.36	620.50
	5:00:00 PM	8.7	31.83	2.26	4.36	614.57
	6:00:00 PM	8.7	31.24	2.96	4.36	617.28
	7:00:00 PM	8.7	30.49	2.93	5.10	618.22
	8:00:00 PM	8.7	30.08	3.55	5.70	622.00
	9:00:00 PM	8.7	30.12	3.80	6.70	579.93
	10:00:00 PM	8.7	30.24	3.73	6.70	527.33
	11:00:00 PM	8.7	30.29	4.05	6.70	513.79
5/12/2023	12:00:00 AM	8.7	30.21	4.35	8.78	486.27
	1:00:00 AM	8.7	30.03	4.65	10.55	468.12
	2:00:00 AM	8.7	29.90	4.56	10.34	452.18
	3:00:00 AM	8.7	29.49	4.56	10.34	373.15
	4:00:00 AM	8.7	29.60	3.64	10.34	381.95
	5:00:00 AM	8.7	29.60	3.64	10.34	376.66
	6:00:00 AM	8.7	29.60	3.64	9.96	362.17
	7:00:00 AM	8.7	29.60	3.34	9.82	362.17
	8:00:00 AM	8.7	29.71	4.42	9.82	351.82
	9:00:00 AM	8.7	29.79	3.17	9.82	349.75
	10:00:00 AM	8.7	29.80	2.81	9.82	349.66
	11:00:00 AM	8.7	30.10	2.81	8.74	349.69
	12:00:00 PM	8.7	30.23	2.81	8.58	334.09
	1:00:00 PM	8.7	30.10	2.81	8.58	362.17
	2:00:00 PM	8.7	30.23	2.81	8.58	351.82
	3:00:00 PM	8.7	32.10	3.37	7.90	349.75
	4:00:00 PM	8.4	31.24	3.02	8.05	330.95
	5:00:00 PM	8.4	29.10	2.84	10.55	340.66
	6:00:00 PM	8.4	29.23	2.90	10.34	344.17
	7:00:00 PM	8.7	29.90	2.25	11.45	393.33
	8:00:00 PM	8.7	29.90	4.75	11.67	382.11
	9:00:00 PM	8.7	29.85	4.44	11.67	322.93
	10:00:00 PM	8.7	29.81	4.56	11.67	303.77
	11:00:00 PM	8.7	29.80	4.65	11.67	271.06
6/12/2023	12:00:00 AM	8.7	29.20	4.18	15.15	622.41
	1:00:00 AM	8.7	29.14	4.18	15.15	622.41
	2:00:00 AM	8.7	29.06	4.54	15.15	622.41
	3:00:00 AM	8.7	28.94	4.54	15.15	622.41
	4:00:00 AM	8.7	28.90	4.54	15.15	622.41
	5:00:00 AM	8.7	28.84	4.54	15.15	622.41
	6:00:00 AM	8.7	28.79	3.94	10.55	622.41
	7:00:00 AM	8.7	28.62	3.94	8.78	622.41
	8:00:00 AM	8.7	28.61	3.94	8.78	621.68
	9:00:00 AM	8.7	28.89	3.41	6.77	622.41
	10:00:00 AM	8.7	28.97	3.84	5.70	622.41

