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Investigation on Water Quality for Farmed Aquatic Species by IoT Monitoring System

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ABSTRACT

The objective of this research is to optimize fish growth in super-intensive aquaculture systems by addressing water quality issues. Changes in water parameters can significantly impact fish growth and even lead to mortality. To overcome this problem, real-time monitoring of water quality parameters is crucial, and the data should be automatically transmitted to the entrepreneur through the Internet of Things (IoT). This allows the owner to access real-time data remotely, eliminating the need to be physically present at the fish cage. By monitoring the data on a smartphone, the owner can efficiently manage the water quality. In this study, a water quality monitoring system utilizing temperature, pH, and ESP32, with the parameter values displayed on the Blynk platform was developed. The system successfully measures real-time water conditions and transmits the data to the Blynk application. The test results demonstrate the system's capability to receive and send data, but further analysis is needed to evaluate the accuracy and reliability of the measurements and identify any noteworthy findings.

1. Introduction

Aquaculture, or pond farming, existed in China as early as 1000 BCE [1]. It became one of the thriving industries at the beginning of the twenty-first century. The increasing demand of the fish protein have encouraged the development of aquaculture industries mostly within Asia countries. One of country that growing rapidly in aquaculture sector in Asia of course Malaysia. Before independence, Malaysia do well in aquaculture activities and recent still one of the top holders of aquaculture products in South East Asia where the freshwater catfish is one of the products in the industries [2]. This investigation is restricted in culturing the quality of water for several species namely Nile Tilapia (Oreochromis Niloticus) and catfish (Pangasius SP.). Those species are very

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famous in Malaysia especially near to east coast state and the market are good. Their growth until reached the level of edible size only takes about 6 months feed with fish pallet with 32% protein [3].

Farm aquatic industry really emphasize quality of water. If not, marine products will be affected. Marin products will be unable to grow and breed normally even worse may will be dead with nonconforming water quality environment [4]. So that, to monitor with a manual method by collecting samples and it takes time because it needs to test in the laboratory and the result may not be accurate. It also wasted of time and money because we need to test frequently to maintain the quality for high yield, health and safety of aquatic if use the manual method [2].

Therefore, modern technologies are essentials. With the technology of IoT, water quality can be monitor and we can take quick action to prevent any problem happen. IoT also can increase the quality of fish or product with high strict monitoring. It will be easier for the freshwater breeders on monitoring status. There are several parameters that important for water to make sure the quality and condition of water does not exceed the unnormal threshold which is water temperature, pH, turbidity, and temperature in the water. The system utilized ESP32 which is connect to the Wi-fi module for internet connection and other sensors to collect data of pH, turbidity, and temperature of the water. Sensor data is only collected once per day at a certain time with correct taking place. The collected data will be sent to the Blynk cloud. Monitoring part Blynk app will monitor all the parameters. Breeders can act with all the monitored parameters to avoid losses. Solar energy for power supply and coding were proposed. This technology not only care the quality of product, but it also makes the production nearer to the market demand [5–7].

Fish death often happened in acceptable time. It always happened without knowing the sign and traced. The common cause of the death of fish is low pH, temperature and often turbidity happen at the water. The main factor that caused all the parameter mentioned become low is because of climate change, bad weather and flood.

Water quality is the most important factor affecting fish health and performance in aquaculture production systems. The phrase "excellent water quality" refers to what the fish want, not what we think they want. This demands a detailed understanding of the farmed fish's water quality requirements. For all their needs, fish are fully reliant on the water in which they live. To survive, grow, and reproduce, various fish species require diverse water quality attributes (temperature, pH, oxygen concentration, salinity, hardness, and so on). Water temperature is a primary predictor of fish growth and offshore farming makes it impossible to control water temperature which is a critical regulator of fish growth. Rather, it is influenced by environmental and geographical factors.

The related project is researched to determine the critical component of this type of monitoring system. Rapid innovations in communication technology and the mobile sector have aided the development and application of ICT in farming production [8]. Throughout the year, many researchers have come out many ways in term of developing wireless communication monitoring system. Developing IoT based with combining an Arduino development board with an ESP8266 or ESP32 Wi-Fi module to build an IoT-based monitoring system [9]. IoT wireless monitoring system also can be develop by using Arduino with combination of Raspberry Pi which is Raspberry Pi has built in with Wi-Fi communication function that Arduino doesn’t has the communication capability such as Arduino Uno, Nano and Mega. As we know, Raspberry Pi is more powerful in terms of system capability than Arduino, but Raspberry Pi is more expensive compared to combination Arduino with ESP32 or Esp8266 Wi-Fi module.

