Faculty of Electrical Technology and Engineering

DEVELOPMENT OF SMART WATER QUALITY MONITORING SYSTEM USING ESP32 BASED SENSORS FOR SUSTAINABLE ENVIRONMENTAL MANAGEMENT

WONG JIA HENG

Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics) with Honours

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DEVELOPMENT OF SMART WATER QUALITY MONITORING SYSTEM USING ESP32 BASED SENSORS FOR SUSTAINABLE ENVIRONMENTAL MANAGEMENT

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A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics) with Honours

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SALEHA BT. MOHAMAD SALEH
PENSYARAH
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Date :

DEDICATION

This project report is devoted to my beloved father, Wong Chan Choon, whose unwavering support sustained me throughout the entire research process. Additionally, I extend my dedication to my cherished mother, Feng Ling, who has diligently and attentively encouraged me over the past months, fostering my work with genuine confidence. My heartfelt dedication also goes to all those individuals who contributed their efforts and hard work to assist me in successfully completing this project.

ABSTRACT

Water quality is paramount for environmental sustainability and human well-being, serving as a cornerstone for healthy ecosystems, sustainable development, and public health protection. However, this critical resource faces escalating threats from pollution, population expansion, and climate fluctuations. Conventional water quality monitoring systems are often prohibitively expensive, complex, and limited in scope, impeding their widespread adoption and accessibility. To confront these challenges head-on, this study endeavors to design and implement a smart water quality monitoring system utilizing the ESP32 microcontroller. This system will possess the capability to accurately measure crucial parameters such as pH, temperature, and turbidity. Additionally, a centralized data management infrastructure will be established to efficiently store, process, and analyze the gathered data, facilitating the identification of trends, patterns, and anomalies in water quality. Moreover, the system will integrate a monitoring mechanism to promptly alert users to abnormal readings, thereby enhancing responsiveness and proactive management. Methodologically, the research will draw upon reputable sources, such as the IEEE website, and employ pH, temperature, and turbidity sensors in conjunction with the ESP32 microcontroller. Real-time observation and monitoring will be facilitated through the utilization of the Blynk.io platform. This study aspires to make significant contributions toward the development of effective and accessible water quality monitoring systems, addressing the urgent need for sustainable water resource management and the protection of public health. Furthermore, the analysis of the table reveals distinct characteristics of various water samples. Sample 4 has the lowest pH and highest turbidity, closely followed by Sample 3. In contrast, Sample 1 has the lowest turbidity and a safe pH level of 7.25. The presence of

acidic and cloudy water near residential areas poses dangers like infrastructure corrosion and environmental harm, necessitating actions like drainage improvements and intensified monitoring. Sample 3, from a stream for human waste, raises concerns due to acidity and potential contaminants. Similarly, Sample 4, from the Malacca River, shows unsafe pH and turbidity levels likely due to pollution. Sample 5, from Lake Ayer Keroh, also has acidity and cloudiness, impacting the ecosystem and aesthetics. All samples maintain a consistent temperature of around 27°C. Overall, the project has achieved its objectives successfully, but it could be further enhanced by incorporating additional sensors to augment water quality measurement capabilities.

ABSTRAK

Kualiti air adalah sangat penting untuk kelestarian alam sekitar dan kesejahteraan manusia, berperanan sebagai batu asas untuk ekosistem yang sihat, pembangunan mampan, dan perlindungan kesihatan awam. Walau bagaimanapun, sumber penting ini menghadapi ancaman yang meningkat dari pencemaran, peningkatan populasi, dan fluktuasi iklim. Sistem pemantauan kualiti air konvensional seringkali terlalu mahal, kompleks, dan terhad dalam skopnya, menghalang penggunaan dan aksesibilitinya secara meluas. Untuk menangani cabaran ini dengan terus terang, kajian ini berusaha untuk merancang dan melaksanakan sistem pemantauan kualiti air pintar menggunakan mikropemproses ESP32. Sistem ini akan mempunyai keupayaan untuk mengukur dengan tepat parameter penting seperti pH, suhu, dan kekeruhan. Selain itu, infrastruktur pengurusan data yang terpusat akan dibangunkan untuk menyimpan, memproses, dan menganalisis data yang dikumpulkan, memudahkan pengenalpastian trend, corak, dan anomali dalam kualiti air. Selain itu, sistem ini akan mengintegrasikan mekanisme pemantauan untuk segera memberi amaran kepada pengguna mengenai bacaan yang tidak normal, dengan itu meningkatkan responsibiliti dan pengurusan secara proaktif. Secara metodologi, penyelidikan ini akan merujuk kepada sumber yang terkenal, seperti laman web IEEE, dan menggunakan sensor pH, suhu, dan kekeruhan bersama-sama dengan mikropemproses ESP32. Pemantauan dan pengawasan secara masa nyata akan dipermudahkan melalui penggunaan platform Blynk.io. Kajian ini bercita-cita untuk memberikan sumbangan yang besar kepada pembangunan sistem pemantauan kualiti air yang efektif dan mudah capai, menangani keperluan yang mendesak untuk pengurusan sumber air yang mampan dan perlindungan kesihatan awam. Selain itu, analisis jadual mengungkapkan ciri-ciri berbeza bagi pelbagai sampel air. Sampel 4

mempunyai pH terendah dan kekeruhan tertinggi, diikuti rapat oleh Sampel 3. Sebaliknya, Sampel 1 mempunyai kekeruhan terendah dan tahap pH selamat pada 7.25. Kehadiran air yang bersifat asidik dan berkekeruhan di kawasan kediaman menimbulkan bahaya seperti korosi infrastruktur dan kerosakan alam sekitar, memerlukan tindakan seperti peningkatan sistem saliran dan pemantauan yang diperketat. Sampel 3, dari sungai sisa manusia, menimbulkan kebimbangan disebabkan oleh keasidan dan pencemar yang berpotensi. Begitu juga, Sampel 4, dari Sungai Melaka, menunjukkan tahap pH dan kekeruhan yang tidak selamat yang mungkin disebabkan oleh pencemaran. Sampel 5, dari Tasik Ayer Keroh, juga mempunyai keasidan dan kekeruhan, memberi kesan kepada ekosistem dan estetika. Semua sampel mengekalkan suhu yang konsisten pada kira-kira 27°C. Secara keseluruhan, projek ini telah mencapai objektifnya dengan berjaya, tetapi ia boleh diperkukuhkan lagi dengan menggabungkan sensor tambahan untuk meningkatkan keupayaan pengukuran kualiti air.

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CHAPTER 1

INTRODUCTION

1.1 Background

Water quality is a critical aspect of environmental management and human well-being. Ensuring access to clean and safe water is essential for maintaining healthy ecosystems, supporting sustainable development, and protecting public health. However, water resources are under increasing pressure from various sources, including pollution, population growth, and climate change.

To address these challenges, effective water quality monitoring systems are crucial. Monitoring the physical, chemical, and biological parameters of water bodies provides valuable data for assessing water quality, identifying potential threats, and implementing appropriate mitigation measures. Timely and accurate information is vital for making informed decisions and taking actions to protect and preserve water resources.

In the context of sustainable environmental management, the purpose of this project is to design and develop a water quality monitoring system that can provide real-time data on key parameters affecting water quality. The system aims to enable proactive management strategies, early detection of pollution incidents, and effective decision-making for water resource protection.

The project will focus on developing a comprehensive monitoring system capable of measuring essential water quality parameters such as pH, temperature, and turbidity. These parameters are critical indicators of water quality and can provide insights into the presence of contaminants, the health of aquatic ecosystems, and the suitability of water for various purposes.

The system will utilize advanced sensors and monitoring devices to collect accurate and reliable data from different water bodies, including rivers, lakes, and reservoirs. The collected data will be transmitted and stored in a centralized database, allowing for real-time monitoring and historical data analysis. A user-friendly interface will be developed to visualize and interpret the data, enabling stakeholders to easily access and understand the information.

By developing a robust and optimized water quality monitoring system, this project aims to contribute to sustainable environmental management practices and support evidence-based decision-making. The system's real-time monitoring capabilities will help identify pollution sources, assess the effectiveness of remedial actions, and track the long-term trends in water quality. Ultimately, the project seeks to enhance the understanding and protection of water resources, promoting their sustainable use for the benefit of ecosystems and human societies.

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1.2 Problem Statement

Access to clean and safe water source is crucial for human health and well-being. However, water pollution is a significant environmental issue that continues to threaten water resources and public health. Traditional water quality monitoring systems are often expensive, complex, and limited in scope, making them inaccessible to many communities. Therefore, there is a need for a smart, affordable, and easy-to-use water quality monitoring system that can accurately measure various water quality parameters, such as pH, temperature, and turbidity. The proposed project aims to design and develop a smart water quality monitoring system using ESP32 for sustainable environmental management. The system will utilize low-cost and widely available sensors to measure various water quality parameters and transmit the data to a centralized data management system for future uses like analyse the data generated by the monitoring system and identify trends and anomalies. The system also reduce the overall cost of operation by using ESP 32 and sensors at affordable prices. Overall, the proposed project seeks to develop an affordable, accessible, and intelligent water quality monitoring system that can improve access to clean and safe drinking water, promote sustainable environmental management, and safeguard public health.

1.3 Project Objective

The objectives of the project are stated as follow:

a) Design a smart water quality monitoring system using ESP32 that can accurately measure various water quality parameters such as pH, temperature and turbidity.
b) Develop a centralized data management system that can store and process the data generated by the monitoring system. This data management system will include data visualization and analysis capabilities, allowing for the detection of trends, patterns, and anomalies in water quality data.
c) Develop a monitoring system that can send warning to user when sense abnormal reading.

1.4 Scope of Project

The scope of this project are as follows:

a) To display the water parameters on an application so that it can be observed by the user.

b) To develop a Wi-Fi system that can observe water parameters through smartphone.

c) To develop a system that can help user to get awareness when the water parameter shows abnormal reading.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review chapter of this project provides a comprehensive exploration of existing scholarly works, research studies, and publications relevant to the topic at hand. By critically analysing and synthesizing the available literature, this chapter establishes a solid theoretical foundation for the research project. It examines key themes, theories, methodologies, and findings in the field, highlighting gaps and limitations in the current knowledge. Through a systematic approach, it aims to contribute to the advancement of understanding in the subject area and provide a rationale for the research objectives and methodology adopted in this study.

2.2 Review of Current Simulation

Water makes up about 70% of the earth's surface and is one of the most important sources vital to sustaining life. It is crucial to assess water quality based on its suitability for human needs or specific purposes, as well as the requirements of various terrestrial or aquatic animal species. The evaluation of water quality involves measuring three primary types of parameters: physical, chemical, and biological properties.

Physical parameters of water quality are determined through the senses of sight, smell, taste, and touch. They encompass factors such as temperature, colour, taste and odour, turbidity, and the content of dissolved solids. These parameters provide insights into the immediate perceptible characteristics of water.

Chemical parameters, on the other hand, reflect the environment that the water has met. They include measurements such as pH, hardness, dissolved oxygen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), chloride and sulphate levels, residual chlorine, nitrogen, and fluoride content, as well as the presence of substances like iron, manganese, copper, zinc, toxic organic and inorganic compounds, and even radioactive elements. Chemical parameters give an indication of the chemical composition and potential contaminants in the water.

Biological parameters focus on the presence and quantity of bacteria, algae, viruses, and protozoa in the water. These measurements are essential to evaluate the overall biological health and potential risks associated with the water source.

Water quality is influenced by both anthropogenic activities and natural factors. Factors such as atmospheric pollution, runoff from agricultural or urban areas, and erosion and sedimentation can significantly impact water quality.

To assess water quality, testing can be conducted either in a laboratory or at home, depending on local conditions and requirements. Laboratory evaluation involves collecting field water samples and subjecting them to instrumental and chemical analysis. This method allows for the measurement of multiple physical, chemical, and biological parameters, providing highly accurate results. However, laboratory testing is often costly and time-consuming.

At-home water quality testing methods offer a more rapid and cost-effective approach. These methods utilize tools such as strips, colour disks, and digital instruments to quickly check for the presence and concentration of common water contaminants. At-home tests serve as screening tools to determine whether further laboratory analysis is necessary. They are commonly used in commercial or industrial settings as initial screening measures. For example, water test strips are employed to assess the quality of aquarium water, ensuring a suitable environment for aquatic life.

The quality of water, whether it is used for drinking, irrigation, or recreational purposes, is significant for health in both developing and developed countries worldwide. Referring to the above sentence, three main dimensions of water quality are water quality for human consumption, water quality for industrial and domestic use, and environmental water quality respectively.

Water quality for human consumption is of utmost importance as it directly impacts public health. Access to safe drinking and cooking water is essential for individuals and societies to thrive. The United Nations recognizes this as a fundamental human right, emphasizing the significance of high-quality water, also known as potable water. However, the unfortunate reality is that many people worldwide lack access to clean drinking water. Disturbingly, statistics from the World Health Organization (WHO) reveal that approximately 785 million people lack basic drinking-water services, and over 2 billion people consume water contaminated with feces. This contamination leads to the transmission of various diseases, resulting in significant health implications. Diarrheal diseases alone claim with the staggering lives of around 370,000 children under the age of 5 each year.

Water quality for industrial and domestic use is also a crucial consideration. In industrial settings, processed water is employed for manufacturing processes, power generation, and other applications. Maintaining specific water quality standards for processed water is essential to prevent machinery damage and product contamination. However, these standards can vary significantly across industries and plants. While the United States has established certain parameters for industrial use in documents like the "Green Book" and "Blue Book," many industries do not have specific guidelines. In such cases, water quality criteria developed for human consumption may be used as substitutes to ensure protection. Similarly, water quality standards for non-drinking domestic purposes, such as sanitation and hygiene, often align with those for potable water.

Environmental water quality plays a vital role in preserving ecosystems and supporting flora and fauna. The well-being of aquatic life and the overall health of oceans, rivers, lakes, wetlands, and other habitats depend on maintaining suitable environmental water quality. Governmental organizations regulate different subcategories of environmental water quality to protect and propagate fish and shellfish populations, waterfowl, shorebirds, coral reefs, marinas, groundwater, and aquifers. However, poor environmental water quality poses a significant threat due to contamination from chemicals and microorganisms originating from agricultural, industrial, and urban sources. Shockingly, more than 80 percent of the world's wastewater flows back into the environment untreated, posing risks to both humans and aquatic wildlife.

Notable incidents of environmental water quality degradation due to chemical contamination occurred in Japan during the 20th century. Itai-Itai and Minamata diseases serve as poignant examples of the consequences of industrial pollution. These diseases resulted from the contamination of water sources with cadmium and methyl mercury, leading to severe health issues for downstream populations who relied on these water sources for irrigation, drinking, washing, and fishing.

In conclusion, water quality is a multi-faceted issue that affects human health, industrial processes, and the environment. Ensuring safe drinking water is a fundamental right, yet millions of people lack access to clean water, leading to devastating health consequences. Industrial and domestic use require specific water quality standards to safeguard machinery and prevent product contamination. Environmental water quality is vital for sustaining ecosystems and protecting aquatic life. Addressing challenges related to water quality is essential for promoting public health, preserving the environment, and ensuring a sustainable future for all.

2.3 Theory

2.3.1 Microcontroller Devices

2.3.1.1 What is a Microcontroller?

Nowadays microcontrollers and embedded systems are almost everywhere in our everyday life. Modern microcontrollers are powerful, versatile, low-cost, reliable, low-consumption tools for solving various tasks in the field of automation, control, entertainment etc.[1] It consists of a processor, memory, and input/output peripherals all integrated into a single chip. Microcontrollers, also known as embedded controllers or microcontroller units (MCUs), are commonly found in various devices such as vehicles, robots, office machines, medical devices, and home appliances.

The functioning of a microcontroller involves interpreting data received from its input/output peripherals using its central processor. The data is temporarily stored in its data memory, which the processor accesses. It uses instructions stored in its program memory to analyze and apply the data. The microcontroller then utilizes its input/output peripherals to communicate and initiate the appropriate action.

Microcontrollers are commonly utilized alongside multiple units within a device to handle various tasks. For example, in a car, there might be several microcontrollers responsible for controlling different systems such as anti-lock braking, traction control, fuel injection, and suspension control. These microcontrollers communicate with each other to synchronize their actions. Some may also interact with a central computer within the car, while others only communicate with fellow microcontrollers. They exchange data through their input/output peripherals and process it to perform their specific functions.

The fundamental components of a microcontroller include the processor (CPU), memory, and input/output peripherals. The processor acts as the "brain" of the device, executing instructions and performing arithmetic, logic, and input/output operations. The memory of a microcontroller comprises program memory and data memory. Program memory stores long-term information about the instructions executed by the CPU, while data memory serves as temporary storage during instruction execution.

Input/output peripherals serve as the interface between the processor and the external world. Input ports receive information and transmit it to the processor as binary data, while output devices carry out tasks based on instructions from the processor. These elements collectively enable the microcontroller to function within the broader embedded system.

Additionally, microcontrollers often incorporate other supportive components. These may include an Analog to Digital Converter (ADC) that converts analog signals from external devices like sensors into digital signals that can be processed by the processor. Conversely, a Digital to Analog Converter (DAC) allows the processor to communicate its outgoing signals to external analog components. The system bus acts as the connection that links all the microcontroller's components together, facilitating data transfer. Serial ports, such as USB or parallel ports, enable the microcontroller to connect to external components and exchange data using a specific method of bit exchange.

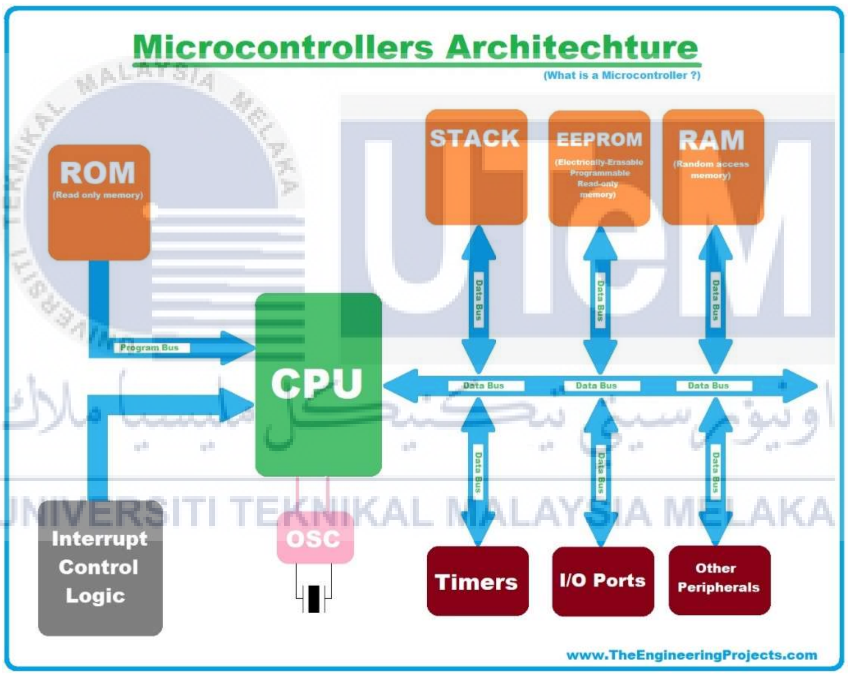

Figure 2.1: Microcontroller Architecture

2.3.1.2 What is Microprocessor?

A microprocessor is an integrated circuit that serves as the core of a computer's central processing unit (CPU). A microprocessor is a chip that can be programmed to perform various tasks. It operates based on a clock signal and utilizes registers for its functioning. When binary data is provided as input, the microprocessor processes it according to the instructions stored in its memory and produces output accordingly. Like the human brain, a microprocessor can be trained to perform a wide range of functions based on its instruction set and capabilities.

