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A Reliable Design of Water Quality Monitoring System for Online River Data Monitoring

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Abstract: In Malaysia, the river water pollution problems are getting worse due to the rapid growth of population and urbanization. Lots of human wastes are flowing or poured into rivers including industrial, commercial, domestic and transportation wastes. The pollution of river water has brought many significant effects towards us and the environment. Hence, a real time monitoring system is required to ensure the quality of river water. In this paper, a portable online river water quality monitoring system is presented using IoT technology. The system consists of a microcontroller, several sensors and a Wi-Fi module. The prototype developed is able to measure the parameters like pH, temperature and turbidity of the river water and send to the end users via Wi-Fi. The uniqueness of the device is the mechanism is designed to make it operates reliably in the river in any weather condition and also easy in term of the installation at the site area.

Keywords: Arduino Uno, pH sensor, Temperature sensor, Turbidity sensor, Wi-Fi module

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1. INTRODUCTION

Water is one of the most precious elements on Earth. Some people might consider water is an unlimited resource on Earth. However, the truth is the clean water is becoming a scarce natural resource. Other countries have to process the rainwater to obtain freshwater [1]. In Malaysia, approximately 98 percent of the total water use originates from the rivers. Among the water use, around 70% are using in the agricultural industry [2]. However, due to the rapid urbanization, the demands for water consumption have increased sharply. This has led to the pollution level of the river water rises tremendously. Consequently, most of the rivers in Malaysia are polluted and cannot be rehabilitate again. The reducing quality of the river water in Malaysia has brought huge impacts to many industries including food, plant and cultivation industry [2]. The quality of the water can be said is closely proportional to the health of all living things on Earth including human beings. However, it is not an easy task to return a polluted river to its original state. Traditional methods have the drawbacks such as long waiting time for results high cost, low measurement precision, and complicated methodology [3]. Hence, a monitoring system is required to ensure the quality of the river water.

A real-time river water quality monitoring system measures the parameters like pH, temperature and turbidity. These parameters can indicate if there is a water contamination [4]. pH of the river water shows the concentration of hydrogen ions [5] and it is used to indicate the water is either acidic or alkaline, ranging from 0-14 pH. The temperature sensor measures the temperature of the river water, indicating the living condition of aquatic organisms. Lastly, the turbidity sensor indicates the cleanliness or visibility of the river water. The cleanliness is directly proportional to the turbidity level. After collecting all the readings from the sensors, those data will be processed by microcontroller and send to the users via Wi-Fi.

2. LITERATURE REVIEW

2.1 Water Quality Monitoring System Based on IOT

In this article in [6], the water quality measuring methods are discussed. The sensors used include pH sensor, temperature sensor, turbidity sensor and flow sensor. It uses Arduino Uno ATMEGA 32 as microcontroller, while ESP8266 as the Wi-Fi module. The block diagram of the system is shown in Figure 1 below.

2.2 Real Time Monitoring of Water Quality using Smart Sensor [7]

The real time monitoring system consists of sensors such as turbidity sensor, pH sensor and temperature sensor, which are using as the monitoring devices to measure the water quality. Arduino Uno is used as the microcontroller while ESP8266 is used as the Wi-Fi module. The sensors can sense and detect the values of parameters and then upload the data to *ThingSpeak* server using Wi-Fi module in it. The end users are able to access the server via the channel ID created by the admin of the server [7]. The system architecture is illustrated in Figure 2.