Multiple sensors attached to the microcontroller measure the quality of the water and send the data to a cloud server through Wi-Fi module. The data will be stored on a cloud server, where it may be processed and displayed on the smartphone and computer. The cloud server will store all data that been monitored and will displayed on the computer centre. Multiple sensors will be use with different type of function. Every type of sensor will monitor the specific parameter based on the function of sensors. By the research made by Saha *et al.,* [10] that used several sensors which is dissolved oxygen, temperature, ammonia, salt, pH, nitrate, and carbonates. However, maintaining many sensors is both costly and time-consuming. So, an inexpensive and adaptable system that can effectively determine the water's overall quality is required, which defines the overall objective of this research.

1.1 pH Water Sensor

A pH metre measures the acidity or alkalinity of water or other liquids. The pH sensor module is made up of three parts: a pH electrode with a BNC connector, an analogue cable, and a pH sensor circuit board. The pH measuring range is 0.0 to 14.0, with an accuracy of 0.1. A pin for analogue pH data is required by this module. An intelligent PH sensor was created in accordance with IEEE145 standards, with the ability to read sensor data and change actuator parameters using Transducers Electronic Data Sheets (TEDS), resulting in "plug and play" functionality. A researcher stated that chemical or electrical methods are used to determine pH. The chemical approach is really straightforward. When a reagent is applied to a sample, the colour change that occurs corresponds to the pH value. The electrical approach employs an electrode that is submerged in water and produces a voltage that is proportional to pH. These units can be interfaced with control systems and are commercially available at a reasonable price.

P450 series pH sensor can measure pH values ranging from -2 to 16. This sensor can measure negative pH values and has a pH resolution of 0.01 pH. A negative pH value indicates that the molarity of the hydrogen ion in an acid solution is greater than one. However, the main disadvantage is that this sensor is expensive. The pH sensor from the company Phidgets was then chosen by Rao *et al.,* [11] to measure the pH value in the water. This model is 3550 0- ASP200-2-1 M-BNC and it can measure pH from 0 to 14 and operate at temperatures ranging from 0°C to 80°C. The sensor also has a BNC connector which requires a pH/ORP adapter to convert the sensor's pH value before sending it to the microcontroller or microprocessor.

1.2 Temperature Sensor

Simbeye *et al.,* [12] employed the DS18B20-PAR digital thermometer, which features a non-volatile alarm function with user-programmable upper and lower trigger points and can measure temperatures in 9 to 12 bits in centigrade. The DS18B20-PAR does not require an external power supply because it gets power directly from the data line ("parasitic power"). The DS18B20-PAR communicates with a central CPU through a 1-Wire bus, which by definition only requires one data line (and ground). It can function at temperatures ranging from –55°C to +100°C and is accurate to 0.5°C throughout a temperature range of –10°C to +85°C. Because no additional voltage regulator is required in the design, it can operate between 3V and 5V, making it suitable for a 3.3V or 5V microcontroller. This sensor also includes a one-wire interface, which cuts down on the number of wires. LM35 temperature sensor is another type of temperature sensor which can detect the temperature in the surrounding environment. The main disadvantage of LM35 sensor is that it is not waterproof and is usually used by integrating it into a circuit board. This sensor has an accuracy of 1°C and operates at 400 µA to 50 mA.

1.3 Turbidity Sensor

Osman *et al.,* [13] used SEN0189 analogue/digital turbidity sensor. This sensor is also commonly used with Arduino. The disadvantage of this sensor is that it cannot be fully submerged into the pond. This sensor has an operating temperature range of 5°C to 90°C, a maximum current of 40mA, and a voltage of 5V DC.

TSD-10 turbidity sensor was made by Rasin and Abdullah [14] to measure the cloudiness of the water. This sensor has a phototransistor output, an operating voltage of 3-5V DC, and can operate in temperatures ranging from -10°C to 90°C. The operating principle of this sensor is that when light passes through, the amount of light transmitted depends on the number of suspended particles in the water; more particles result in less light transmitted. This sensor cannot be completely submerged in water.

The system developed by Arifin *et al.,* [15] used turbidity sensor which is polymer optical fiber. This sensor is originally own designed. They used LED, photodetector, fiber optic and binder sensor. The sensor can detect turbidity ranging from 0.12 NTU to 20 NTU. This sensor measures turbidity by sending light from an LED through a plastic optical fibre and receiving it at the other end via a photodetector. A photodetector that receives less light indicates that the water turbidity is higher.

2. Methodology

The method of research is divided into three sections: (1) system architecture design; (2) manufacturing hardware for implementation and (3) making software that describes each's functions component.