The microprocessor comprises several essential components. The Arithmetical and Logical Unit (ALU) is responsible for executing mathematical calculations and logical operations on the data. The Control Unit manages the flow of instructions and data throughout the microprocessor. It coordinates the execution of instructions and ensures the appropriate sequence of operations. The Register Array consists of multiple registers, such as the accumulator (A), B, C, D, and others, which function as quick-access memory locations for temporarily storing and manipulating data during processing.

In summary, the microprocessor functions by accepting input from various input devices. It then processes the input data according to the instructions stored in its memory, using the ALU for calculations and logical operations. The Control Unit manages the flow of instructions and data, while the Register Array acts as fast temporary memory. Finally, the microprocessor generates the desired output based on the processed data and instructions.

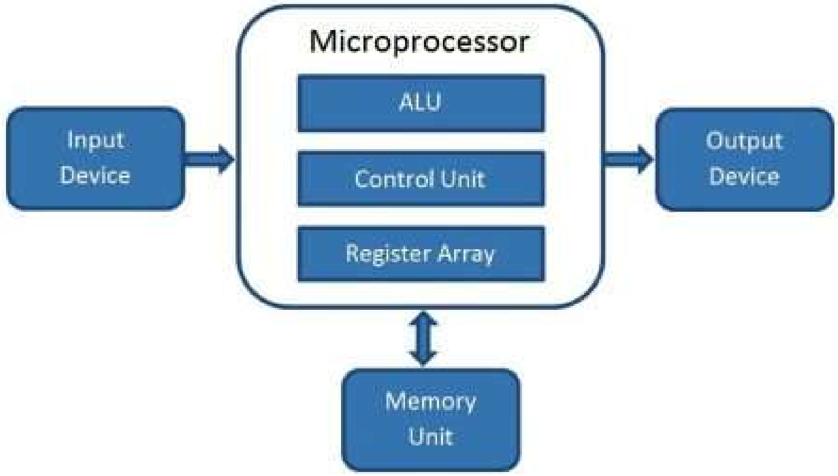

Figure 2.2: Block Diagram for Microprocessor

2.3.1.3 Comparison betweeen Microcontroller and Microprocessor

Table below indicates the comparison between microcontroller and microprocessor.

Table 2.1: Comparison between Microcontroller and Microprocessor

Microcontroller	Microprocessor
A compact integrated circuit that is designed to control a specific function in an embedded system.	An integrated circuit that serves as the core of a computer's central processing unit (CPU)
An external processor along with internal memory and I/O.	Just a processor.
Smaller due to internal memory and I/O	Larger due to outer connection between memory and I/O required
Harvard architecture	Von Neumann architecture
Lower cost	Higher cost
Have power-saving modes like idle mode. Less power consumption	Mostly don't have power-saving features.
8bit/ 16bit/ 32bit	32bit/ 64bit

2.3.1.4 Raspberry Pi

Raspberry Pi is a Linux microcomputer that runs thru a Linux based operating system like Raspbian Jessie.[2] It is a programmable device that encompasses all the essential features of a typical computer motherboard, albeit without built-in peripherals or internal storage. Raspberry Pi is powered by an ARM CPU coupled with operating systems such as RASPBIAN, PIDORA, OPENELEC, RASPBMC, RISC OS, and ARCH LINUX.[3] To set up the Raspberry Pi computer, users must insert an SD card into the designated slot, which should contain the installed operating system necessary for booting. Raspberry Pi computers are compatible with Linux operating systems, which reduces memory requirements and promotes versatility. Once the operating system is set up, the Raspberry Pi can be connected to output devices such as computer monitors or High-Definition Multimedia Interface (HDMI) televisions. Input devices like mice and keyboards also need to be connected. The precise applications and uses of this minicomputer depend on the buyer and can encompass a wide range of functions.

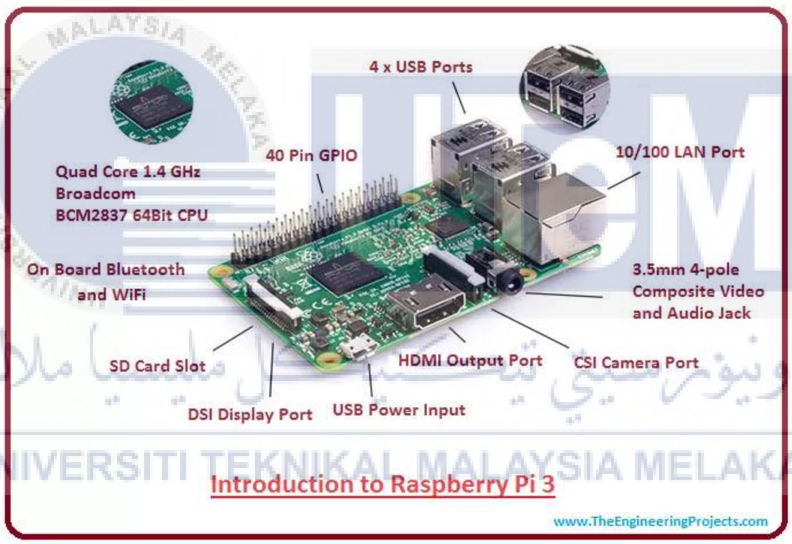

Figure 2.3: Raspberry Pi pin diagram

Table 2.2: Comparison between different Raspberry Pi models

	Raspberry Pi 1 Model A	Raspberry Pi 1 Model A+	Raspberry Pi 1 Model B	Raspberry Pi 1 Model B+	Raspberry Pi 2 Model B	Raspberry Pi 3 Model B	Raspberry Pi Zero
USB 2.0 Ports	1	1	2	4	4	4	1 (Micro-USB)
Ethernet	None	None	10/100 Mbit/s	10/100 Mbit/s	10/100 Mbit/s	10/100 Mbit/s	None
Bluetooth	None	None	None	None	None	4.1	None
WiFi	None	None	None	None	None	802.11n	None
Audio In	I^2S	I^2S	I^2S	I^2S	I^2S	I^2S	I^2S
Audio Out	I^2S, analog (3.5mm jack), digital (HDMI)	I^2S, analog (3.5mm jack), digital (HDMI)	I^2S, analog (3.5mm jack), digital (HDMI)	I^2S, analog (3.5mm jack), digital (HDMI)	I^2S, analog (3.5mm jack), digital (HDMI)	I^2S, analog (3.5mm jack), digital (HDMI)	Digital (mini-HDMI), analog GPIO PWM
Video In	CSI Camera Connector	CSI Camera Connector	CSI Camera Connector	CSI Camera Connector	CSI Camera Connector	CSI Camera Connector	None
Video Out	HDMI, Composite (RCA)	HDMI, Composite (TRRS)	HDMI, Composite (RCA)	HDMI, Composite (TRRS)	HDMI, Composite (TRRS)	HDMI, Composite (TRRS)	Mini-HDMI, GPIO Composite
External Storage	SD	MicroSD	SD	MicroSD	MicroSD	MicroSD	MicroSD

2.3.1.5 Arduino

Arduino microcontroller is an open-source system which can be programmed for wide variety of applications.[4] Furthermore, the utilization of Arduino enables developers to address real-world challenges. Arduino grants access to the realm of microcontrollers, employing the ATmega AVR microcontroller as its core. The Arduino IDE serves as the development platform, facilitating programming tasks using the C++ language. Arduino microcontroller, which is a physical open-source IT platform for developing interactive autonomous objects or objects which connect to the computer, can be used[5] due to the user-friendly features and advantages of Arduino have opened extensive opportunities for learning. However, it is crucial to be mindful of the drawbacks associated with Arduino when selecting the most suitable board for your project.

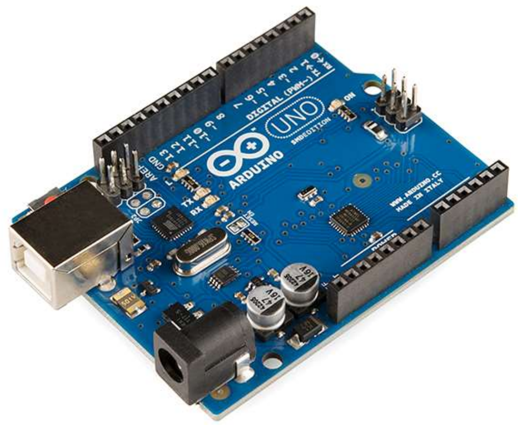

Figure 2.4: Example Arduino board – Arduono UNO R3

Table 2.3: Arduino UNO specifications

Microcontroller Type	ATmega328P-8-bit
Operating Voltage	5 V
Suggested Voltage	7-12 V
Analog Input Pins	6 (A0-A5)
Digital I/O Pins	14 (6 gives PWM output)
DC Current on 3.3V Pin	50 mA
DC Current on I/O Pin	40 mA
Flash Memory	32 kB
SRAM	2 kB
EEPROM	1 kB
Frequency (Crystal Oscillator)	16 MHz

2.3.1.6 ESP-32

The ESP32 module is a series of low-cost, low-power frameworks on a chip microcontroller with integrated Wi-Fi and dual-mode Bluetooth usefulness via its SPI/SDIO or I2C/UART interfaces. It is a double-centered 32cycle LX6 chip, working at 160 or 240 MHz and performing at up to 600 DMIPS. It has around 4MB of internal streak memory.[6] With robust wireless connectivity options, including integrated Wi-Fi and dual-mode Bluetooth, the ESP32 excels in creating interconnected and communicative IoT ecosystems. Its extensive array of GPIO pins provides unparalleled flexibility for interfacing with a myriad of external devices and sensors, making it a versatile choice for electronic projects. Moreover, the inclusion of a real-time operating system enhances its multitasking capabilities, allowing for the simultaneous execution of multiple tasks. This combination of wireless connectivity, advanced GPIO, and RTOS makes the ESP32 an ideal choice for developers seeking a comprehensive solution for diverse IoT applications, where seamless communication, flexible hardware interfacing, and efficient multitasking are paramount.

Figure 2.5: ESP 32 Wi-Fi Module

Table 2.4: ESP 32 Wi-Fi Module

Processor	Dual-core LX6, 32-bit
Clock Frequency	160 or 240 MHz
Performance	Up to 600 DMIPS
Memory	520 KB SRAM, 16 MB Flash
Wireless Connectivity	Wi-Fi (802.11 b/g/n), Bluetooth (Classic and BLE)
GPIO Pins	48 pins
DAC (Digital-to-Analog Converters)	2 (8-bit)
Operating System	Real-Time Operating System (RTOS)
Security Features	Secure boot, flash encryption, cryptographic accelerators
Power Consumption	Low power modes for energy efficiency
Community Support	Strong online community and documentation

2.3.1.7 Comparison between ESP 32 and Raspberry Pi

The table below indicates the comparison between ESP 32 and Raspberry Pi.

Table 2.5: Comparison between ESP 32 and Arduino UNO R3

Feature	ESP 32	Raspberry Pi
Primary Use	Microcontroller for IoT applications	Single-board computer for various projects and applications
Processor	Dual-core LX6, 32-bit	Broadcom BCM2835, ARM Cortex-A72 (Pi 4)
Clock Frequency	160 or 240 MHz	1.5 GHz (Pi 4)
Performance	Up to 600 DMIPS	Varies depending on the Raspberry Pi model
Memory (RAM)	520 KB SRAM	Varies (e.g., 2GB, 4GB, or 8GB on Pi 4)
Memory (Storage)	16 MB Flash	MicroSD card slot for external storage
Wireless Connectivity	Wi-Fi (802.11 b/g/n), Bluetooth (Classic and BLE)	Wi-Fi (802.11 b/g/n/ac), Bluetooth (Pi 3 and 4)
GPIO Pins	48 pins	40 GPIO pins (varies by Raspberry Pi model)
DAC (Digital-to-Analog Converters)	2 (8-bit)	Onboard audio and HDMI output

Operating System	Low power modes for energy efficiency	Varies depending on Raspberry Pi model and usage
USB Ports	Limited (depending on specific ESP32 module)	Multiple USB ports (Pi 4 has 4 USB ports)
Cost	Generally lower cost	Higher cost, but varies based on the model

Table 2.6: Comparison between ESP 32 and Arduino UNO R3

Feature	ESP 32	Raspberry Pi
Primary Use	Microcontroller for IoT applications	Microcontroller for various electronic projects
Processor	Dual-core LX6, 32-bit	ATmega328P, 8-bit
Clock Frequency	160 or 240 MHz	16 MIPS
Performance	Up to 600 DMIPS	16 MIPS
Memory (RAM)	520 KB SRAM	2 KB SRAM
Memory (Storage)	16 MB Flash	32 KB Flash (Expandable with external storage)
Wireless Connectivity	Wi-Fi (802.11 b/g/n), Bluetooth (Classic and BLE)	No built-in wireless connectivity
GPIO Pins	48 pins	14 digital I/O pins, 6 analog input pins

DAC (Digital-to-Analog Converters)	2 (8-bit)	0 (can use PWM for rudimentary analog output)
Operating System	Low power modes for energy efficiency	No operating system (bare-metal programming)
USB Ports	Limited (depending on specific ESP32 module)	1 USB port for programming and power
Cost	Generally lower cost	Relatively lower cost compared to ESP32

2.4 Related Journal

2.4.1 Design and Development of Monitoring System on Carp Farming Ponds as IoT Based Water Quality Control

This project is designed by Mesita Evi Ramadani, Brian Raafi'u, Mahirul Mursid, Rizaldy Hakim Ash-Shiddieqy, Alex Taufiqurrohman Zain and Ahmad Fauzan 'Adziimaa. The main objective is to develop water quality monitoring instruments that can produce continuous and real-time quality data. monitoring water quality in fish farming freshwater pond.[7] A fishpond water quality monitoring system was developed by incorporating temperature, pH, and turbidity sensors. The sensor measurements are processed using a microcontroller, and the system utilizes the ESP32 wireless module for communication. An Android application was created to display the integrated monitoring results online, serving as an Internet of Things (IoT) implementation. Users can access the system through a smartphone application, which provides notifications and enables automated water replacement based on the sensor readings.

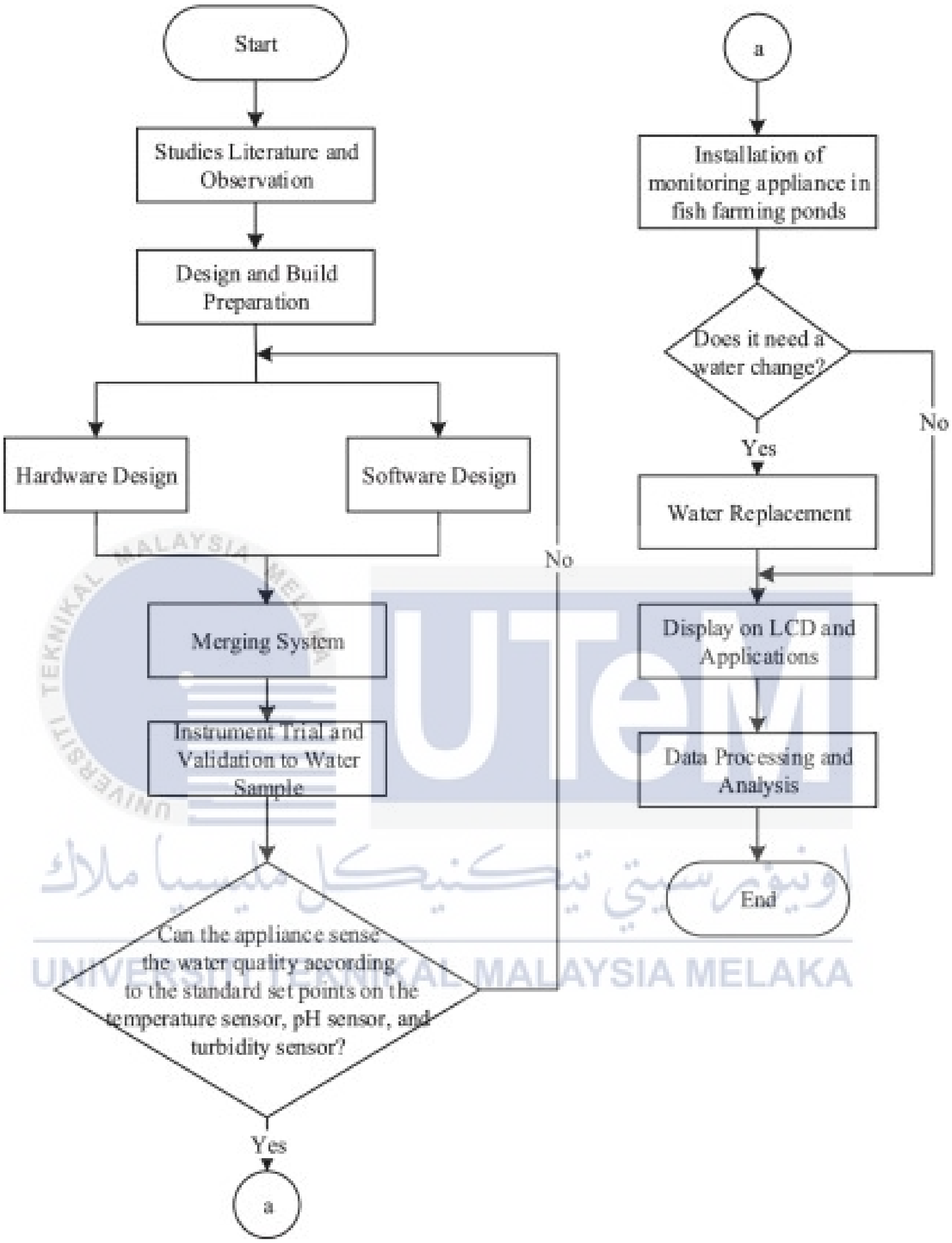

Figure 2.6: Flowchart of the project

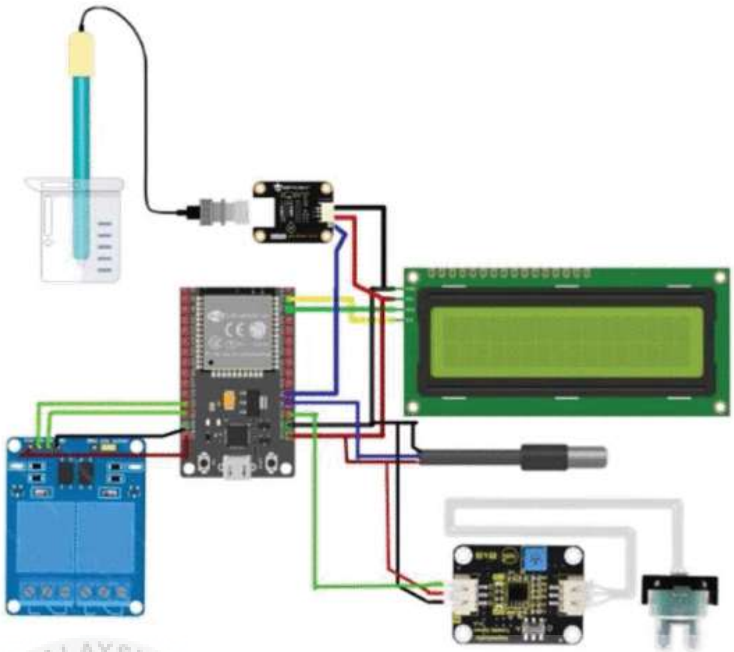

Figure 2.7: Simulation wiring circuit design

Figure 2.8: Hardware circuit inside panel box

2.4.2 Automation System for Monitoring the Quality of Water Sources to Maintain Their Sustainability Using Microcontroller

Ahmed Aziz Atiast and Khansaa Dheyaa Aljafaar conducted this project with the objective of proposing a system to maintain water quality suitable for human use and reduce water waste. The project employed the Arduino microcontroller and sensors to design an automated water pollution monitoring system. The system focused on monitoring physiochemical parameters of the water environment affected by industrial waste dumping into rivers.[8] Parameters such as pH, temperature, turbidity, and dissolved oxygen were measured to detect impurities originating from industries. The Arduino microcontroller processed the collected values from the pH sensor, temperature sensor, turbidity sensor, and ultrasonic sensor. If the water quality parameters deviated from predefined standard values, the system sent an alert message through GSM. The proposed system aimed to prevent harmful pollutants from entering water resources, ensuring the availability of safe drinking water while reducing river pollution by continuously monitoring and informing users about the impact of water pollutants. This enabled intervention and removal of pollutants, thereby preserving water resources as essential sources for sustaining human life.