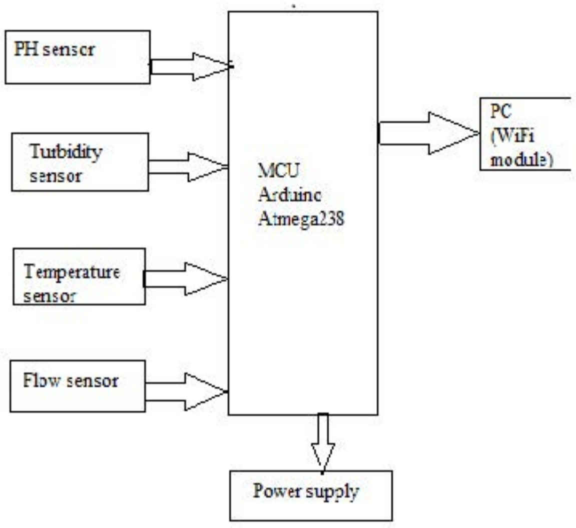

Figure 1. Block diagram for the system [7]

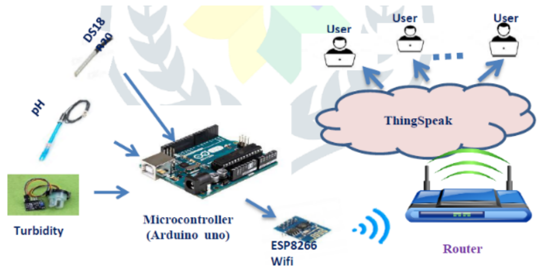

Figure 2. System architecture of the project [7]

2.3 A System for Monitoring Water Quality in A Large Aquatic Area using Wireless Sensor Network Technology [8]

In this article, the sensors used include temperature sensor, pH sensor and dissolved oxygen (DO) sensor. In this paper, it is using WSN technology as well as Global System for Mobile Communication (GSM) and the use is to transmit the detected data from the sink node to the base station [8]. The network architecture is illustrated in Figure 3 as below.

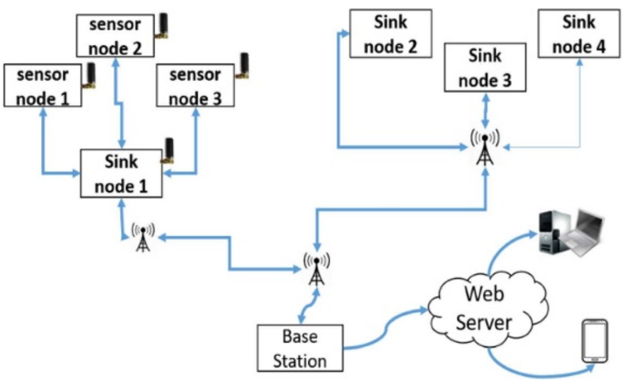

Figure 3. System Network Architecture [8]

2.4 Design and Development of Water Quality Monitoring System in IOT [9]

This paper suggests the use of various sensors as the inputs which are turbidity sensor, temperature sensor, pH sensor, water flow sensor and CO2 sensor. The microcontroller used is Raspberry Pi and the GSM module is used to transmit data via SMS. The system block diagram is displayed at Figure 4 while the system architecture is illustrated in Figure 5. The data obtained from the sensors are sent to the users through SMS.

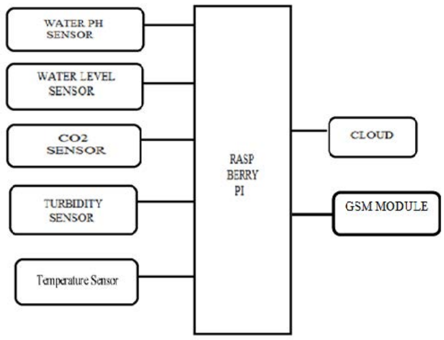

Figure 4. System Block Diagram [9]

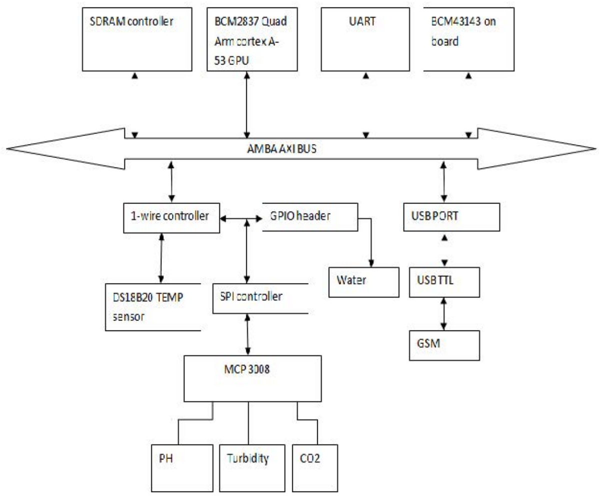

Figure 5. System Architecture [9]