2.1 System Architecture Design

First, this system comprises of variety of components, including an Arduino module, sensors, a database, Web services, a mobile app, and a desktop app. Figure 1 presents the data flow as well as the system's three main components: sensors, connectivity, and deployment.

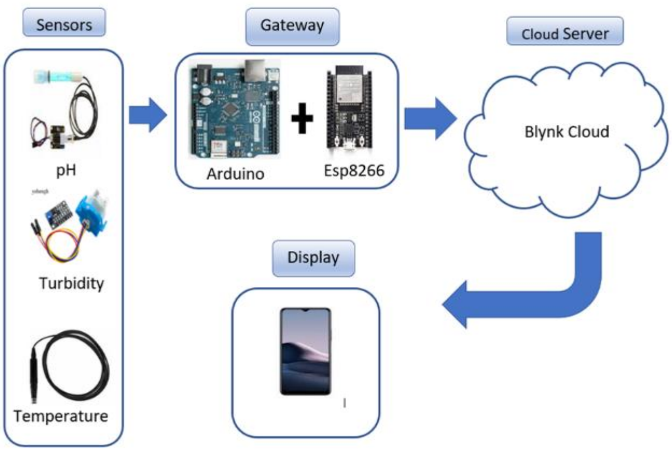

Fig. 1. Block diagram of the water quality IoT system

2.2 Manufacturing Hardware

As equipment storage, we use two junction box that for microcontroller and sensors in one box and for power module in one box. The junction box is 215x150x110 mm.

i. Power module

The power module includes a DC-DC buck converter, a solar charger and 5-unit lead acid batteries with a capacity of 24000 mAh and a voltage of 5.4V. The battery is used to provide control 24 hours and the battery last long till 3 days. Need to monitor within 24 hours because water quality parameters change regularly based on time and weather [16]. A DC-DC buck converter is used to convert voltage to a scale controller module that operates at 5 V and to prevent overvoltage to the ESP32 and sensors.

ii. Sensor Modules

The sensor module that used in this project is pH, temperature, and turbidity sensors. These sensors are connected to the ESP32 for detecting the water parameter. The sensor used is a BNC-connected aquarium hydroponic spare laboratory pH electrode probe. Furthermore, this sensor includes an analogue to digital converter (ADC) that converts analogue values to digital so that the data can be processed by the microcontroller. Aside from that, this sensor can measure pH values from 0 to 14 at temperatures ranging from 0 to 60 degrees Celsius with an accuracy of 0.1 pH. Aside from that, this sensor will be able to submerge completely under water, making it suitable for the system.

Not all temperature sensors can submerge and waterproof in the water. A temperature sensor (DS18B20) that can measure temperature of water is used. With an accuracy of 0.5°C, this temperature sensor can monitor temperatures ranging from -55°C to 125°C. Because 0.5°C differences from actual temperature have little impact on aquatic life, the accuracy tolerance is acceptable in aquaculture water quality monitoring.

Turbidity sensor is very important to aquaculture because it can detect the turbidity of the water. This sensor was chosen to detect haziness in water caused by microparticles that are invisible to the naked eye when present in small quantities. The turbidity sensor is made up of a light transmitter and a receiver. When the water is very hazy, the amount of light transferred to the receiver decreases dramatically, lowering the measured value. Because the output signal is analogue, it must be converted to digital. Furthermore, the operational temperature ranges from 5°C to 90°C, making it excellent for use in aquaculture water quality monitoring.

iii. Microcontroller

The ESP32 modules serve as the primary controller in this project. The ESP32 is a low-cost Wi-Fi module with easy write and read data programming in the Arduino language that sends data to an IoT platform.

iv. Software

This system makes use of the ESP32 and the Arduino programming language. A programmed reading serial sensor data, analogue sensor data, analogue to digital data conversion, connection to Blynk, and data sending to Blynk. Blynk is an iOS and Android platform for controlling Arduino, ESP32, Raspberry Pi, and other Internet-connected devices. It can manage hardware remotely, show sensor data, store data, visualize it, and perform a variety of other fascinating things. This platform was chosen because it has numerous characteristics, including a real-time database, cloud machine learning, authentication, and function, among others.

It also very common with others user because it easy to use. It's also in charge of all data transfers between the smartphone and the hardware. It can either use Blynk cloud or run locally on a private Blynk server. It's open source, can handle thousands of devices, and can even run on several platforms.

2.3 Hardware design

The circuit will be powered by solar panel and the energy generate by the solar will be store in the lead acid battery. Solar panel use is 12 V and 100Wp and the five-lead acid battery that total capacity 60 Ah. With size of solar panel and battery, the system can stay long about 2 or 3 days. Furthermore, to protect overcurrent to the circuit, DC-DC converter will be use. Figure 2 above are complete power system architecture for this project.