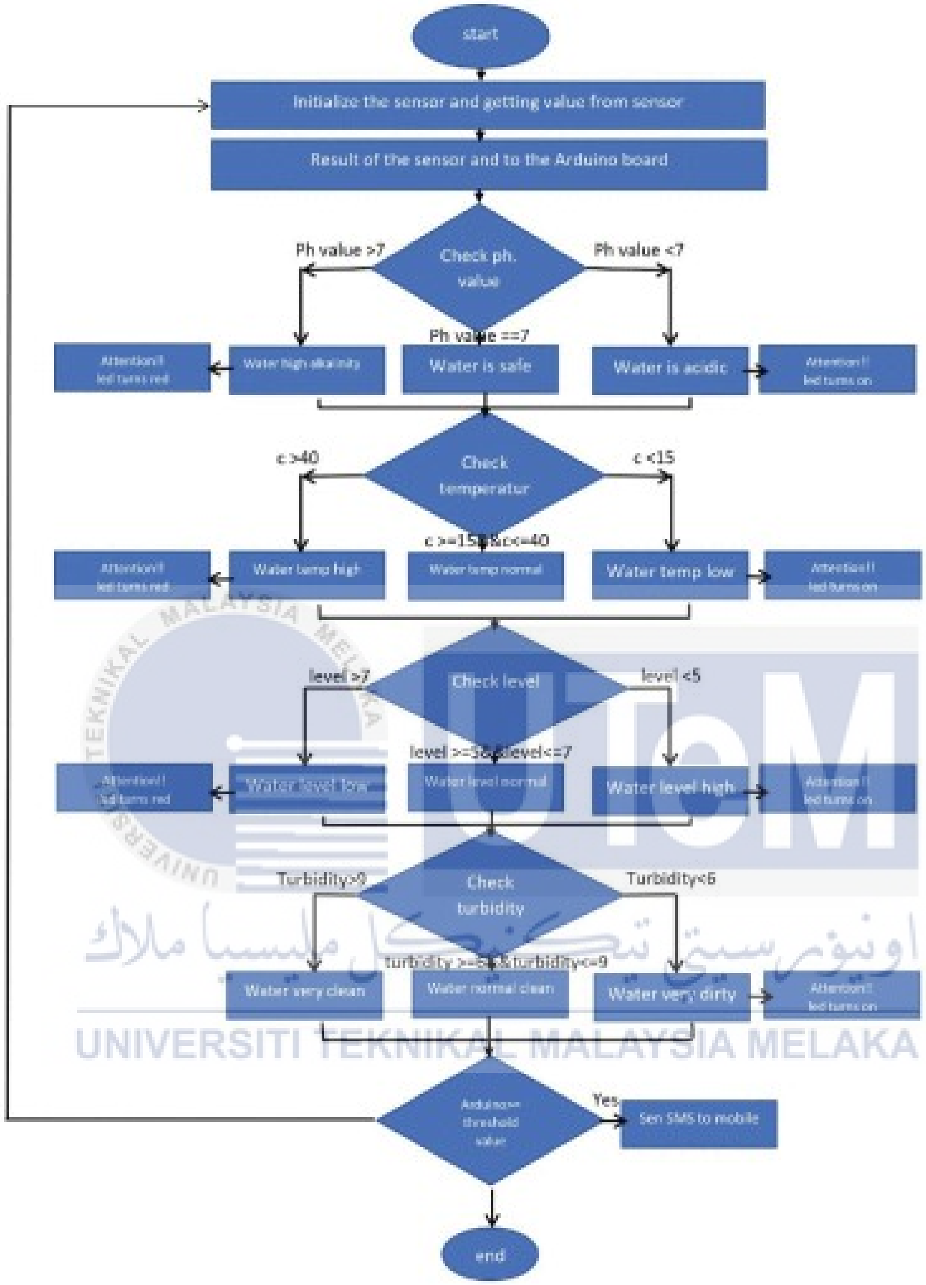

Figure 2.9: Flowchart of the project

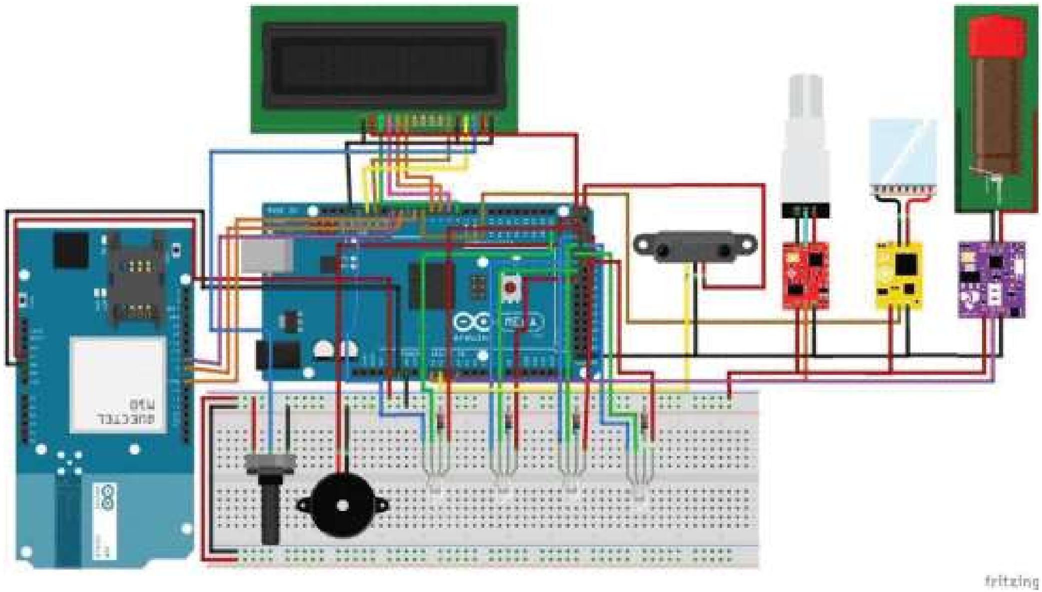

Figure 2.10: Simulation wiring circuit design

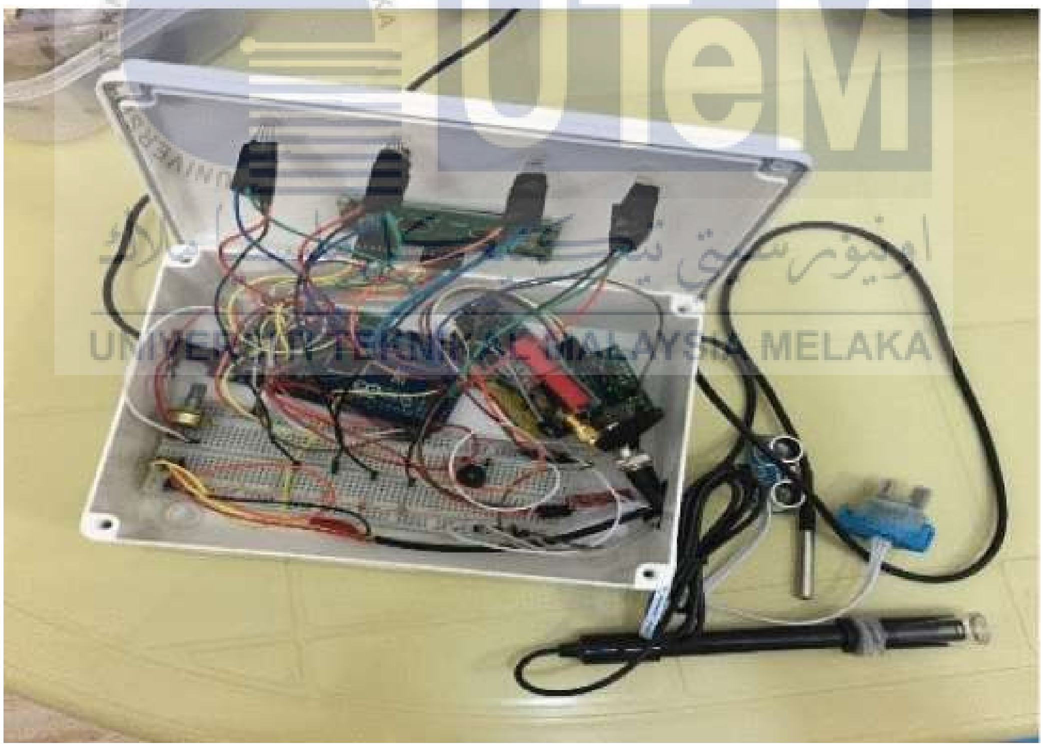

Figure 2.11: Hardware wiring full implementation

2.4.3 An IoT-Based System for Water Quality Monitoring and Notification System of Aquaculture Prawn Pond

This project was developed by Ramzi Adriman, Maya Fitria, Afdhal Afdhal and Alfy Yusyfa Fernanda from Indonesia. The main objective of this project was to develop an IoT-based system that not only monitors the quality of water in a prawn pond but also warns the users when the quality of the water pond is not in great condition.[9] The construction of this system involves various key elements, including the pH sensor, salinity sensor, and ultrasonic sensor for pond water level measurement. The ESP32 microcontroller is employed to process all incoming data. The data obtained from these sensors is stored in the Firebase cloud, facilitating transmission and display through the Android application developed using the Flutter framework.

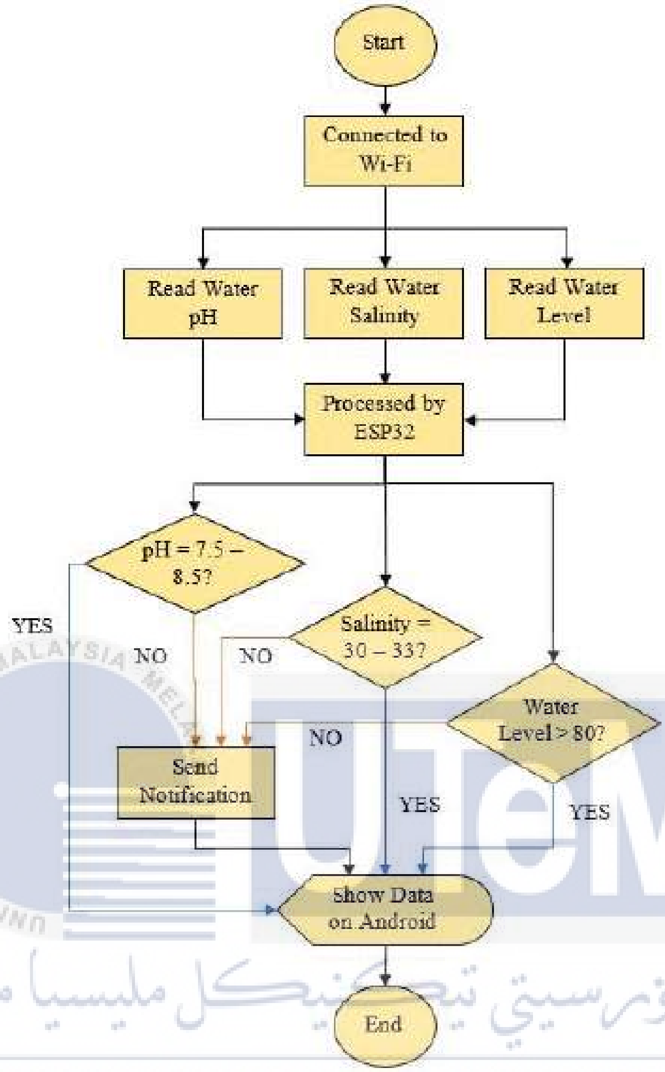

Figure 2.12: Project flowchart

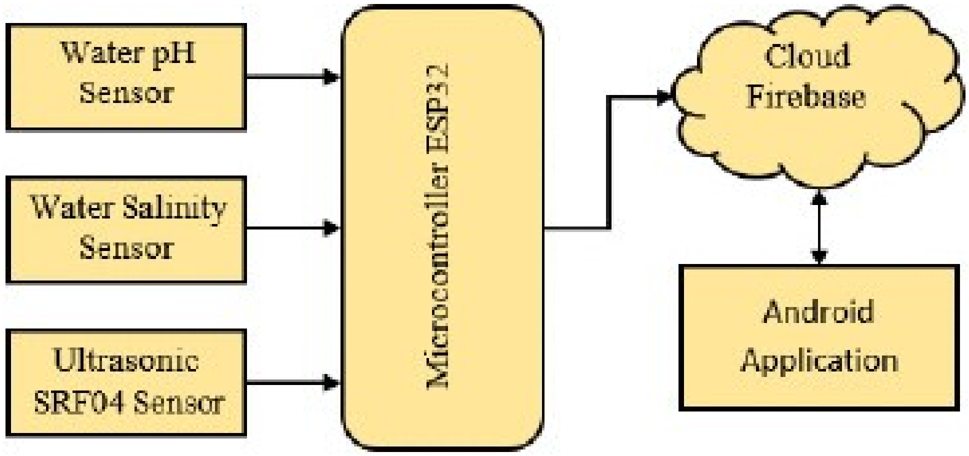

Figure 2.13: Block diagram

Figure 2.14: Physical Design of the System

2.4.4 IoT Based Water Quality Monitoring for Smart Aquaculture

This project has been made by Krishna Reddy D, S. Siva Priyanka, Aruru Sai Kumar, Jhansi Kunduru and Nandhini Batta. They suggested an IoT-based system that uses sensors to monitor water parameters such as pH, temperature, and turbidity remotely.[10] The gathered data is transmitted to a cloud platform via the ESP32 for thorough analysis. In cases where the readings diverge from the specified values, immediate alert notifications are dispatched to the mobile devices of the farmer. The envisaged system is poised to significantly benefit the aqua farming economy.

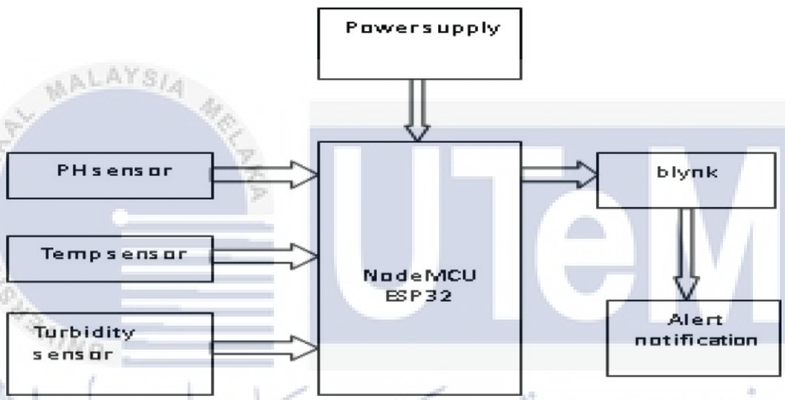

Figure 2.15: Project floating platform structure

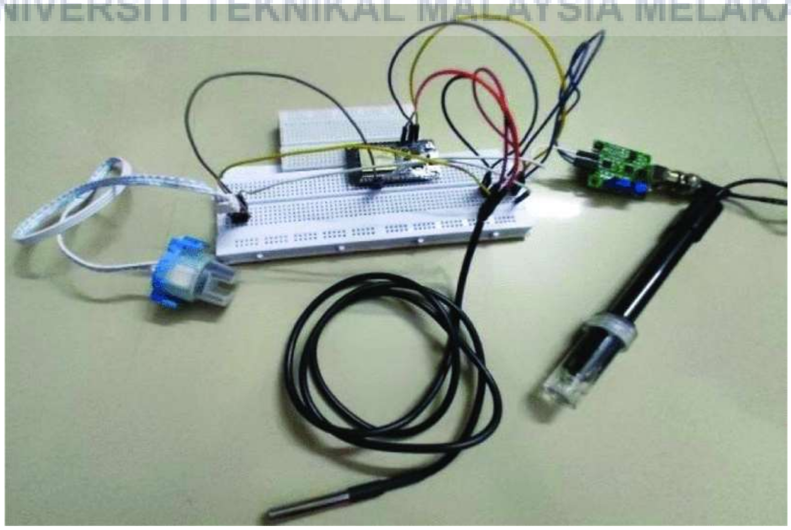

Figure 2.16: Circuit connections of water quality monitoring system

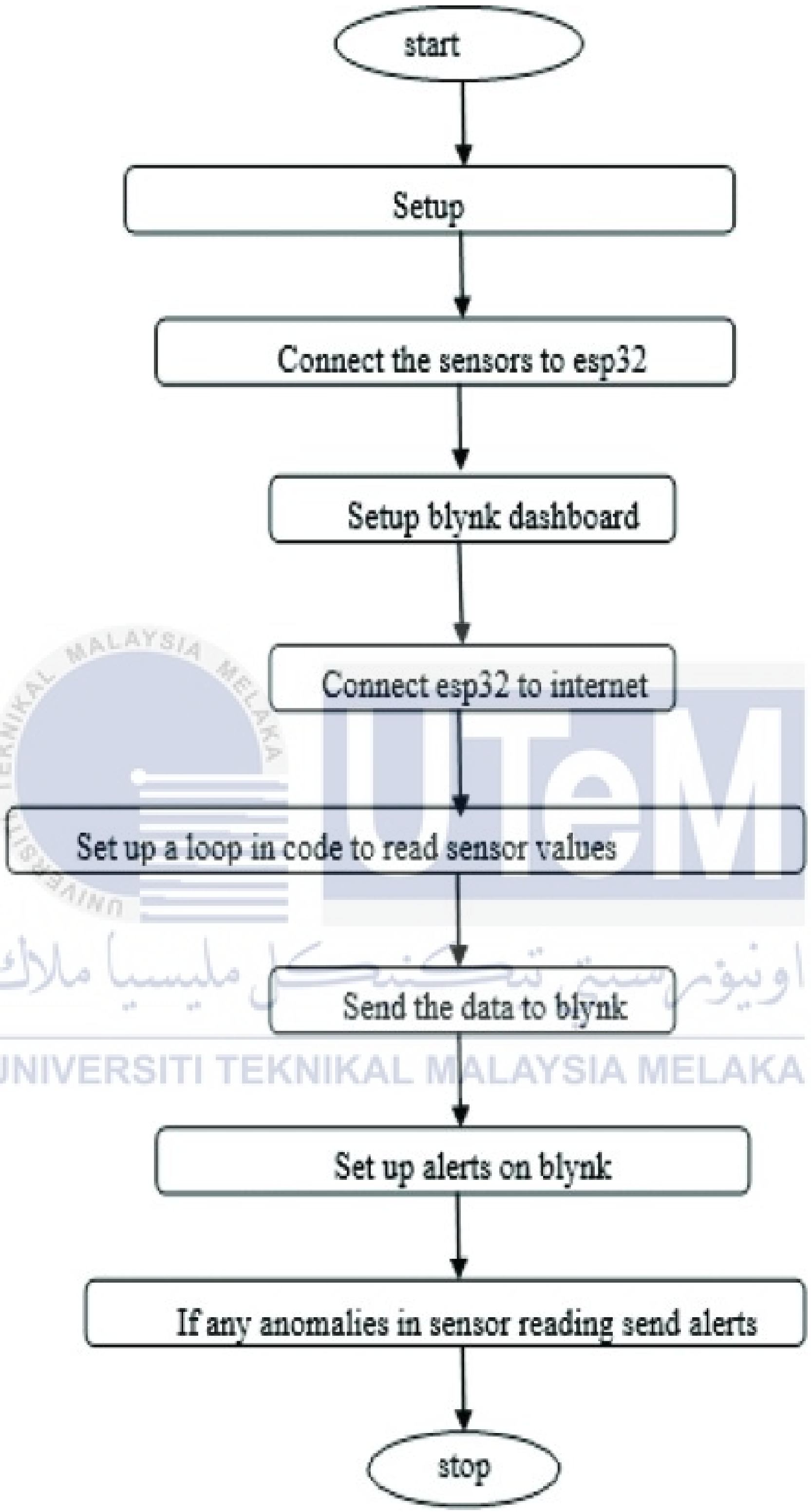

Figure 2.17: Flowchart for software

2.4.5 Smart System with IoT for Water Quality Monitoring

This project is designed by Nivedita Pande and Aakib Sayyad. The objective of this project is to propose an system to ensure that standards of water are checked before it is used or consumed.[11] They assert that due to the substantial expansion of the global industry, the shift from rural to urban living, and the extensive consumption of natural resources such as sea and land, the quality of water accessible to humans has significantly deteriorated. The ongoing surge in the use of chemicals and fertilizers in both agriculture and industries has adversely impacted water quality on a global scale. The system comprises three sensors: TDS, Turbidity, and Temperature that interconnect with ESP32. A regulated 5V supply is ensured for the entire system through a voltage regulator (7805), derived from a 12V source. Additionally, the system is linked to the Arduino Cloud, enabling the retrieval of data on smartphones or computers.