3. PROPOSED METHODOLOGY

3.1 The Proposed System

In this section, the theory and working principles of the portable design of online water quality monitoring system for flexible operation in the river is presented. The overall block diagram is displayed in Figure 6 below.

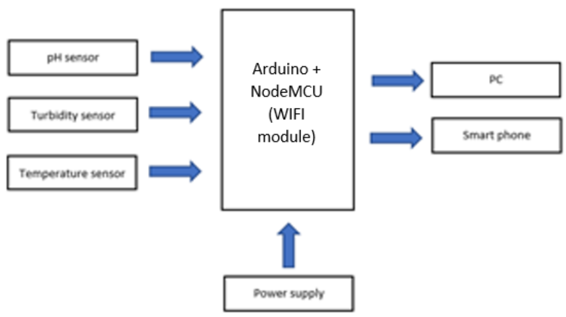

Figure 6. Block Diagram of the project

The proposed block diagram consists of various sensors like pH sensor, turbidity sensor and temperature sensor. They are connected to the microcontroller, which is Arduino Uno. The system is connected to an external power supply to ensure the system is working all the time. The microcontroller is used to obtain and process the sensors readings and then transmit the data to the end users through Wi-Fi via NodeMCU or Wi-Fi module. The users can view all the readings using Blynk app in their smart phones.

3.2 Hardware

3.2.1 Arduino Uno

Arduino Uno is one of the microcontroller board designed based on the ATmega328P. It consists of up to 14 digital input or output pins. In these pins, 6 of them can be used as PWM outputs. It also consists of 6 analog inputs and a 16 MHz ceramic resonator (CSTCE16M0V53-R0). It also includes a USB connection, a power jack, an ICSP header and a reset button. Figure 7 below illustrates the diagram of an Arduino Uno. It works together with a software called Arduino IDE.

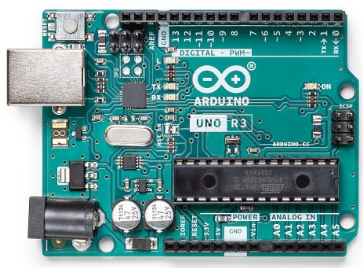

Figure 7. Arduino Uno

3.2.2 pH Sensor

The main function of the pH sensor is to measure the acidity or the alkalinity of the medium to be tested. The pH scale is ranged from 0-14. It is a logarithmic scale. The calculation of a pH is normally an acidity balancing test or the alkaline content of the ions of hydrogen in the water [9]. The neutral point is normally 7 while the value below 7 indicates acidic solution and the value above 7 indicates an alkaline or basic solution. This pH sensor operates with 5 V power supply and is suitable to use with Arduino Uno. Before using the sensor, the sensor needs to be calibrated using buffer solutions. Figure 8 below shows the diagram of pH sensor.

Figure 8. pH sensor

3.2.3 Temperature sensor

Temperature normally used to determine the hotness or coldness of water. The temperature sensor used in the project is DS18B20 which is shown in Figure 9 below. It is waterproof sealed with stainless steel and have a range from -55°C to+125°C, with an accuracy of ±0.5°C. It operates at voltage 3.0V to 5.5V.

Generally, there are three scales can be used to denote the temperature, which are. Fahrenheit (°F), Celsius (°C) and Kelvin (K) scales. The Kelvin (K) scale is beginning with 0K, and it is called as an absolute temperature scale. The relationship between Kelvin (K) scale and Celsius (°C) can be illustrated as Equation (1) below.

$$C = K - 273.15 \tag{1}$$

where C is the temperature unit in degree Celsius (°C) and K is the temperature unit in Kelvin (K).