	11:00:00 AM	8.7	29.31	3.36	5.70	622.41
	12:00:00 PM	8.7	29.90	3.89	4.79	622.41
	1:00:00 PM	8.7	30.63	3.58	4.36	622.41
	2:00:00 PM	8.7	31.34	3.23	4.36	622.15
	3:00:00 PM	8.7	31.33	3.51	4.36	622.36
	4:00:00 PM	8.7	31.39	3.84	4.36	622.41
	5:00:00 PM	8.7	31.19	3.84	4.36	568.84
	6:00:00 PM	8.7	30.91	4.60	4.36	485.77
	7:00:00 PM	8.7	30.73	4.82	4.36	471.22
	8:00:00 PM	8.7	30.56	3.94	5.10	477.11
	9:00:00 PM	8.7	30.33	3.78	5.70	466.31
	10:00:00 PM	8.7	30.13	3.87	6.70	456.90
	11:00:00 PM	8.7	29.99	3.87	6.70	512.30
7/12/2023	12:00:00 AM	8.7	29.80	4.03	13.11	185.58
	1:00:00 AM	8.7	29.80	3.67	13.11	182.83
	2:00:00 AM	8.7	29.80	3.67	13.11	179.46
	3:00:00 AM	8.7	29.65	3.67	13.11	182.83
	4:00:00 AM	8.7	29.60	3.67	13.11	179.46
	5:00:00 AM	8.7	29.58	3.67	13.11	182.83
	6:00:00 AM	8.7	29.45	3.67	13.11	179.46
	7:00:00 AM	8.7	29.40	3.67	13.11	182.83
	8:00:00 AM	8.7	29.40	3.61	13.42	179.46
	9:00:00 AM	8.7	29.46	4.01	13.42	180.93
	10:00:00 AM	8.7	29.72	3.37	13.42	150.94
	11:00:00 AM	8.7	29.91	3.37	13.42	144.83
	12:00:00 PM	8.4	30.03	2.75	12.02	144.26
	1:00:00 PM	8.5	29.98	2.86	13.11	145.25
	2:00:00 PM	8.1	29.75	2.86	13.11	148.26
	3:00:00 PM	8.0	29.98	2.86	13.11	148.26
	4:00:00 PM	7.9	29.40	3.62	13.11	144.26
	5:00:00 PM	7.9	29.98	3.44	13.11	152.12
	6:00:00 PM	7.9	29.71	3.44	13.11	145.73
	7:00:00 PM	7.8	29.81	3.38	13.11	150.87
	8:00:00 PM	7.8	29.98	3.38	13.11	144.26
	9:00:00 PM	7.8	29.98	3.80	13.11	139.70
	10:00:00 PM	7.8	28.80	3.80	13.11	129.70
	11:00:00 PM	7.8	28.80	3.51	13.11	129.70
8/12/2023	12:00:00 AM	8.7	28.40	3.51	13.11	140.14
	1:00:00 AM	8.7	28.40	3.02	13.11	137.27
	2:00:00 AM	8.7	28.40	3.02	13.11	137.27
	3:00:00 AM	8.7	28.40	3.02	13.11	137.27
	4:00:00 AM	8.7	28.20	3.02	13.11	137.27
	5:00:00 AM	8.7	28.20	3.02	13.11	138.01
	6:00:00 AM	8.7	28.19	3.02	15.15	139.57

	7:00:00 AM	8.7	28.18	4.32	15.15	140.06
	8:00:00 AM	8.7	28.43	4.32	15.15	138.01
	9:00:00 AM	8.7	28.56	4.60	15.15	139.57
	10:00:00 AM	8.4	28.75	3.59	15.15	141.06
	11:00:00 AM	8.4	29.03	3.86	15.15	142.00
	12:00:00 PM	8.4	31.44	3.86	13.42	144.06
	1:00:00 PM	8.00	32.64	3.86	13.42	145.06
	2:00:00 PM	8.4	30.98	3.86	13.42	141.06
	3:00:00 PM	8.3	31.88	3.16	12.02	140.85
	4:00:00 PM	7.6	30.98	3.16	12.02	144.86
	5:00:00 PM	7.6	30.96	3.16	12.02	154.86
	6:00:00 PM	7.8	29.81	3.16	12.02	154.86
	7:00:00 PM	7.9	29.66	4.15	13.42	156.86
	8:00:00 PM	8.1	29.55	4.09	13.42	154.86
	9:00:00 PM	7.7	29.45	4.09	13.42	157.79
	10:00:00 PM	8.7	29.45	4.52	15.15	158.63
	11:00:00 PM	8.7	29.45	4.52	15.15	161.57