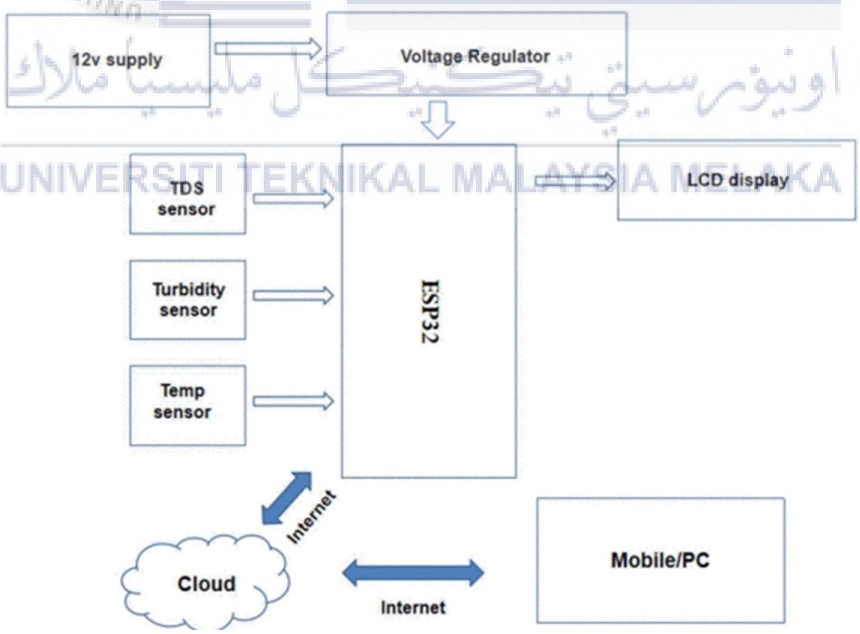

Figure 2.18: Block diagram for proposed model

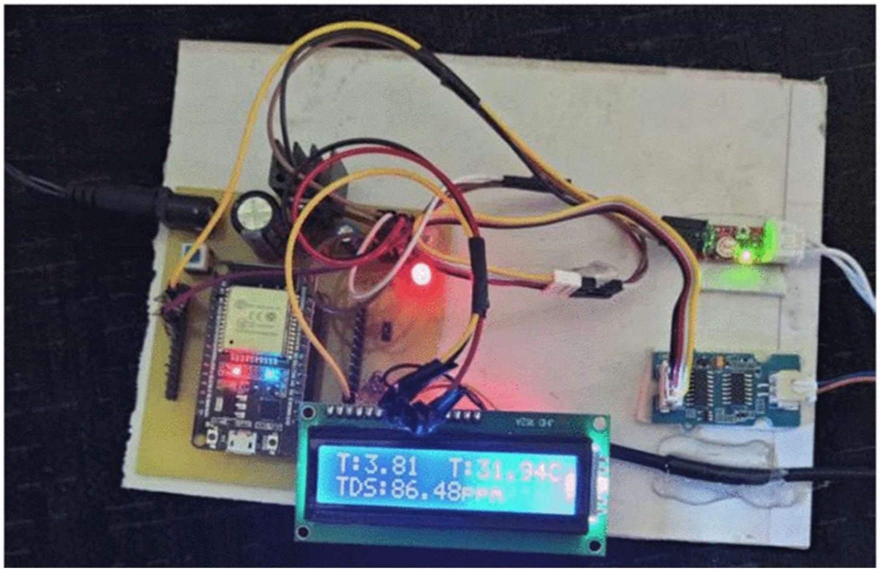

Figure 2.19: Hardware assembly

2.4.6 Comparison Between Different Methods Used by Previous Researcher

Table 2.7: Comparison of previous Research

No.	Author	Year	Title	Variables	Method	Advantage
1	Mesita Evi Ramadani, Brian Raafi'u, Mahirul Mursid, Rizaldy Hakim Ash-Shiddieqy, Alex	2021	Design and Development of Monitoring System on Carp Farming Ponds as IoT-Based Water	Temperature pH level Turbidity	Use Arduino UNO and ESP 32 to transmit data to smartphone through Wi-Fi	-Easier for farmers to monitor and control fishpond water by measuring objects in real-time.

	Taufiqurrohman Zain and Ahmad Fauzan 'Adziimaa		Quality Control			-Has good accuracy
2	Ahmed Aziz Atiast and Khansaa Dheyaa Aljafaar	2022	Automation System for Monitoring the Quality of Water Sources to Maintain Their Sustainability Using Microcontroller	pH level Temperature Turbidity Dissolved oxygen	Use Arduino Mega to process the data and display at LCD, and by connecting the GSM all parameters will send as a text to observer's mobile.	-System can monitor water quality automatically -Low cost -Good flexibility -Enables self-protection and provides smart environment
3	Ramzi Adriman, Maya Fitria, Afdhal Afdhal	2022	An IoT-Based System for Water	pH level Salinity Water level	The assembly of this system involves	-System can monitor water quality

	and Alfy Yusyfa Fernanda		Quality Monitoring and Notification System of Aquaculture Prawn Pond		several key components measurement along with the microcontroller ESP32 tasked with processing all input data.	automatically -Low cost -Enables self-protection and provides smart environment
4	Krishna Reddy D, S. Siva Priyanka, Aruru Sai Kumar, Jhansi Kunduru and Nandhini Batta	2023	IoT Based Water Quality Monitoring for Smart Aquaculture	pH level Turbidity Temperature	Utilizing IoT technology, this system employs sensors to remotely monitor water parameters like pH, temperature, and turbidity, with the collected data	-System can monitor water quality automatically -Low cost -Enables self-protection and provides smart environment

					transmitted to a cloud platform via ESP32 for analysis.	
5	Nivedita Pande and Aakib Sayyad	2022	Smart System with IoT for Water Quality Monitoring	Total dissolved solid Temperature Turbidity	Use ESP 32 as microcontroller with integrated Wi-Fi to implemetn IoT technology	-System can monitor water quality automatically -More proficient -Enables self-protection and provides smart environment
6	Sheikameer Batcha. S, Pushpalatha. N, Kasthuri. M, Rokith. K,	2022	Monitoring System for Water Quality	-pH level -Turbidity	Use Arduino UNO and ESP 32 as its Wi-Fi microchip to	-More proficient,

	Subathra. D and Ragul. S		Using Solar Powered IoT		implement IoT technology	
7	Yande Xiang, Luyang Cai, Xinwei Li, Yingwen Sun and Yongyan Gu	2022	A Study and Design of Photovoltaic Water Monitoring Management Oxygenation System Based on Internet of Things	-Oxygen -PH value -Turbidity -Water level -Temperature -PM2.5	Use Arduino Mega to for data processing and uses cloud computing, pattern recognition using camera module which adopt Wi-Fi technology to implement IoT technology	-Avoid environmental pollution -Provides simple and safe operation -Automatically travel to specific location through mobile control to reduce multifarious manual monitoring and labour cost.

8	Yafei Yang, Pengxiang Li, Hui Li and Ruiqing Zhang	2019	Design of Water Quality Intelligent Monitoring System for Nuclear Power Station Intake	-Temperature -Ammonia nitrogen content -Chlorophyll content -Turbidity -pH level -Dissolved oxygen	Use STC89C52RC microcontroller to process parameters obtained and transmit them to LabVIEW platform at the water surface through a wireless Ad hoc using nRF24L01 modules.	-data error small, stable, and reliable
9	Wondimagegn T Beshah, Jane Moorhead, Padmanava Dash, Robert J. Moorhead,	2021	IoT Based Real-Time Water Quality Monitoring and Visualization	-Chlorophyll a -Phycocyanin -Phycoerythrin	Use ASV to predetermine data collection path using GPS waypoints.	-Easy to capture and visualize large data sets in real-time while querying

	James Herman, M. S. Sankar, Daniel Chesser, Wes Lowe, Jessica Simmerman and Gray Turnage		System Using an Autonomous Surface Vehicle	-Coloured Dissolved Organic Matter -Dissolved Oxygen -Temperature -Turbidity -Salinity -pH level -Partial Pressure of Carbon Dioxide -Backscattering	Data captured through sensors and transmitted through cellular network to a server.	historical data in few clicks.
10	Supriya R. Khaire and Revati M. Wahul	2018	Water Quality Data Analysis and Monitoring System in IoT Environment	-Carbon Dioxide -pH -Turbidity -Temperature	Use ARM-based microcontroller to convert analog signal to digital signal and	-Wide use applications in many different areas - Provide possible

				-Water Level	transmit parameters through Zig-Bee module to personal computer to do data analysis	impact to many different aspects that may affect species and habitats of different places.

2.5 Summary

By referring to the works and theories of researchers, the information related to the project provided insights into the methods utilized by previous researchers, thereby expanding my knowledge. Furthermore, comparisons between microcontrollers, variables methods and benefits are created to show the common and distinctive between the knowledge given by previous researchers. Throughout the comparison method between the previous research, the most common microcontroller and Wi-Fi module are ESP 32, Arduino UNO and ESP-8266. For me, I choose to use ESP 32 module because it is a combination of Arduino UNO and ESP-8266 since it can act as microcontroller and Wi-Fi module at the same time.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The methodology chapter of this project serves as a comprehensive guide to the research approach, data collection methods, data analysis techniques, and ethical considerations employed in investigating this project. By outlining the systematic procedures and tools utilized, this chapter ensures the reliability, validity, and transparency of the research findings. It begins by elucidating the research design and rationale, followed by a detailed discussion of the population or sample selection, data collection procedures, and data sources. Additionally, it addresses measures taken to enhance data quality and protect the rights of participants. The methodology chapter plays a critical role in establishing the credibility and robustness of the study, enabling readers to evaluate the research process and understand how the data was obtained and analyzed to address the research questions.

3.2 Project Explanation

A project explanation is created after the entire project has been completed. Figure 3.1 shows the procedure to accomplish this project.

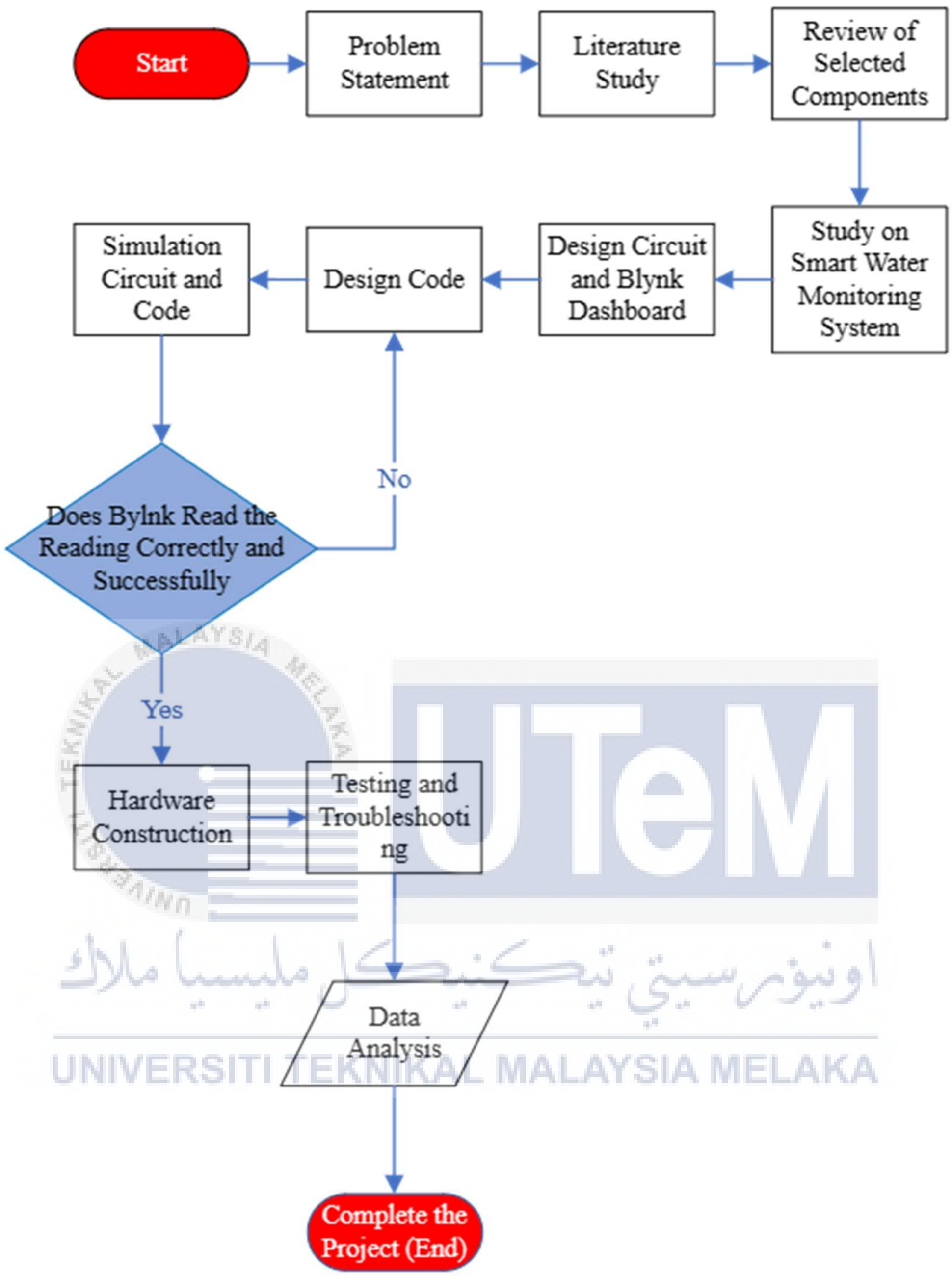

Figure 3.1: Project flowchart

3.2.1 Literature Study

To gain insight and knowledge regarding the development of smart water quality monitoring systems, a comprehensive literature study has been conducted, encompassing research articles and conference papers by scholars from various regions across the globe. The literature study process involved several key steps to ensure a systematic and reliable approach.

Initially, relevant sources were gathered by conducting keyword searches on Google, Google Study, IEEE, ScienceDirect, and ResearchGate. These platforms serve as valuable repositories of scholarly work in the field of IoT and smart monitoring systems. The identified sources were then meticulously evaluated to determine their relevance and significance to the current research topic.

Following the evaluation, a careful selection was made, focusing on the most pertinent and influential sources. This selection process aimed to gather high-quality literature that could provide valuable insights and contribute to the development of the project. Only sources that met rigorous criteria in terms of reliability, credibility, and alignment with the research objectives were included.

Subsequently, an in-depth study of these selected sources was conducted to extract valuable information and establish the foundation for the project's outline. This stage involved a thorough analysis of the literature, assimilating key findings, methodologies, and theoretical frameworks from the selected sources. It was crucial to ensure that the information incorporated into the project originated from reputable and trustworthy sources, thereby enhancing the reliability and validity of the research.

Figure 3.2 illustrates the systematic process followed during the literature study, depicting the sequential steps undertaken to acquire, evaluate, select, and incorporate relevant information from reliable sources. This flowchart serves as a visual representation of the comprehensive literature review process, which played a pivotal role in informing and shaping the current research on IoT-enabled smart monitoring systems.

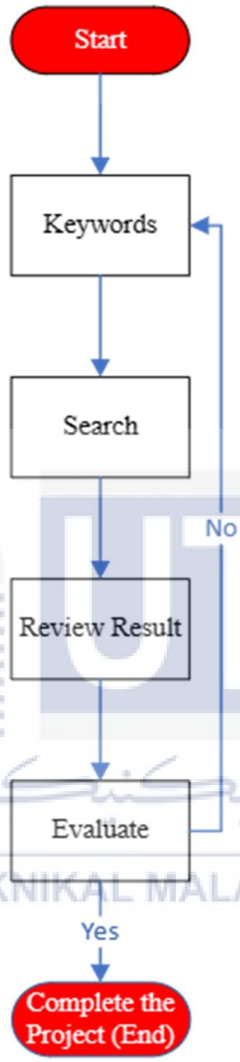

Figure 3.2: Flowchart of the literature study

By conducting this thorough literature review, a solid foundation of knowledge has been established, enabling the project to benefit from the valuable insights and expertise contributed by researchers worldwide.

3.3 Hardware Development of the System

3.3.1 Review on Selected Components

The hardware development aspect of the project focuses on designing and integrating the necessary components to create an efficient and reliable Smart Water Quality Monitoring System.

a) ESP32-WROOM-32 module

The ESP32 is a family, having features like cost effective, less power consumption, system-on-a-chip microcontrollers that include Wi-Fi on chip and dual-mode Bluetooth.[11] It has a dual-core processor, 520 KB SRAM, 16 MB flash memory, and a wide range of input/output interfaces such as GPIO, I2C, SPI, and UART. The ESP32 is an ideal platform for developing smart devices due to its powerful features, flexibility, and low cost.[12] The ESP32 microcontrollers support various sleep modes, enhancing their energy efficiency for battery-powered applications. They come with a built-in real-time clock (RTC) that allows them to keep track of time even when in low-power states. Additionally, the ESP32 family features a variety of peripherals such as touch sensors, capacitive touch pins, and an analog-to-digital converter (ADC), providing versatility for different applications. The microcontrollers are compatible with popular development platforms, including the Arduino IDE and the Espressif IoT Development Framework (ESP-IDF), simplifying the development process. The ESP32 modules often have multiple variants, catering to specific application requirements, and their community support continues to grow, fostering a rich ecosystem of libraries, tutorials, and projects.