The relationship between Fahrenheit scale and Celsius scale is shown in Equation (2) as below.

$$F = \frac{9}{5}C + 32 \tag{2}$$

where F is the temperature unit in Fahrenheit (°F) and C is the temperature unit in Celsius (°C).

Figure 9. Temperature sensor

3.2.4 Turbidity Sensor

Turbidity of liquid can be defined as the measure of the cloudiness and the haziness of the liquid [10]. It is usually related to the cleanliness or the quality of the water. The principle of turbidity can be said is the detection of the presence of invisible particles that cannot be detected by our naked eyes. It can be closely related to the white smoke in the air. When the light penetrates or passes through a liquid, the presence of the tiny particles will disperse light waves. Hence, the light dispersed can be related to the turbidity of the liquid [10]. The Figure 10 below shows the turbidity sensor to be used.

The turbidity generally is measured in two units which are Jackson turbidity units (JTLJ) or nephelometric turbidity units (NTU), depending on the method used for water quality measurement. Those two units are equal in terms of water quality. However, NTU is the most common unit to be used. In this project, NTU is related to the sensor value and voltage after conversion. The relationship between sensor value and voltage and between voltage and turbidity are shown in Equation (3) and (4) below [11].

$$V = \frac{1}{1023} A * 5 \quad (3)$$

where V is the voltage and A is the analog value obtained from turbidity sensor

$$ntu = (-1.0324V + 3.84) * 1300 \quad (4)$$

where V is the voltage and ntu is the turbidity in NTU unit.

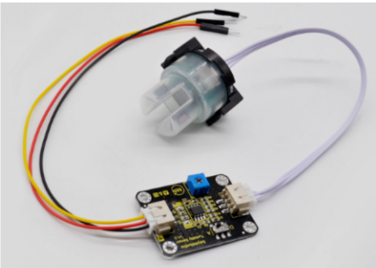

Figure 10. Turbidity sensor

3.2.5 ESP32

ESP32 Node MCU is created by Espressif Systems. It is a low-cost, low-power system on a chip (SoC) series that supports Wi-Fi and dual-mode Bluetooth. There is a dual-core or single-core Tensilica Xtensa LX6 microprocessor at its heart with a clock rate of up to 240 MHz. Besides that, with built-in antenna switches, RF baluns, power amplifiers, low noise receive amplifiers, filters, and power management modules, the ESP32 is a highly integrated device. ESP32 is designed for mobile devices, wearable electronics, and IoT applications, and it uses power-saving technologies including fine resolution clock gating, numerous power modes, and dynamic power scaling to achieve ultra-low power consumption [12].

Figure 11. ESP32 Module

3.3 Software

3.3.1 Arduino IDE

Arduino IDE is an open-source software, and it is easy to write code and upload it to the board. This software can be used with any Arduino board. The Arduino Integrated Development Environment (IDE) is a cross-platform application, for example, Windows, macOS and Linux, that is written in functions from C and C++. In this project, it is used to write code for Arduino Uno and the ESP32.

3.3.2 Blynk

Blynk is a hardware-agnostic IoT platform with white-label mobile apps, private clouds, device management, data analytics, and machine learning. It was designed for the IOT platform (Internet of Things). It can control hardware remotely, display sensor data, store data, as well as visualize it.

3.4 System Integration

In this project, the design is developed using IOT concept. It is mainly focus in two parts, which are the hardware and software. Hardware parts mainly consists of sensors which are used to collect or measure the parameters of the river water in real-time. Besides, it also consists of Arduino Uno microcontroller which is used to convert the analog signal received from sensors into digital signal. Another part is Wi-Fi module which allow the communication between hardware and the software. The schematic diagram of this project is illustrated in Figure 12.