APPENDIX G

PSM1 Gantt Chart

NO.	ACTIVITIES		WEEK													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	PSM1 briefing	PLAN														
		ACTUAL														
2	Supervisor selsction/title release/ 1st meeting	PLAN														
		ACTUAL														
3	Find article for literature review	PLAN														
		ACTUAL														
4	Chapter 1: Introduction	PLAN														
		ACTUAL														
5	Problem statement	PLAN														
		ACTUAL														
6	Objective	PLAN														
		ACTUAL														
7	Scope of research	PLAN														
		ACTUAL														
8	2nd meeting/ Chapter 1 checked by supervisor	PLAN														
		ACTUAL														
10	Chapter 2 : Literature riview	PLAN														
		ACTUAL														
11	Issue about river pollution at sungai melaka	PLAN														
		ACTUAL														
12	Past research method	PLAN														
		ACTUAL														
13	Water Quality Parameters	PLAN														
		ACTUAL														
14	3rd meeting/ Chapter 2 checked by supervisor	PLAN														
		ACTUAL														
15	Chapter 3 : Methodology	PLAN														
		ACTUAL														
16	Introduction	PLAN														
		ACTUAL														
17	Project Planning	PLAN														
		ACTUAL														
18	Project method	PLAN														
		ACTUAL														
19	4th meeting / chapter 3 discussion	PLAN														
		ACTUAL														
20	3D print using SLS machine	PLAN														
		ACTUAL														
21	HydroQS parts painting	PLAN														
		ACTUAL														
22	HydroQS parts assembly and fitting	PLAN														
		ACTUAL														
23	Installing sensors and other electronic	PLAN														
		ACTUAL														
24	Testing: leak test, floating test, sensors calibrati	PLAN														
		ACTUAL														
25	PSM 1 Presentation	PLAN														
		ACTUAL														

APPENDIX H

PSM2 Gantt Chart

NO	Activity		PSM 2													
			WEEKS													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	PSM 2 Briefing	Plan														
		Actual														
2	Fabrication of new rig for HydroQS and installation of new water quality sensors	Plan														
		Actual														
3	Pre test the rig and functionality of water quality sensors	Plan														
		Actual														
4	Installation of rig and HydroQS into sungai melaka	Plan														
		Actual														
5	Calibration of water quality sensors	Plan														
		Actual														
6	Testing of the HydroQS system sensors and its rig for 24 hours	Plan														
		Actual														
7	Monitoring of the hydroqs using Home Assistant Application	Plan														
		Actual														
8	Analyze data of water quality sensors for 24 hours readings	Plan														
		Actual														
9	Comparison of actual data and NWQS data	Plan														
		Actual														
10	Chapter 4: result of previous	Plan														
		Actual														
11	Simulation result	Plan														
		Actual														
12	Chapter 5: Conclusion	Plan														
		Actual														
13	Report , summary, logbook submition	Plan														
		Actual														
14	Poster drafting	Plan														
		Actual														
15	Poster submition	Plan														
		Actual														
16	Final presentation	Plan														
		Actual														

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA

TAJUK: **IMPROVEMENT OF WATER QUALITY SENSORS' DEVELOPMENT FOR HYDRO QUALITY SYSTEM MONITORING DEVICE AT SUNGAI MELAKA**

SESI PENGAJIAN: **2023/2024 Semester 1**

Saya **SAFURAA AGHNIA BINTI SHAMSUL**

mengaku membenarkan tesis ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)
☑ √	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☐	TIDAK TERHAD	

Disahkan oleh:

Alamat Tetap:

LOT 679A KAMPUNG SUNGAI LAR

DONG, 27400, RAUB, PAHANG

Tarikh: 19/1/2024

Cop Rasmi:

TS. MAZRAN BIN AHMAD
Jurutera Pengajar
Jabatan Teknologi Kejuruteraan Pembuatan
Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan
Universiti Teknikal Malaysia Melaka

Tarikh: 31/1/2024

** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya,
76100 Durian Tunggal,
Melaka, Malaysia.

+606 270 1000
+606 270 1022
www.utem.edu.my

FAKULTI TEKNOLOGI DAN KEJURUTERAAN INDUSTRI DAN PEMBUATAN
Tel : +606 270 2571 | Faks : +606 270 1047

Rujukan Kami (Our Ref):
Rujukan Tuan (Your Ref):
Tarikh (Date): 31 Januari 2024

Ketua Pustakawan
Perpustakaan Laman Hikmah
Universiti Teknikal Malaysia Melaka

Melalui

Dekan
Fakulti Teknologi dan Kejuruteraan Industri dan Pembuatan
Universiti Teknikal Malaysia Melaka

Puan

PENGKELASAN TESIS SEBAGAI TERHAD BAGI TESIS PROJEK SARJANA MUDA

Dengan segala hormatnya merujuk kepada perkara di atas.

2. Dengan ini, dimaklumkan permohonan pengkelasan tesis yang dilampirkan sebagai TERHAD untuk tempoh **LIMA** tahun dari tarikh surat ini. Butiran lanjut laporan PSM tersebut adalah seperti berikut:

Nama pelajar: SAFURAA AGHNIA BINTI SHAMSUL (B092010024)
Tajuk Tesis: IMPROVEMENT OF WATER QUALITY SENSORS FOR HYDRO QUALITY SYSTEM MONITORING DEVICE AT SUNGAI MELAKA.