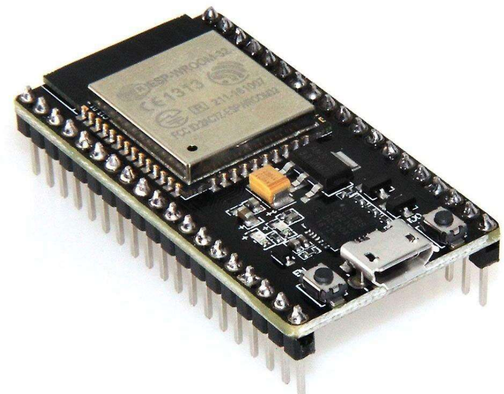

Figure 3.3: ESP32-WROOM-32 module

b) E-201-C pH sensor

The pH and temperature sensor offers a versatile solution for accurate measurement in various applications. With its dual functionality, this sensor eliminates the need for separate sensors, saving both cost and space. It provides reliable and precise measurements, making it ideal for research, monitoring, and control purposes. The sensor operates at a heating voltage of 5 ± 0.2V (AC · DC) and has a low working current of 5-10mA, ensuring energy efficiency. It can detect a wide concentration range from pH 0 to 14, allowing for comprehensive pH analysis in different environments. In addition to pH measurement, this sensor also incorporates temperature detection within a range of 0-80 °C. This feature enables simultaneous monitoring of both pH and temperature, providing valuable insights into the correlation between these parameters. With a fast response time of ≤5 seconds and settling time of ≤60 seconds, the sensor delivers quick and accurate results, minimizing waiting time and enhancing efficiency in data collection. Its compact module size of 42mm × 32mm × 20mm, along with four M3 mounting holes, ensures easy installation and integration. The output of the sensor is an analog voltage signal, facilitating compatibility with various data acquisition systems or microcontrollers. With its reliable performance, wide operating temperature range (-10 ~ 50 °C), and high humidity tolerance (95% RH nominal), the pH and temperature sensor are suitable for this project.

Figure 3.4: pH Sensor

c) TS-300B turbidity sensor

Turbidity sensors are valuable technological devices designed to assess the clarity of water samples. By directing a beam of light through the water, the sensor can detect any particulate matter present. When the light encounters these particles, it scatters, allowing the turbidity sensor to measure the extent of scattering. If the scattering exceeds the expected level, it indicates a higher concentration of contaminants in the water. It is important to note that only solid particles that are not dissolved in the water can cause light scattering. A 30mmx20mmx12mm turbidity sensor operates at a working voltage of DC5V, the sensor ensures compatibility with common power sources. It has a maximum working current of 30mA, allowing for efficient power consumption during operation.

Figure 3.5: Turbidity Sensor

d) DS18B20 temperature sensor

The DS18B20 waterproof temperature sensor is a versatile and reliable device designed for temperature measurement in various applications. It has the ability of bi-directional communication with the microcontroller. Its stainless-steel tube, measuring 6mm in diameter and 30mm in length, ensures durability and water resistance, making it suitable for use in both indoor and outdoor environments. With a temperature range of -55°C to 125°C (-67°F to +257°F) and an accuracy of ±0.5°C in the range of -10°C to +85°C, the DS18B20 sensor provides precise temperature readings for critical monitoring. It supports selectable resolution of 9 to 12 bits, allowing users to adjust the level of detail required in temperature measurements. The sensor uses the efficient 1-Wire interface, requiring only a single digital pin for communication, simplifying the integration process. It also features a unique 64-bit ID burned into the chip, enabling easy identification and differentiation when using multiple sensors in the same system. The DS18B20 temperature sensor includes a temperature-limit alarm system, allowing users to set custom thresholds for temperature monitoring and trigger alerts or actions accordingly. With its quick query time of less than 750ms, the sensor provides fast and reliable temperature data, enabling real-time monitoring and control in various applications.

Figure 3.6: Temperature Sensor

e) Blynk.io

Blynk is an IoT platform specifically designed for iOS and Android smartphones, serving to remotely control Arduino, Raspberry Pi, and NodeMCU devices over the internet. With Blynk, users can create intuitive graphical interfaces or human machine interfaces (HMIs) by configuring and assigning appropriate addresses to the available widgets. This versatile application caters to various IoT functionalities, including remote hardware control, sensor data visualization, data storage, and more. The Blynk platform consists of three essential components. Firstly, the Blynk App empowers users to design visually appealing interfaces for their projects using a diverse range of widgets provided within the application. Secondly, the Blynk Server acts as the communication hub between the smartphone and the connected hardware. Users have the flexibility to utilize the Blynk Cloud service or deploy their own private Blynk server locally. The open-source nature of Blynk allows for scalability, capable of managing thousands of devices and even running on a Raspberry Pi. Lastly, the Blynk

Libraries facilitate seamless communication between the hardware platforms and the server, efficiently processing incoming and outgoing commands. When a button is pressed within the Blynk application, a series of data transmission occurs. The data is transmitted to the Blynk Cloud, which then intelligently routes the data to the corresponding hardware device that has been configured and connected to the Blynk platform, enabling seamless interaction and control between the smartphone and the physical hardware.

Figure 3.7: Blynk.io

f) Arduino IDE

The Arduino IDE (Integrated Development Environment) is a software application that provides a user-friendly interface for writing, compiling, and uploading code to Arduino boards. It is designed to simplify the process of creating and programming Arduino projects, even for individuals with limited programming experience. The Arduino IDE offers a straightforward platform for writing code in the Arduino programming language, which is based on C and C++. It provides a set of libraries and functions specific to Arduino boards, making it easier to interact with the hardware components connected to the board. The IDE features a text editor where users can write their code, complete with syntax highlighting and auto-completion to assist in coding. Once the code is written, it can be compiled within the IDE to check for any syntax errors or compilation issues. The IDE also supports easy integration of libraries, allowing users to expand the functionality of their projects with pre-built code modules. One of the key features of the Arduino IDE is its ability to upload compiled code to Arduino boards. By selecting the appropriate board and port settings, users can seamlessly transfer their code to the connected Arduino board, making it ready to run the programmed functionality. The Arduino IDE provides a user-friendly and accessible environment for programming Arduino boards, empowering individuals to bring their ideas to life and create interactive projects. With its intuitive interface and extensive community support, the Arduino IDE remains a popular choice for beginners and advanced users alike.

Figure 3.8: Arduino IDE software

g) Dev C++

Dev-C++ is an esteemed integrated development environment (IDE) renowned for its user-friendly programming language and extensive features, providing a comprehensive platform for programming in C and C++. It is released under the GNU General Public License and is available at no cost. Notably, the Arduino compiler accepts both C and C++, with a significant portion of its libraries written in C++. While the Arduino language is primarily based on C++, it exhibits the potential for object-oriented programming. Therefore, when referring to the "Arduino language," it encompasses the usage of C++ or C. Dev-C++ serves as an invaluable tool for developers, students, and researchers seeking a powerful and accessible environment for their C and C++ programming endeavors.

Figure 3.9: Dev C++

3.3.2 Parameters

Parameters are a measurable or observable characteristic or quantity that is used to define, describe, or evaluate a system, process, phenomenon, or object. In the context of scientific research or data analysis, parameters are often variables or factors that are studied or measured to understand their influence or relationship with certain outcomes or phenomena. Parameters can be physical, chemical, biological or any other measurable attribute that is relevant to the specific study or analysis. Parameters serve as essential components in experimental design, statistical analysis, modelling, and decision-making processes, providing objective measures for comparison, evaluation, and prediction. In this project, the parameters that will be evaluated are the pH level, temperature, and turbidity of water.

3.3.2.1 Water Quality Index (WQI)

Water quality index (WQI) is the singular measure that indicates the quality of water, and it is calculated using various parameters that are truly reflective of the water's quality[13][14]. The objective of the WQI is to classify the waters relative to biological, chemical, and physical characteristics defining their possible uses and managing their allocations[15]. In this project, the parameters are chosen from the table of WQI to test the water quality, so the project can follow the world standard. The parameters are temperature, pH level and turbidity.

Table 3.1: Parameter for 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)*	5000 (20000)*	-
Total Coliform	count/100 ml	100	5000	5000	50000	50000	> 50000

3.3.2.2 pH level

pH, is divided into acidic and alkaline properties.[16] pH level is a measure of the acidity or alkalinity of a solution. It represents the concentration of hydrogen ions (H+) in a solution, determining whether it is acidic, neutral, or alkaline. The pH scale ranges from 0 to 14, where a pH of 7 is considered neutral. Values below 7 indicate acidity, with lower numbers indicating higher acidity, while values above 7 indicate alkalinity, with higher numbers indicating higher alkalinity. The pH scale is logarithmic, meaning that each unit represents a tenfold difference in acidity or alkalinity. pH level is an important parameter in various fields, including chemistry, biology, environmental science, and water quality assessment, as it influences chemical reactions, biological processes, and the overall balance of ecosystems.

Table 3.2: Examples of pH level for each type of water

Type	pH level
Tap Water	6.5 – 8.5
Bottled Drinking Water	6.5 – 8.5
Natural Spring Water	6.5 – 8.5
Freshwater Lakes and Rivers	6 – 8.5
Seawater	7.5 – 8.4
Swimming Pool Water	7.2 - 7.8
Aquarium Water	6 – 8
Rainwater	5.6 – 6.9
Distilled Water	7

3.3.2.3 Turbidity

Turbidity, as a parameter in a water quality monitoring system, refers to the measurement of suspended particles or sediment in water. It is a crucial indicator of water clarity and quality. Turbidity is typically measured using a turbidimeter or turbidity sensor, which quantifies the amount of light scattered or absorbed by the suspended particles in the water sample. The measurement is usually expressed in Nephelometric Turbidity Units (NTU) or Formazin Nephelometric Units (FNU). Monitoring turbidity levels in water provides valuable information about the presence of particulate matter and can indicate pollution, sediment runoff, or other contaminants that may affect the overall water quality. By incorporating turbidity measurement into a water quality monitoring system, researchers and water resource managers can assess the impact of land use activities, identify sources of pollution, and make informed decisions for effective water management and conservation strategies.

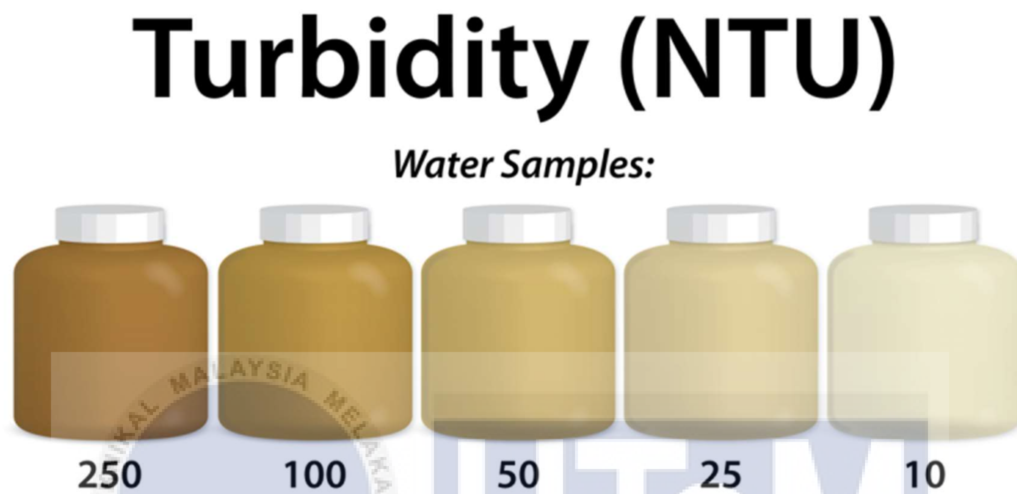

Figure 3.10: Turbidity for different water sample

3.3.2.4 Temperature

Temperature, as a parameter in a water quality monitoring system, refers to the measurement of the thermal condition of water. It plays a vital role in understanding the physical and biological characteristics of aquatic ecosystems. Changes in water temperature can affect the solubility of gases, nutrient availability, metabolic rates of organisms, and overall ecosystem dynamics. It is an essential parameter in assessing water quality, as certain species have specific temperature requirements for survival, reproduction, and growth. The change of temperature also will affect dissolved oxygen level of water. DO in hot water is relatively small, so it also decreases in the common sewer where the tofu wastewater is disposed.

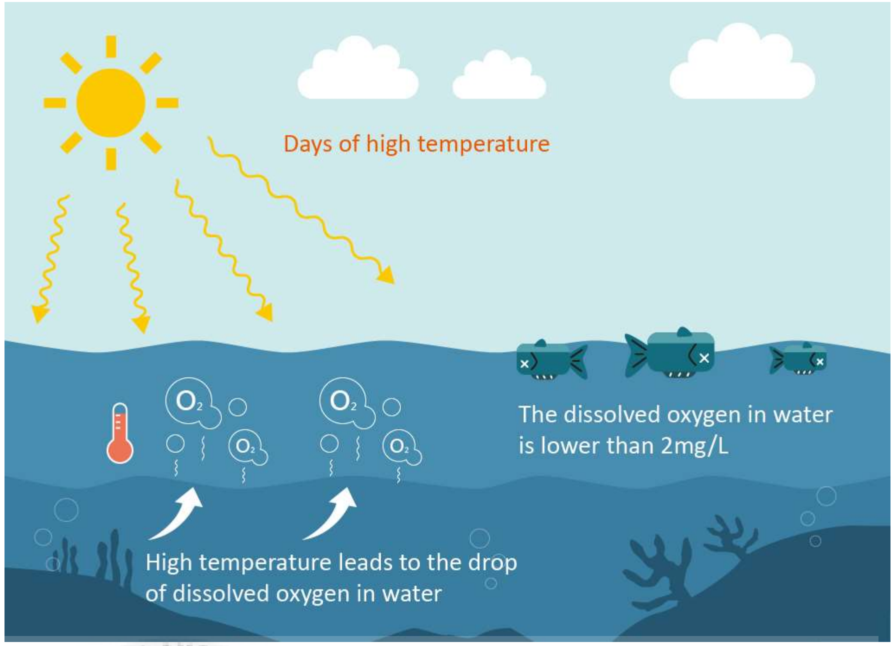

Figure 3.11: Effect of higher water temperature

3.4 Wiring Connection

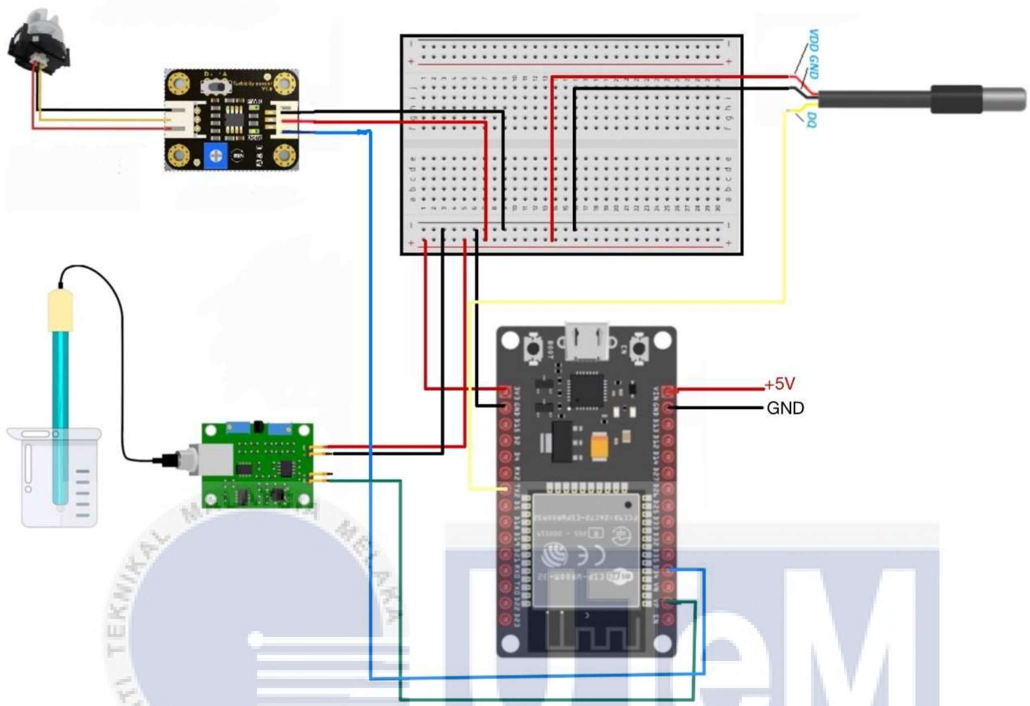

Figure 3.12: Wiring connection of the project

The wiring connection in Figure 3.12 connects all the sensors to the ESP 32 module. To make viewer easier to differentiate the function of wires, the colour of wires is set differently in the figure. The red wire indicates the power supply wire. The black wire is the wire that is connected to the ground. The power supply pin I choose to connect to all sensors is 3.3V of the ESP 32. An external power supply is connected to the Vin pin on the right side of ESP 32. The pH sensor is connected to pin 36 or A0 with green colour wire. The turbidity sensor is connected to pin 34 with blue colour wire. Both sensors use the analog pin to transfer data because the output signal from the sensors is analog voltage that varies with the parameters of the solution it is measuring. The analog output voltage from the sensors provides a continuous range of values corresponding to different parameters reading. While for temperature sensor, it is connected to the pin 17 or TX2 at the left side of ESP 32 by yellow colour wire because it communicates using the OneWire protocol, which is a digital communication protocol.