The main software used is Arduino IDE which is used to program the hardware by using C language. The mobile app interface is designed using Blynk app to display the outputs of the project. The end users are able to view the data through mobile app with the auth token given when Wi-Fi is available.

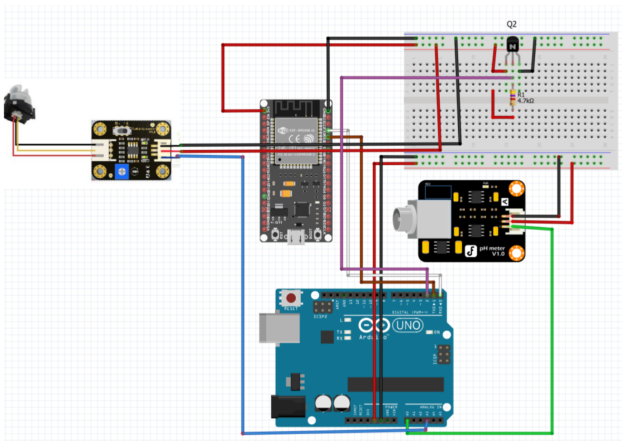

Figure 12. Schematic diagram of the project

3.5 Mechanical Structure

To ensure that the prototype can perform its function well in the river, a waterproof as well as weatherproof enclosure is required to cover all the hardware inside. Hence, in this project, a weatherproof PVC junction box is chosen as the enclosure for the system. The main advantages of the materials are hard and high impact strength, waterproof and weatherproof and resistance to most chemical substances. Some holes are drilled at the bottom of the box for the sensors to measure the river water quality.

To ensure that the system can float on water stably, a large polystyrene foam board is placed at the bottom of the prototype. The large surface area of the polystyrene foam board may help to distribute the weight of the system and hence make the system more likely to float on the water Aluminum rods are used to anchor the system on a fix position and prevent being flushed by the water wave or wind blow. It also may help in balance the system on the water surface. Hence, the sensors can collect consistent data at certain position. Figure 13 below shows the enclosure used in the project. Figure 14 and Figure 15 shows the top view and the side view of the structure respectively. Figure 16 shows the working principle of the prototype on the river.