3. Hal ini adalah kerana IANYA MERUPAKAN PROJEK YANG DITAJA OLEH SYARIKAT LUAR DAN HASIL KAJIANNYA ADALAH SULIT.

Sekian, terima kasih.

“BERKHIDMAT UNTUK NEGARA”
“KOMPETENSI TERAS KEGEMILANGAN”

Saya yang menjalankan amanah,

MAZRAN BIN AHMAD
Penyelia Utama
Fakulti Teknologi dan Kejuruteraan Industri dan Pembuatan
Universiti Teknikal Malaysia Melaka

BMMU3764_BMMD_B092010024_SAFURAA AGHNIA BINTI_SHAMSUL

ORIGINALITY REPORT

28%	22%	14%	23%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Universiti Teknikal Malaysia Melaka Student Paper	5%
2	Submitted to University of Energy and Natural Resources Student Paper	2%
3	kids.britannica.com Internet Source	1%
4	Submitted to Universiti Malaysia Perlis Student Paper	1%
5	eprints.utem.edu.my Internet Source	1%
6	www.mdpi.com Internet Source	1%
7	www.ncbi.nlm.nih.gov Internet Source	1%
8	businessdocbox.com Internet Source	1%

9	Submitted to Fr Gabriel Richard High School Student Paper	1 %
10	link.springer.com Internet Source	1 %
11	Submitted to University Tun Hussein Onn Malaysia Student Paper	1 %
12	www.intechopen.com Internet Source	<1 %
13	Submitted to Technological University Dublin Student Paper	<1 %
14	umpir.ump.edu.my Internet Source	<1 %
15	Submitted to University of Sheffield Student Paper	<1 %
16	Submitted to Newham College of Further Education, London Student Paper	<1 %
17	digitalcollection.utem.edu.my Internet Source	<1 %
18	Submitted to Fiji National University Student Paper	<1 %
19	fdocuments.net Internet Source	<1 %

20	www.researchgate.net Internet Source	<1%
21	www.ajifahreza.com Internet Source	<1%
22	Submitted to Landmark University Student Paper	<1%
23	J. R. Florence, S. S. Priyadharsini, G. S. Chandran. "Sensor Based Classification and Evaluation Methods using Machine Learning Algorithm for the Evaluation of Indian Traditional Medicine (Siddha)", Journal of Scientific Research, 2022 Publication	<1%
24	www.ecoeet.com Internet Source	<1%
25	Submitted to Sri Lanka Institute of Information Technology Student Paper	<1%
26	Submitted to University of Central England in Birmingham Student Paper	<1%
27	ebin.pub Internet Source	<1%
28	eprints.uthm.edu.my Internet Source	<1%

29	Submitted to University of South Africa (UNISA) Student Paper	<1 %
30	www.sigmaelectronica.net Internet Source	<1 %
31	Submitted to British University in Egypt Student Paper	<1 %
32	Submitted to University of East London Student Paper	<1 %
33	Submitted to Our Lady of Fatima University Student Paper	<1 %
34	Submitted to Rutgers University, New Brunswick Student Paper	<1 %
35	A A M Damanhuri, A S A Subki, A Hariri, B T Tee, M H F M Fauadi, M S F Hussin, M S S Mustafa. "Comparative study of selected indoor concentration from selective laser sintering process using virgin and recycled polyamide nylon (PA12)", IOP Conference Series: Earth and Environmental Science, 2019 Publication	<1 %
36	www.coursehero.com Internet Source	<1 %
37	Submitted to General Sir John Kotelawala Defence University	<1 %

Student Paper

38	repository.nwu.ac.za Internet Source	<1 %
39	Submitted to Federal University of Technology Student Paper	<1 %
40	Submitted to Universiti Teknologi MARA Student Paper	<1 %
41	Submitted to University of Greenwich Student Paper	<1 %
42	journal.uinjkt.ac.id Internet Source	<1 %
43	www.ijeat.org Internet Source	<1 %
44	Submitted to Imperial College of Science, Technology and Medicine Student Paper	<1 %
45	Sagar Kolekar, Pranav Sankapal, Kanchan Khare, Pennan Chinnasamy. "Assessment of Recycled Treated Wastewater for Sustainable Tomato Crop Production: A Comprehensive Review", Environmental Challenges, 2023 Publication	<1 %
46	Submitted to Universiti Putra Malaysia Student Paper	<1 %
47	Submitted to University of Sunderland Student Paper	