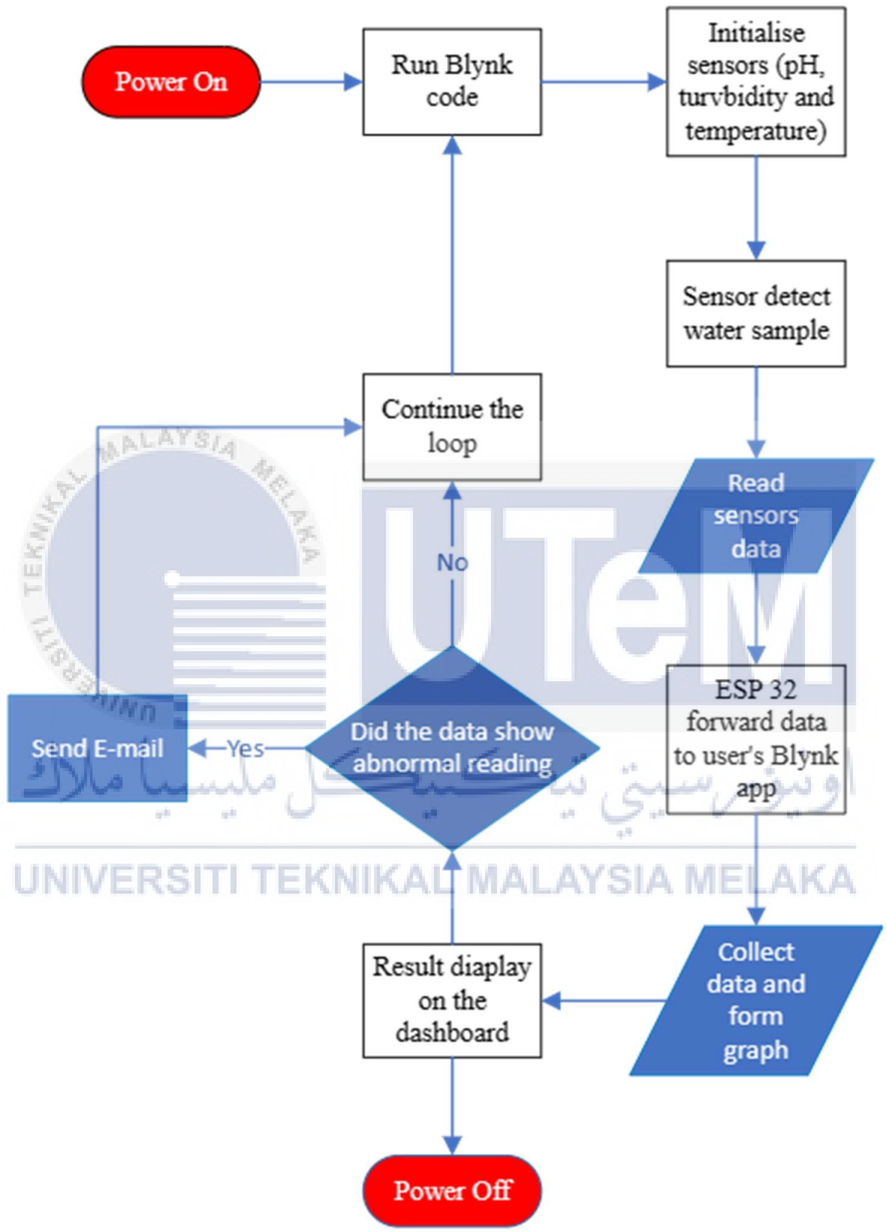

Figure 3.13: Flowchart at microcontroller

3.5 Limitation of proposed methodology

Limitations refer to constraints or factors that arise during a study and are beyond the researcher's control, restricting the scope and potentially influencing the overall findings and conclusions. Regardless of the meticulousness of a study, every research project has inherent limitations. In the present study, one limitation pertains to the allocated budget of RM 200. With a higher budget allocation, additional sensors such as a water level sensor for measuring water levels, a conductivity sensor for assessing ion concentration, a dissolved oxygen sensor to determine oxygen content, and more could have been utilized to further evaluate water quality based on crucial parameters. Additionally, the collection of water samples posed a challenge in this project. Due to the inconvenience of traffic, the range for water collection is limited. Due to the insufficient budget, the process of buying components also bothers me. The quality of components cannot be guaranteed if I buy the cheap components.

.

3.6 Summary

The methodology chapter provides a comprehensive overview of the research approach, data collection methods, data analysis techniques, and ethical considerations employed in the project. It outlines the systematic procedures and tools used to ensure the reliability and validity of the research findings. The chapter discusses the research design, sample selection, data collection procedures, and data sources. It also highlights measures taken to enhance data quality and protect the rights of participants. The methodology chapter plays a critical role in establishing the credibility and robustness of the study, enabling readers to evaluate the research process and understand how the data was obtained and analyzed to address the research questions.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

In this section, the outcomes and analysis of the creation of a smart water quality monitoring system using ESP32-based sensors for sustainable environmental management are presented. Case studies have been conducted to showcase the system's effectiveness in assessing the quality of water samples. The water samples were sourced from various locations in Malacca. Employing the proposed approach, pH and turbidity values were acquired within a 15-minute interval.

4.2 Prototype

The completion of the project prototype involved several phases. The prototype assembly included four 1.2V batteries, an ESP32 module, a turbidity sensor, a pH sensor, a temperature sensor, a push-button switch, and a four-cell battery holder, all before delving into the procedures. The system was energized by Direct Current (DC) sourced from the batteries. To ensure a safe operation, all connections between the components had to be securely established before activating the power supply. The design of the prototype's casing aimed to conceal the wires and other components, providing a neat appearance once the results were accurate and reliable.

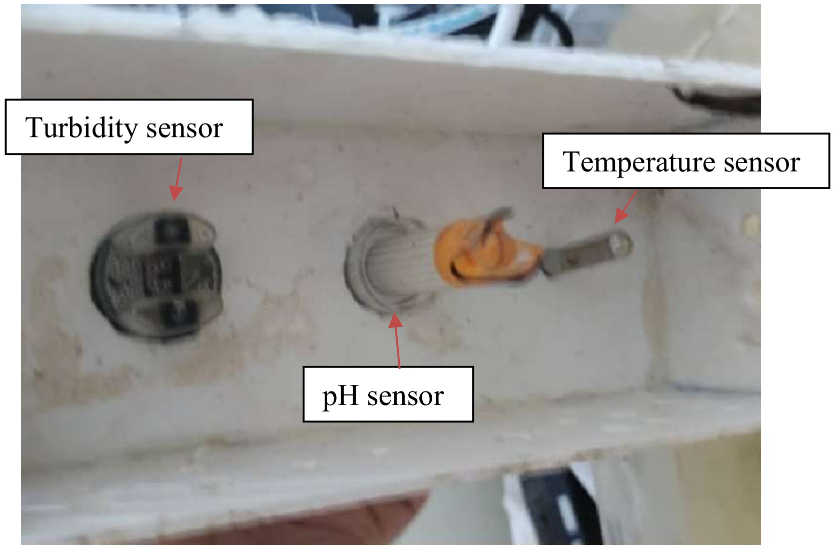

Figure 4.1: Sensors of project prototype

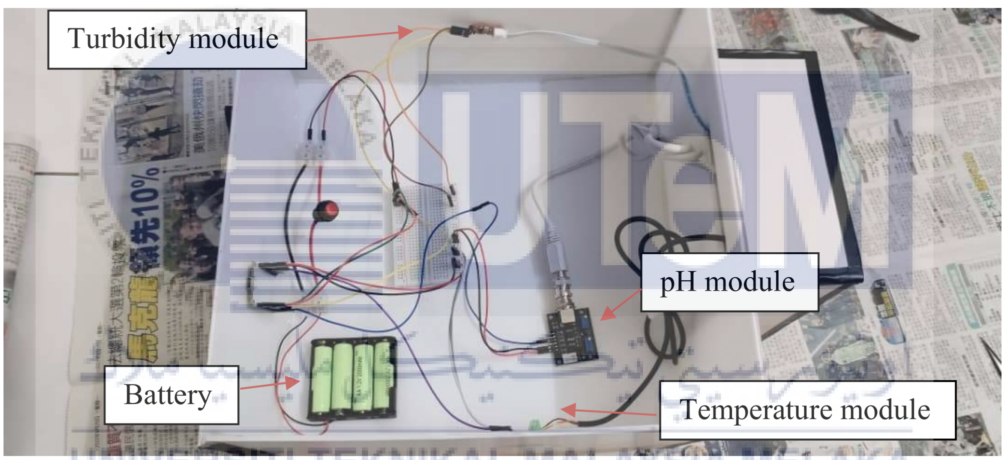

Figure 4.2: Inside view of project prototype

Figure 4.3: Whole view of prototype

4.3 Results

The water samples were sourced from various locations, including pipe water, accumulated water beside the MMU College's car park, Malacca River, a stream behind the residential area of Jalan Pulau Nibong, and Lake Ayer Keroh. The pH level, turbidity value and temperature reading from each of the water samples were taken based on the information gained to evaluate the water quality. When the pH level lower than 5.5 or higher than 8.5 and turbidity reading higher than fifty, Bylnk will send warning through app notification and E-mail for the user once every 5 minutes.

4.3.1 Pipe Water

Below was the water sample collected from the pipe in the student dormitory. It was stored in the pool for easier testing purpose.

Figure 4.4 Pipe water in pool

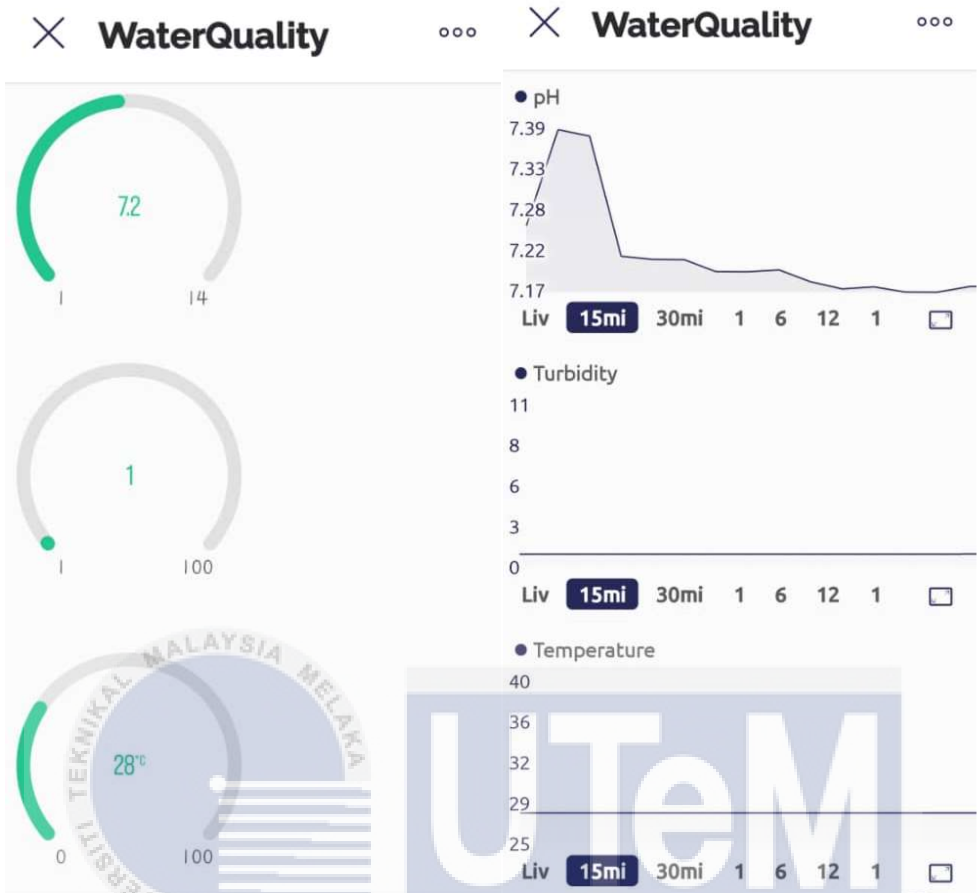

Figure 4.5 Parameters reading for water sample 1 on Blynk

The recorded values for each parameter include a pH level of 7.2, turbidity value of 1 NTU, and a temperature of 28°C, as depicted in Figure 4.4 on the smartphone screen. This display enables users to quickly assess water quality. For users seeking detailed changes in water quality, the ability to zoom in on the graph provides a closer look at specific parameters plotted against time. Additionally, users can choose to track the water quality trend over various durations, including the last 15 minutes, 30 minutes, 1 hour, 6 hours, 12 hours, and 1 day.

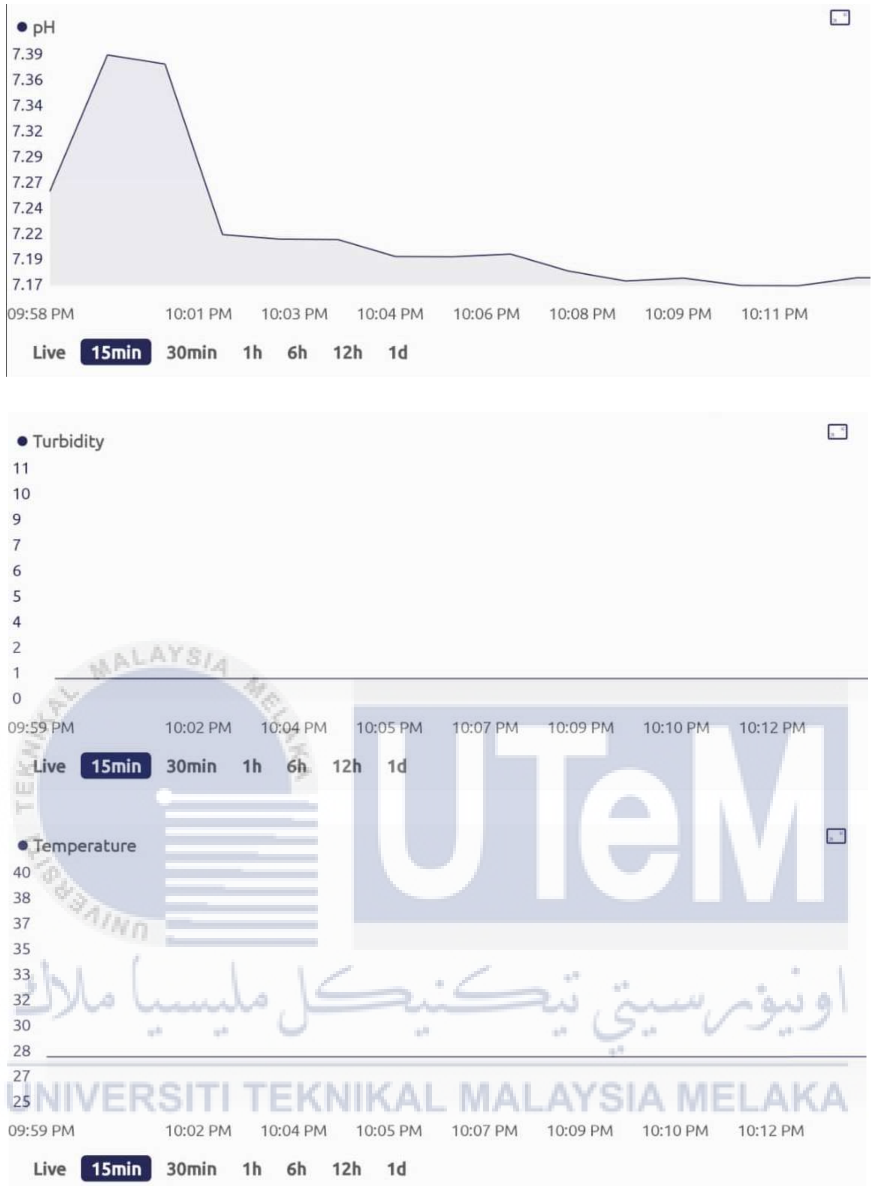

Figure 4.6 Graph represent the parameters reading against time for the past 15 minutes for water sample 1

The pH, turbidity, and temperature readings of the initial water sample indicate its cleanliness and suitability for both human consumption and daily life activities. By examining the graph, it becomes evident that the sole parameter exhibiting a change was the pH level, with a marginal difference of only 0.19 within a 15-minute interval.

4.3.2 Accumulated water in front of MMU Cniversity

Below is the accumulated water beside MMU College's car park area. The prototype collected set 2 sample data from this water source.

Figure 4.7 Accumulated water beside MMU College's carpark area

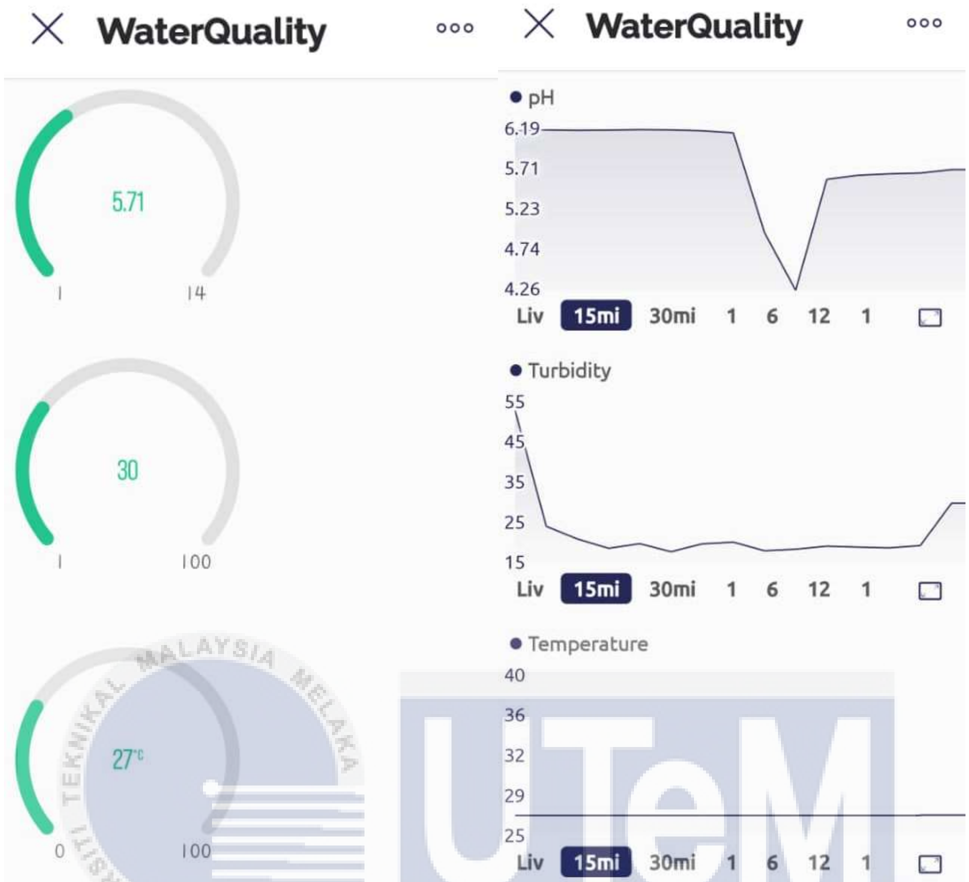

Figure 4.8 Parameters reading for water sample 2 on Blynk

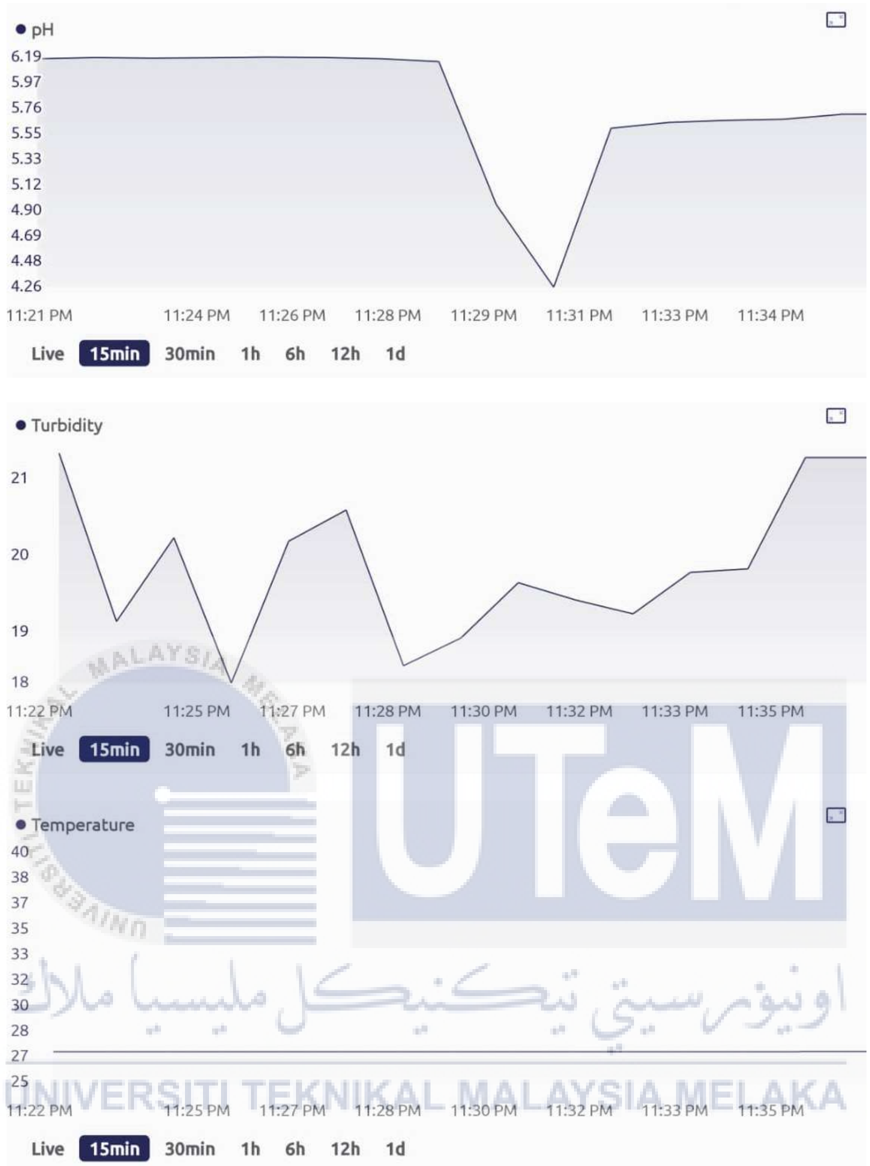

Figure 4.9 Graph represent the parameters reading against time for the past 15 minutes for water sample 2