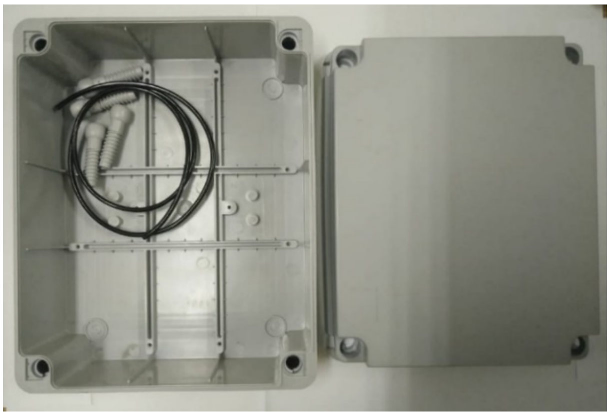

Figure 13. PVC junction box

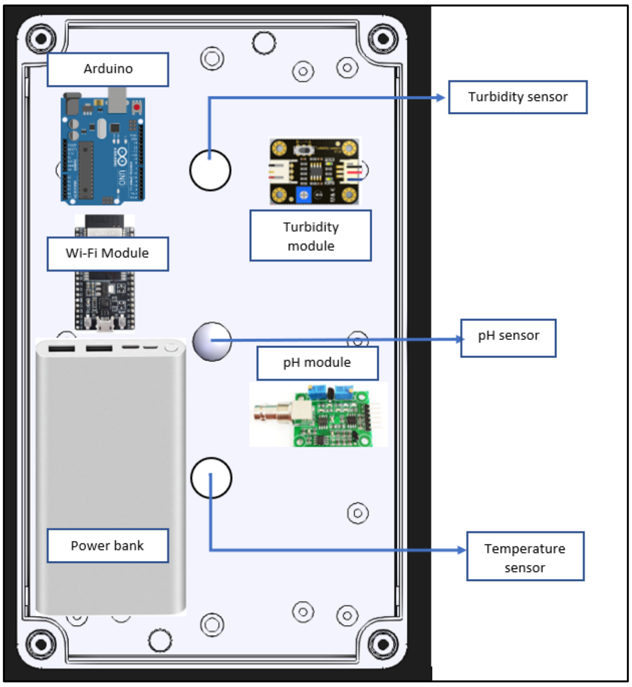

Figure 14. Top view of the structure

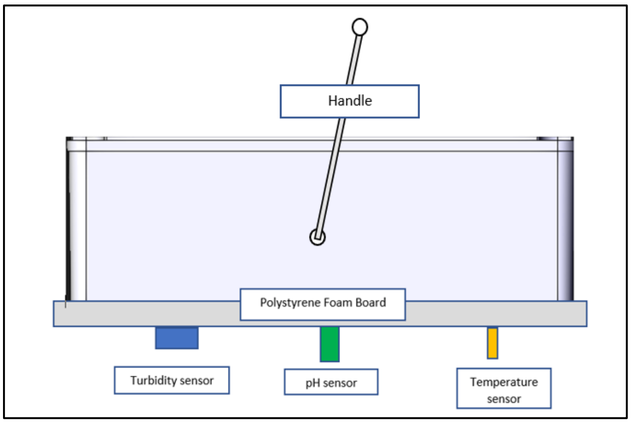

Figure 15. Side view of the structure

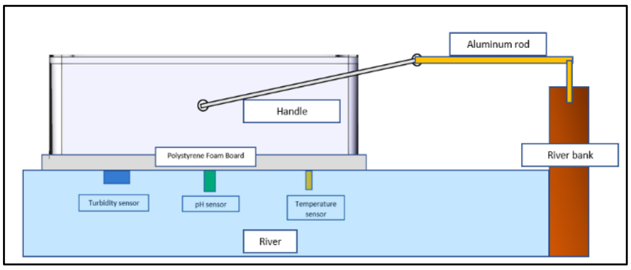

Figure 16. Working principle of the system

3.6 Product Prototype

Figure 17 below shows the circuit connection for the hardware parts including sensors and Arduino Uno. All the sensors are tested and calibrated well. The project is powered consistently with a large solar power bank. The enclosure is a PVC junction box with all the electronic components placed inside and sensors are exposed outside by drilling some holes at the bottom. Figure 17 to Figure 19 illustrate the side views and bottom view of the prototype.

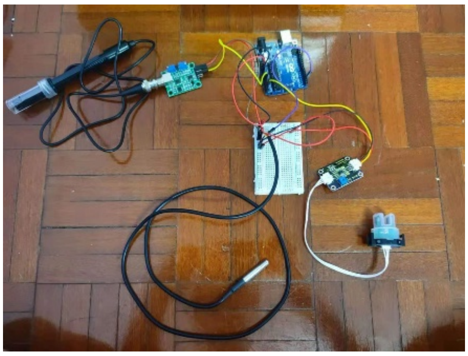

Figure 17. Circuit connection of the project

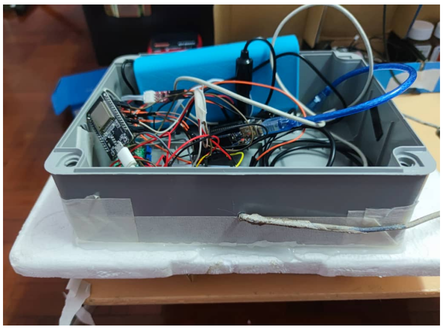

Figure 18. Prototype without cover

Figure 19. Prototype with cover

Figure 20. Bottom view of the prototype

4. RESULTS AND DISCUSSION

The preliminary experiments are started with the calibration of the sensors. All the sensors are well calibrated to ensure that the readings obtained are accurate and precise. The data can be obtained via serial monitor at Arduino IDE or view at Blynk app on users' smart phone. Table 1 to 3 shows the pH, turbidity and temperature readings obtained from tap water and river water. The Figure 21 to Figure 23 illustrate the graph of pH, turbidity, and temperature against the number of samples. Figure 24 and Figure 25 shows the data displayed at Blynk app. Figure 26 illustrate the working of prototype on the river.