		<1%
48	www.dausen.com Internet Source	<1%
49	Submitted to Al Quds University Student Paper	<1%
50	Submitted to De Montfort University Student Paper	<1%
51	Prasad M. Pujar, Harish H. Kenchannavar, Raviraj M. Kulkarni, Umakant P. Kulkarni. "Real-time water quality monitoring through Internet of Things and ANOVA-based analysis: a case study on river Krishna", Applied Water Science, 2019 Publication	<1%
52	www.thestar.com.my Internet Source	<1%
53	Submitted to Academy Of Our Lady Of Peace Student Paper	<1%
54	Submitted to Universiti Tenaga Nasional Student Paper	<1%
55	Submitted to Vietnamese-German University Student Paper	<1%
56	amsdottorato.unibo.it Internet Source	<1%

57	ise.ait.ac.th Internet Source	<1%
58	www.ijert.org Internet Source	<1%
59	ntnuopen.ntnu.no Internet Source	<1%
60	www.scirp.org Internet Source	<1%
61	M.F. Mukhtar, M.I.F. Rosley, A.M.H.S. Lubis, N. Tamaldin, M.S.F. Hussin, A.A.M. Damanhuri, K.A. Azlan, N.H. Hanizat. "DEVELOPMENT OF RIVER TRASH COLLECTOR SYSTEM", Journal of Physics: Conference Series, 2020 Publication	<1%
62	Submitted to Visayas State University Student Paper	<1%
63	eprints.umpo.ac.id Internet Source	<1%
64	ir.unimas.my Internet Source	<1%
65	jurnal-stiepari.ac.id Internet Source	<1%
66	os.unil.cloud.switch.ch Internet Source	<1%

67	www.farnell.com Internet Source	<1 %
68	www.istockphoto.com Internet Source	<1 %
69	DiBeneditto, Lukas W.. "Temporary Liver Support Using Artificial Lung Technologies: Ammonia Removal via Peritoneal Dialysis for Acute Liver Failure With PFC and PDMS at Vacuum Pressure", Carnegie Mellon University, 2023 Publication	<1 %
70	Mohd Arizam Abdul Wahap, Mohd Kamal Musa, Mohamad Syafiq Mohamad Noor, Abdul Munir Hidayat Syah Lubis et al. "Chapter 29 Determination of Design Specifications for Sungai Melaka Cleaning Boat Design Improvement Through House of Quality", Springer Science and Business Media LLC, 2022 Publication	<1 %
71	Ton Duc Thang University Publication	<1 %
72	enviro2.doe.gov.my Internet Source	<1 %
73	eprints.utar.edu.my Internet Source	<1 %

74 epsmg.jkr.gov.my
Internet Source
<1%

75 utem.edu.my
Internet Source
<1%

76 Hormann, L. B., M. Steinberger, M. Kalcher, and C. Kreiner. "Using a remote lab for teaching energy harvesting enhanced wireless sensor networks", 2013 IEEE Global Engineering Education Conference (EDUCON), 2013.
Publication
<1%

77 Brinda Das, P.C. Jain. "Real-time water quality monitoring system using Internet of Things", 2017 International Conference on Computer, Communications and Electronics (Comptelix), 2017
Publication
<1%

78 Fowzia Akhter, Hasin Reza Siddiquei, Md Eshrat E. Alahi, Subhas C. Mukhopadhyay. "Recent Advancement of the Sensors for Monitoring the Water Quality Parameters in Smart Fisheries Farming", Computers, 2021
Publication
<1%

79 M.M. Mahbubul Syeed, Md Shakhawat Hossain, Md Rajaul Karim, Mohammad Faisal Uddin, Mahady Hasan, Razib Hayat Khan. "Surface water quality profiling using the
<1%

water quality index, pollution index and statistical methods: A critical review", Environmental and Sustainability Indicators, 2023
Publication

80	Ryota Murakami, Hiroshi Yamamoto. "Growth Estimation Sensor Network System for Aquaponics using Multiple Types of Depth Cameras", 2022 International Conference on Artificial Intelligence in Information and Communication (ICAIIC), 2022 Publication	<1 %
81	melakamajunegerikusayang.blogspot.com Internet Source	<1 %

Exclude quotes On
Exclude bibliography On
Exclude matches Off