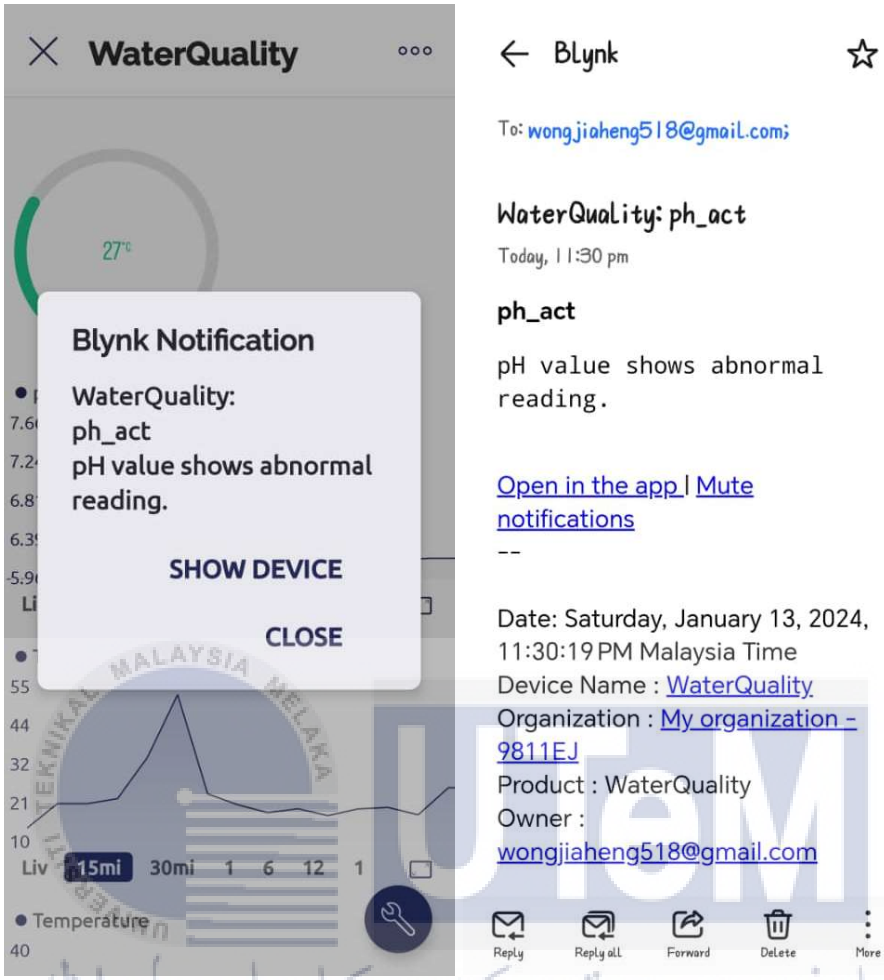

Figure 4.10 Warning send by Blynk app

The second water sample indicated a pH level of 5.71, a turbidity value of 30 NTU, and a temperature of 27°C. Within a one-minute interval, the pH level experienced a significant drop from 6.19 to 4.26. This sudden change was attributed to an inadvertent contact of the prototype with sediment at the bottom of the accumulated water, causing the pH sensor to register abnormal readings during that 15-minute duration. Blynk promptly detected this anomaly and issued warnings through Blynk notifications and emails, as illustrated in Figure 4.10. Additionally, the water appeared cloudy, corresponding to the peak turbidity reading of 30 on the graph.

4.3.3 Stream behind the residential area of Jalan Pulau Nibong

Below is the stream behind the residential area of Jalan Pulau Nibong. The prototype collected set 3 sample data from this water source.

Figure 4.11 Stream behind the residential area of Jalan Pulau Nibong

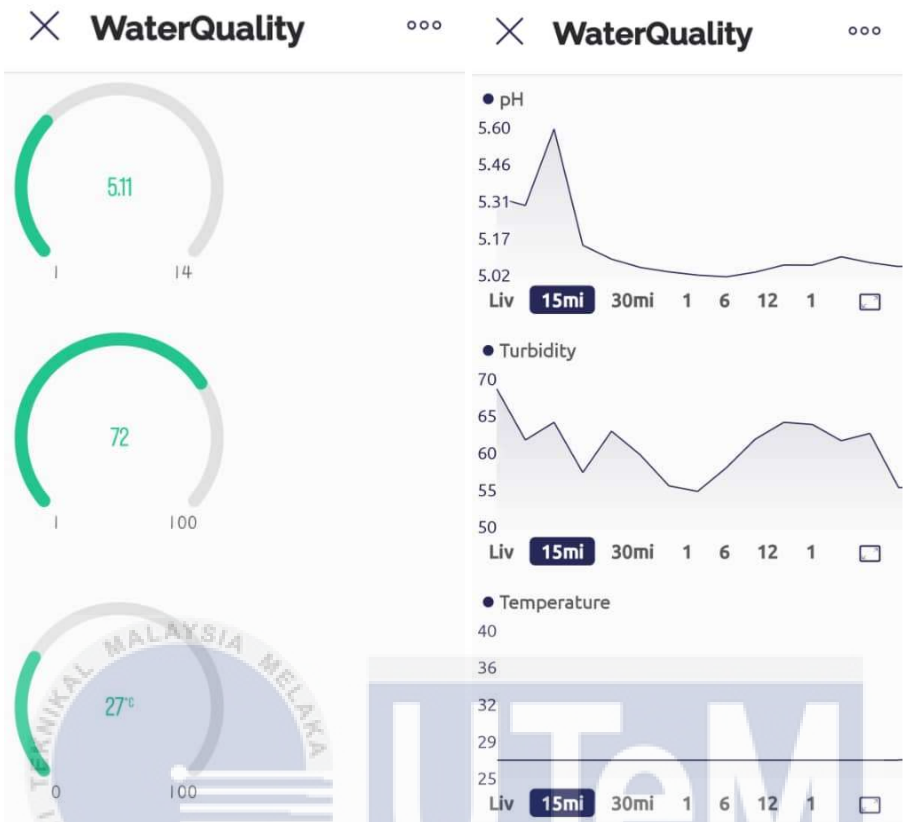

Figure 4.12 Parameters reading for water sample 3 on Blynk

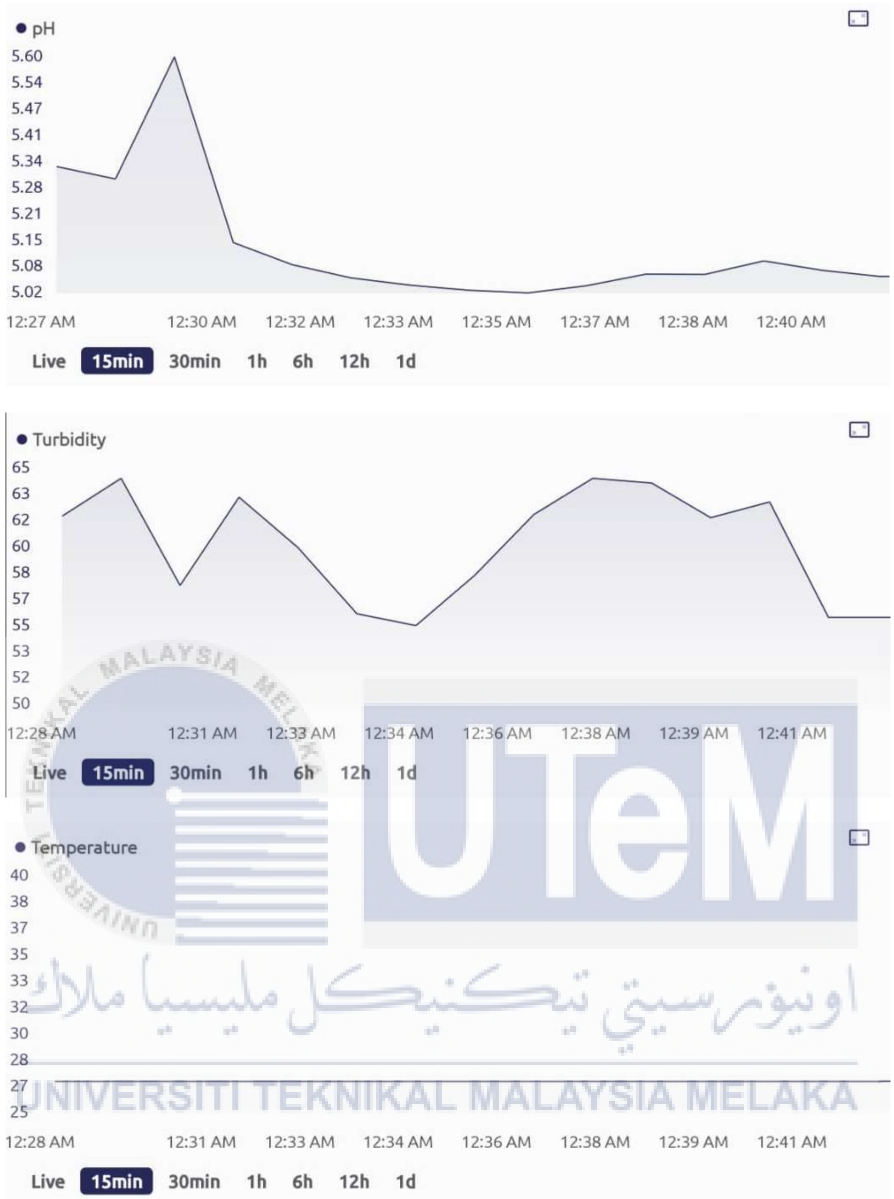

Figure 4.13 Graph represent the parameters reading against time for the past 15 minutes for water sample 3

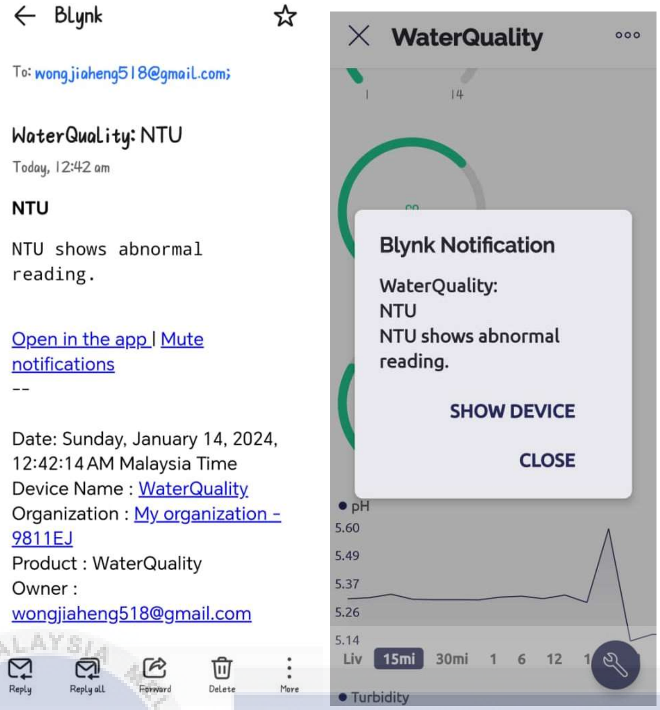

Figure 4.14 Warning send by Blynk app

The subsequent sample is extracted from a stream located behind the residential area of Jalan Pulau Nibong, featuring a pH level of 5.11, a turbidity value of 72 NTU, and a temperature of 27°C. Within a minute, the pH level exhibited a decline from 5.60 to 5.15, reflecting a substantial variance of approximately 0.45 pH units, indicating an acidic nature of the water. The turbidity readings for this sample started at 62 NTU and escalated to 72 NTU by the end, signifying an increase in water impurities. During this period, the Blynk app detected abnormal pH and turbidity values, issuing warnings for both parameters concurrently.

4.3.4 Malacca River

Below is the Malacca River. The prototype collected set 4 sample data from this water source.

Figure 4.15 Malacca River

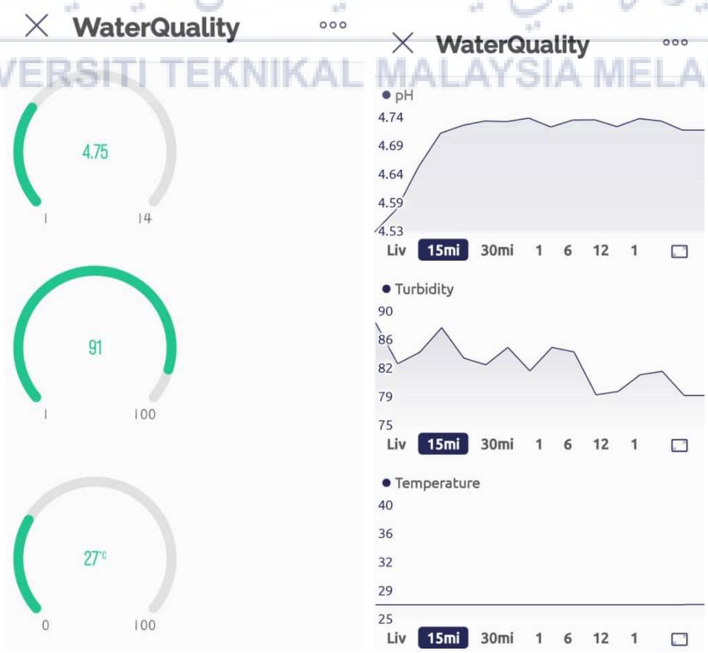

Figure 4.16 Parameters reading for water sample 4 on Blynk

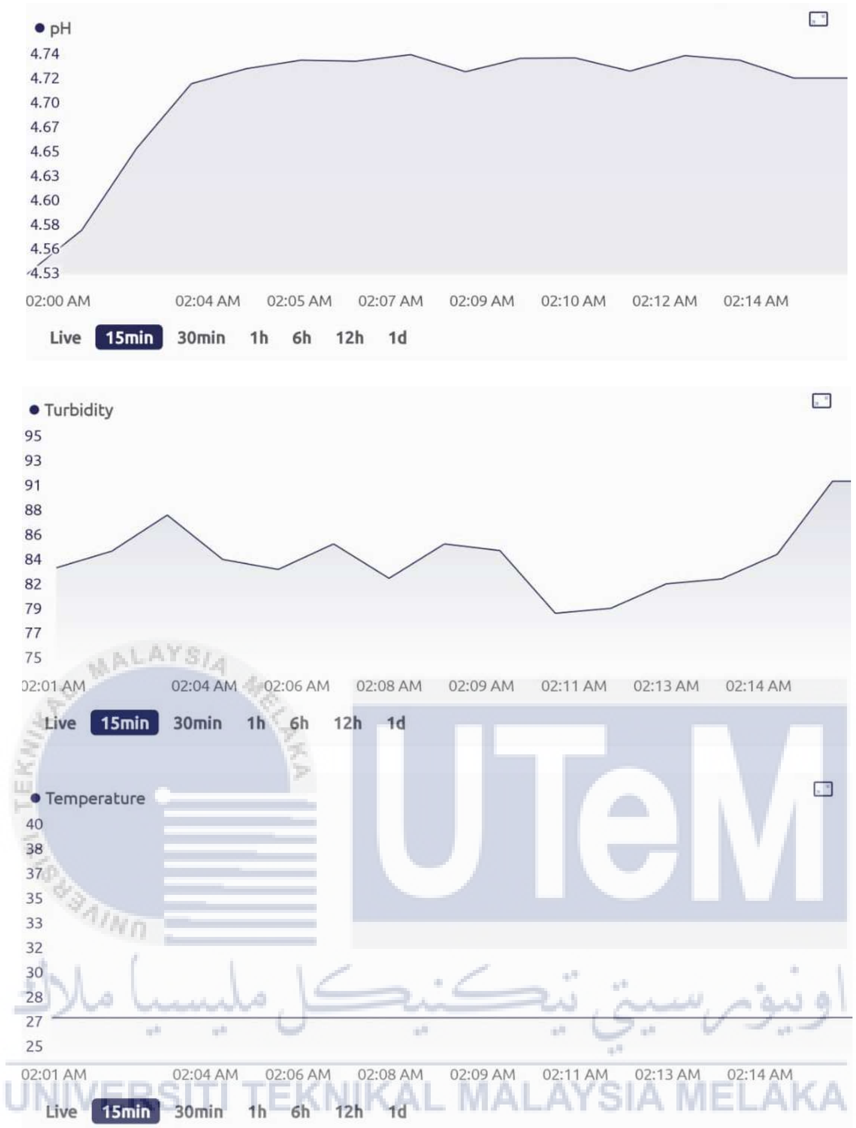

Figure 4.17 Graph represent the parameters reading against time for the past 15 minutes for water sample 4

The following sample is derived from the Malacca River, showcasing a pH level of 4.75, a turbidity value of 91 NTU, and a temperature of 27°C. By analyzing the graph, it becomes apparent that the pH level initiated at its lowest point, recording 4.53. Despite its subsequent increase to 4.72 by the conclusion of the testing period, the pH level remains highly acidic and hazardous. As for turbidity, the river water exhibits significant pollution. The recorded values indicate that the maximum turbidity reached 93 NTU, closely approaching the predetermined maximum value of 100 NTU. Due to abnormal readings in pH level and turbidity, warning notifications and emails were received on the smartphone.

4.3.5 Lake Ayer Keroh

Below is Lake Ayer Keroh. The prototype collected set 5 sample data from this water source.