Table 1. pH obtained from tap water and river water

	pH			
	1	2	3	4
Tap water	7.230	7.250	7.316	7.298
River water	6.590	6.600	6.703	6.694

Table 2. Turbidity for tap water and river water

	Turbidity (NTU)			
	1	2	3	4
Tap water	0.00	0.00	0.00	0.00
River water	13.52	13.52	40.30	40.30

Table 3. Temperature for tap water and river water

	Temperature (°C)			
	1	2	3	4
Tap water	25.188	25.188	29.620	29.620
River water	26.950	26.950	29.620	29.620

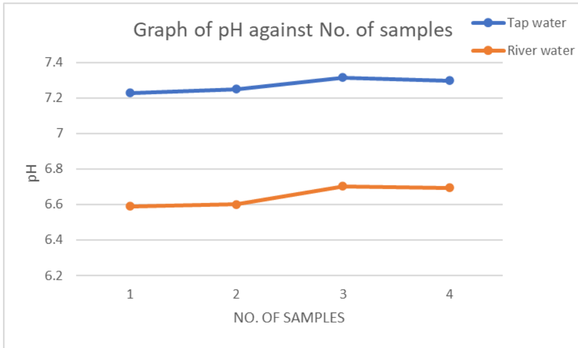

Figure 21. Graph of pH against number of samples

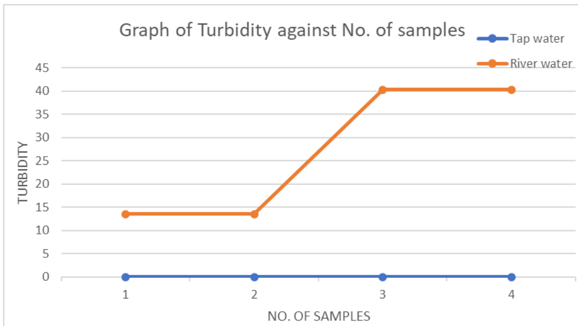

Figure 22. Graph of turbidity against number of samples

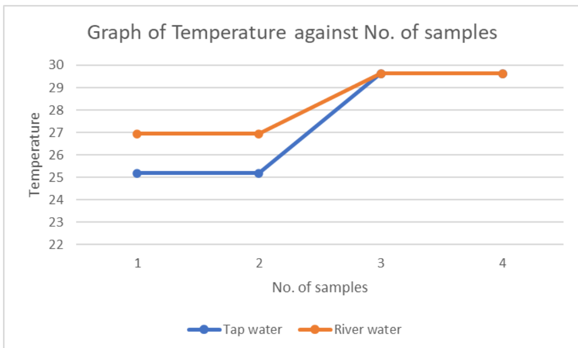

Figure 23. Graph of temperature against number of samples

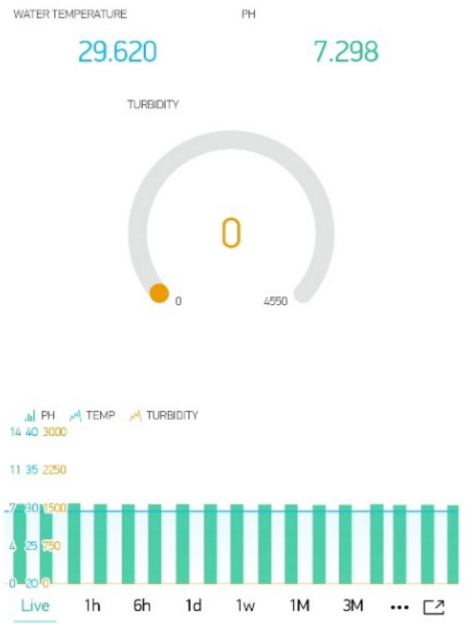

Figure 24. Blynk data for tap water

Figure 25. Blynk data for river water

Figure 26. Testing of prototype on the river

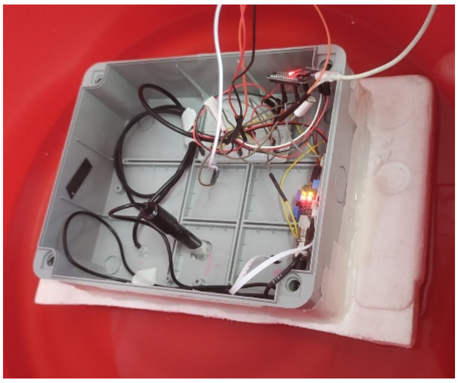

Figure 27. Testing of prototype on the tap water collected

Samples 1 and 2 are taken and measured in the afternoon, around 2 pm, while samples 3 and 4 are taken in the evening which is around 7:30 pm. All the readings taken are recorded and listed in Table 1 to 3 as above.

For pH value, the river water has lower pH, which is between 6.6 and 6.7, compared to the tap water, between 7.2 and 7.3. Usually, river water is slightly acidic due to the anthropogenic activities. There are some oil palm plantations and paddy fields surrounding the Rejang river and hence affect the pH of the river. The lower pH is most likely due to the pollution of nitrogen from fertilize usage and domestic wastewater pouring into the river. In the other hand, tap water has undergoes a series of filtering and purification process. During the process, some fluoride has been added to improve dental health. As a result, the pH may be increased due to alkaline properties of fluoride, hence the pH can reach up to 7.3.

In terms of turbidity, the tap water has 0 NTU, no matter in the afternoon or evening. The tap water is filtered and purified; hence the water is usually clean and transparent. So, the tap water will have very low turbidity. The river water measured has turbidity range of 13.52 NTU to 40.3 NTU when measured with the sensor. Generally, the river water may contain some suspension or solids like soils and other biological particles. Hence, it will have higher turbidity than clean water. However, due to some limitations of the turbidity sensor used in the project, the accuracy and sensitivity of the sensors are very low. The sensor used in this project has very short detecting probe which can only tested on the water surface where it usually has lower turbidity and less suspension. In the normal condition, it should range from 10 NTU to 500 NTU on the water surface depending on the location to be tested based on the reports done by T. Y. Ling [13].

The temperature of the tap water obtained are around 25.188 degree Celsius in the afternoon which is acceptable in room temperature. In the evening, the sensor recorded 29.62 degree Celsius for tap water. For river water, water temperature is around 26.95 degree Celsius in the afternoon and 29.62 degree Celsius in the evening. The temperature obtained is in the normal range and acceptable.

The data collected from each sensor will be uploaded to Blynk server in real time via Wi-Fi. Each parameter for temperature, turbidity and pH can be viewed clearly through the Blynk app. Besides that, all data will be collected in the form of graph and the users are able to view the live data, hourly, every sixth hour, daily, weekly, monthly and even three month. Hence, the users can have a look of previous data and view the changes easily. Through the Blynk app, users can even export the data in terms of Excel file for others' usage. It can be shared to other users as well.

5. CONCLUSION

In conclusion, the design has been done successfully and the results obtained are acceptable and similar to the expected result. All the sensors are working properly and able to detect the parameters of the river water continuously and consistently which represents the quality of the river water.

However, the current project still can have some improvements to make it better. More researches on the technologies are suggested in order to improve online, integrated and low-cost sensor that will enhance the automatic water monitoring system [14]. Some future improvements that can be implemented are:

- Multiple sensors can be added to increase the parameters to be measured
- Improvement of floating mechanism using motor to create stable floating effects
- A large solar-power supply is used to provide enough energy
- A better turbidity sensor can be replaced for better accuracy and sensitivity

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