Figure 4.18: Lake ayer Keroh

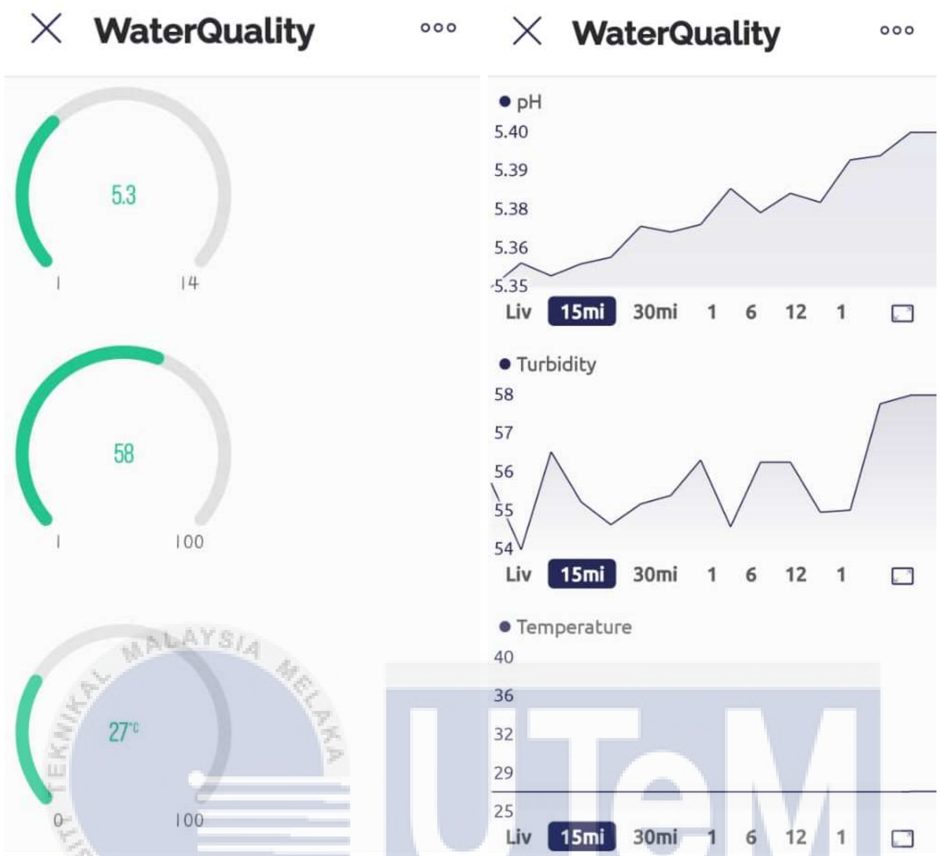

Figure 4.19: Parameters reading for water sample 5 on Blynk

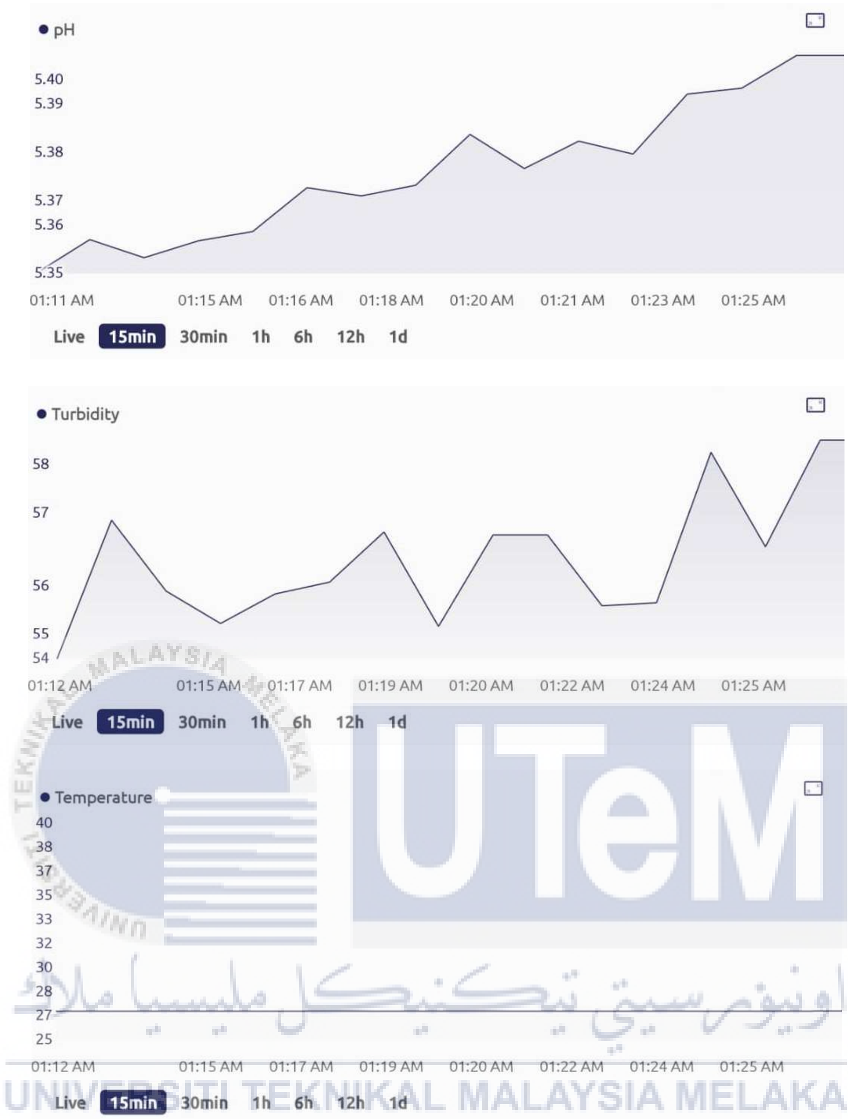

Figure 4.20: Graph represent the parameters reading against time for the past 15 minutes for water sample 5

The final sample analyzed was obtained from Lake Ayer Keroh, presenting a pH level of 5.3, a turbidity value of 58 NTU, and a temperature of 27°C. By scrutinizing the graph, it is apparent that the pH level experienced a minor increase from 5.35 to 5.40. Conversely, the turbidity readings hovered around 57 NTU over a 15-minute duration. The recorded parameters indicate that the lake water is both acidic and polluted. Consequently, warnings were issued for both parameters, emphasizing the compromised safety of the lake water.

4.4 Analysis of all water samples

Table 4.1: Results of pH, turbidity and temperature from different water samples

Water Sample	Time (minute)	pH	turbidity (NTU)	temperature (°C)
Water Sample 1	1	7.27	1	27
Pipe Water	3	7.39	1	27
	5	7.22	1	27
	10	7.18	1	27
	15	7.17	1	27
Water Sample 2	1	6.19	22	27
Accumulated water beside MMU College' car park	3	6.19	20	27
	5	6.19	20	27
	10	4.26	19	27
	15	5.55	21	27
Water Sample 3	1	5.34	62	27
Stream behind the residential area of Jalan Pulau Nibong	3	5.41	58	27
	5	5.15	60	27
	10	5.04	63	27
	15	5.08	56	27
Water Sample 4	1	4.53	83	27
Melacca River	3	4.65	86	27
	5	4.72	83	27
	10	4.7	80	27
	15	4.72	91	27
Water Sample 5	1	5.35	54	27
Lake Ayer Keroh	3	5.35	55	27
	5	5.37	55	27
	10	5.38	55	27
	15	5.4	58	27

Examining the table above reveals distinct characteristics of the water samples. Water sample 4 stands out with the lowest pH level and the highest turbidity value, followed closely by water sample 3. In contrast, water sample 1 exhibits the lowest turbidity value and a pH level deemed safe for human daily uses at 7.25. The findings from the second water sample indicate that the accumulated water has already become acidic and cloudy, presenting a range of concerns.

The accumulation of acidic and cloudy water around a car park near a residential area poses various dangers. Firstly, the acidic nature of the water may lead to the corrosion of infrastructure components, such as metal surfaces and concrete structures, compromising structural integrity and safety. Secondly, the environmental hazards associated with acidic water extend to potential infiltration into nearby soil and water bodies, causing harm to aquatic ecosystems and disrupting environmental balance. Lastly, the aesthetic issues arising from acidity and cloudiness contribute to an unattractive appearance, negatively impacting the visual quality of the area. Addressing these concerns necessitates comprehensive measures, including proper drainage systems, environmental monitoring, and remediation efforts to ensure resident well-being and ecosystem sustainability.

Moving on to the third water sample, sourced from a stream designated for human waste drainage behind houses, it raises significant concerns. The low pH level indicates acidity, potentially harming plants and animals in the water. Additionally, cloudy water suggests potential contaminants that could make it unhealthy for various uses, such as watering plants. There's also a health risk to people if they meet or drink this water, given its acidity and cloudiness. Swift action is crucial, involving thorough water quality checks, waste management improvements, and community awareness initiatives.

The fourth water sample is obtained from the Malacca River, the primary river in the center of the state. Connected to numerous drainage systems, the river exhibits the most unsafe pH level and turbidity value for human use. This may be attributed to various factors like pollution from drainage systems, industrial discharges, and agricultural runoff. The unsafe pH level poses a threat to aquatic life and the ecosystem, while elevated turbidity compromises water quality. Addressing these issues is paramount for the health of the river, its ecosystem, and the surrounding communities.

Lastly, the fifth water sample is collected from Lake Ayer Keroh within the recreational park. With an acidic pH level of 5.2 and a turbidity value of 55 out of 100, concerns arise. The acidic pH may impact the aquatic ecosystem, and the turbidity value indicates cloudiness, affecting water clarity and aesthetics. Although the turbidity value is not extremely high, it could influence the overall visual appeal of the lake. It's noteworthy that the temperature for all five samples remains consistent at around 27°C, reflecting the ambient temperature of the water in the environment.

4.5 Summary

This chapter showcased case studies to illustrate the practicality of the smart water monitoring system. The case study focused on four water samples from Malacca. The initial sample, pipe water, serves as a baseline parameter for evaluating the other four samples since it represents the cleanest water readily available everywhere. The smart water quality monitoring device provides users with instant warnings about the water sources. Moreover, the system offers consumers the flexibility to personalize monitoring intervals according to their preferences. Users can assess water quality and make informed judgments through the graphical representation provided.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The Internet of Things (IoT) is employed to introduce a wireless approach to the suggested smart water quality monitoring system, focusing on measuring pH, turbidity, and temperature using an ESP32 module. The findings from the water quality tests affirm the system's reliability and practicality for real-time monitoring operations. Users can customize the monitoring intervals through a smartphone, addressing specific needs. Given the far-reaching consequences of poor water quality on health, mortality, and socioeconomic progress, the proposed method contributes to safeguarding water resources and reducing waterborne illnesses.

In summary, the proposed system successfully achieved its three objectives: the development of a smart water monitoring system for real-time quality assessment. This is evident as users can access water sample data via a smartphone using the "Blynk" app. The second objective is accomplished through the app's graphical representation of precise pH, turbidity, and temperature values, allowing users to customize time intervals for real-time monitoring. The third objective is fulfilled by sending warning emails to users in case of abnormal pH or turbidity levels. The device, costing RM295, is cost-effective and can be further optimized by using a more affordable sensor instead of a RM180 pH meter that lacks smartphone monitoring capabilities. This device proves valuable for individuals concerned about water source status, ensuring compliance with required standards.

5.2 Potential for Commercialization

The commercialization potential of a water quality monitoring system is significant as it addresses the growing global concern for water quality management. With increasing industrialization, urbanization, and environmental challenges, there is a heightened demand for efficient and automated solutions to monitor and ensure the safety of water resources. A commercialized water quality monitoring system offers industries, municipalities, and environmental agencies a reliable and cost-effective means to continuously assess and manage water quality parameters. The ability to provide real-time data, customizable monitoring intervals, and instant alerts through modern communication platforms enhances its appeal. Moreover, the potential for integration with IoT technologies, cloud-based platforms, and user-friendly interfaces further positions such systems as valuable assets in sustainable water resource management. The commercial success of these systems not only promotes environmental conservation but also contributes to public health and regulatory compliance.

5.3 Future Works

For future improvements, the water quality monitoring system could be improved as follow:

i) Add more types of sensors that can measure other parameters to increase the reliability of the system such as ammoniacal nitrogen, biochemical oxygen demand, chemical oxygen demand, dissolved oxygen etc.

ii) Design and develop a new project based on this project to make it like a boat, giving it the ability to move freely in the water, enabling it to detect values in other aquatic areas.

iii) Use different type of pH sensor because the one used now is not stable and very fragile.

iv) Avoid using turbidity sensor, TS-300B since it is totally unstable and less sensitive.

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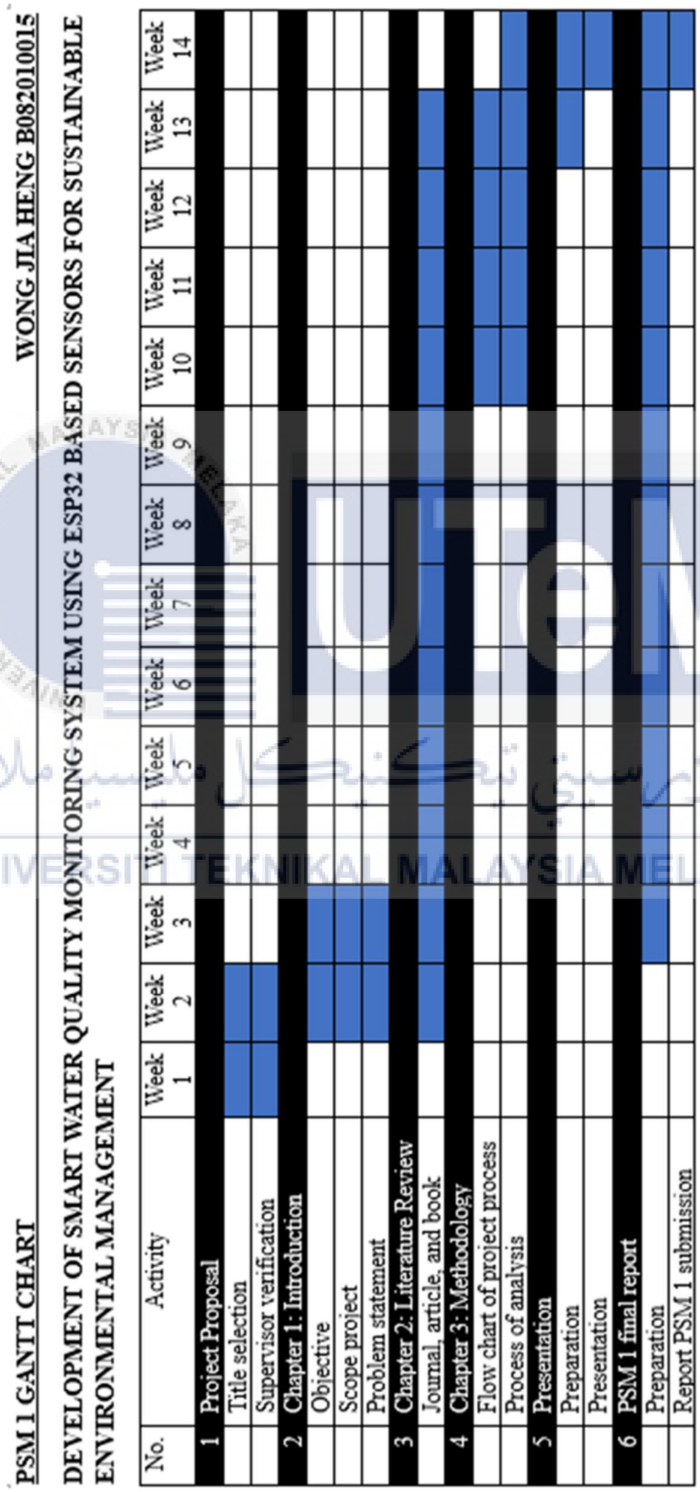
APPENDICES

Appendix A Gantt Chart PSM 1



Appendix B Gantt Chart PSM 2

PSM 2 GANTT CHART **WONG JIA HENG B082010015**

DEVELOPMENT OF SMART WATER QUALITY MONITORING SYSTEM USING ESP32 BASED SENSORS FOR SUSTAINABLE ENVIRONMENTAL MANAGEMENT

No.	Activity	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
1	Device testing and Instrument														
	Buy components														
	Testing														
2	Electrical design and Mechanical design														
	Design coding														
	Testing														
	Prototype														
3	Discussion with supervisor														
4	Completion for Chapter 1, 2 and 3														
5	Completion of Chapter 4 and 5														
	Result collecting process														
	Analysis														
6	Preparation for presentation														
	Preparation														
	Report PSM 1 submission														

Appendix C Project Coding

```
//DEVELOPMENT OF SMART WATER QUALITY MONITORING SYSTEM USING
ESP32 BASED SENSORS FOR SUSTAINABLE ENVIRONMENTAL MANAGEMENT
#define BLYNK_TEMPLATE_ID        "TMPL6c4WCvpbr"
#define BLYNK_TEMPLATE_NAME      "WaterQuality"
#define BLYNK_AUTH_TOKEN         "Xf30Bs7T-qLG5DSATMkCZAPWre4-U25G"
#define BLYNK_PRINT Serial

#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
#include <OneWire.h>
#include <DallasTemperature.h>
#include <Wire.h>

//Wifi credential
char auth[] = BLYNK_AUTH_TOKEN;

char ssid[] = "WONGJH";
char pass[] = "wong0315";


float calibration_value = 21.34 - 1.23; //calibration for pH sensor
int phval = 0;
unsigned long int avgval;
int buffer_arr[10],temp;

float ph_act;
float temperatureC;
float NTU;

#define ONE_WIRE_BUS 17 //temperature pin

OneWire oneWire(ONE_WIRE_BUS);

DallasTemperature DS18B20(&oneWire);

void setup()
{
  Wire.begin();
  DS18B20.begin();
  Serial.begin(9600); //Baud rate
  Blynk.begin(auth, ssid, pass, "blynk.cloud", 8080);
}

void loop()
{
```

```
Blynk.run();
{
  //ph coding
  for(int i=0;i<10;i++)
  {
   buffer_arr[i]=analogRead(36); // pH pin
   delay(30);
  }
  for(int i=0;i<9;i++)
  {
   for(int j=i+1;j<10;j++)
   {
    if(buffer_arr[i]>buffer_arr[j])
    {
     temp=buffer_arr[i];
     buffer_arr[i]=buffer_arr[j];
     buffer_arr[j]=temp;
    }
   }
  }
  avgval=0;
  for(int i=2;i<8;i++)
  avgval+=buffer_arr[i];
  float volt=(float)avgval*3.3/4095/6;
  ph_act = -5.70 * volt + calibration_value;

  Serial.print("pH Val: ");
  Serial.println(ph_act);

  if (ph_act < 5.5 || ph_act > 8.5)
  {
   Blynk.logEvent("ph_act"); //assign event
  }

  Blynk.virtualWrite(V0,ph_act); //assign virtual pin to monitor data on Blynk

  delay(1000);
}

{
  // Turbidity coding
  int sensorValue = analogRead(34); // turbidity pin
  float NTU = map(sensorValue, 0, 3103, 100, 10); // mapping function, when turbidity =
100

  if(NTU<0)
  {
   NTU = 0.5;
```

```
  Serial.print("Turbidity: ");
  Serial.println(NTU);
  Serial.println("Clear");
 }

 if((NTU>0)&&(NTU<20))
 {
  Serial.print("Turbidity: ");
  Serial.println(NTU);
  Serial.println("Clear");
 }

 if((NTU<0)&&(NTU<50))
 {
  Serial.print("Turbidity: ");
  Serial.println(NTU);
  Serial.println("Cloudy");
 }

 if(NTU>50)
 {
  Serial.print("Turbidity: ");
  Serial.println(NTU);
  Serial.println("Dirty");
 }

 if (NTU > 50)
 {
  Blynk.logEvent("NTU");
 }

 Blynk.virtualWrite(V1,NTU);

 delay(500);
}

{
 // temperature coding
 DS18B20.requestTemperatures();
 temperatureC = DS18B20.getTempCByIndex(0);

 Serial.print("Temperature: ");
 Serial.print(temperatureC);
 Serial.println("°C");

 Blynk.virtualWrite(V2,temperatureC);
 delay(1000);
}
```