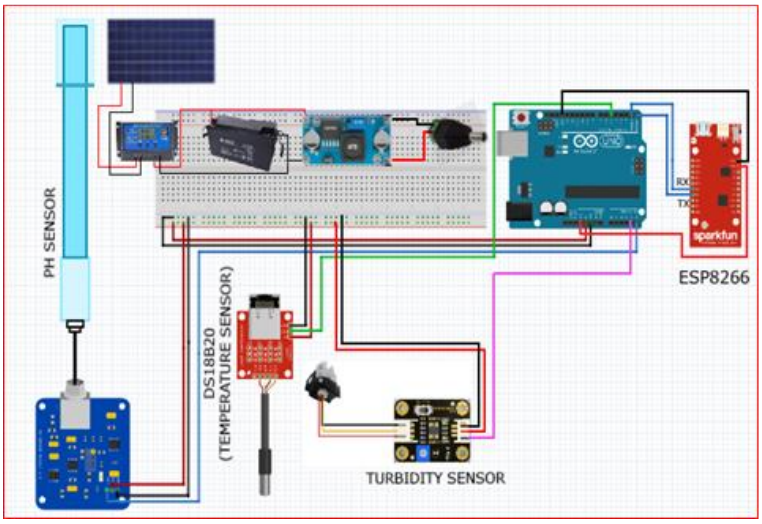

Fig. 2. Power system architecture circuit design

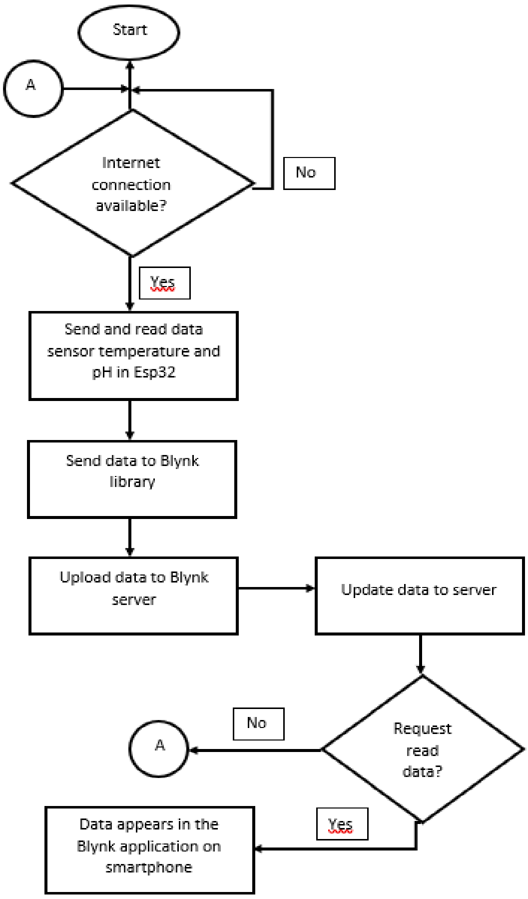

Fig. 3. Flowchart of the system

The software's flowchart begins with the detection of an internet connection. It needs to be linked to the Blynk server. If there is an internet connection, the sensor begins sending data, which is received by the ESP32 and forwarded to the Blynk server. After the Blynk server is updated, the data will be displayed on the smartphone's Blynk application.

2.4 Cloud Connectivity

To enable cloud connectivity, the ESP32 board must first be connected to the internet. In this project, the Blynk platform already includes a cloud database for users, so there is no need to create a database or a cloud for the system. For the code testing was developed to allow the connection between the ESP32 board and the Blynk cloud to be tested. The authentication token, SSID, and password for the SSID are all that is required for code testing.

An authentication token is a number received from the Blynk application via the user's email during the registration of a new project. Millions of people use Blynk as a platform to communicate with microcontrollers. So, the authentication token is a microcontroller identification number that assists the Blynk cloud in determining which microcontroller was connected.

It is the interface between the hardware and the smartphone that is responsible for communication. It is an open-source project that can control a wide range of hardware and devices in addition to being run on the ESP32. Blynk provides all standard hardware stages to improve cloud communication and the total movement of approaching and active instructions. The connection between the ESP32 and the Blynk cloud is the critical step that has been achieved as the main role of the beginning process to obtain the result and data from the listed parameters.

3. Results

The results of the IoT system for farm aquatic species testing will be demonstrated and discussed in detail in this chapter. In context of IoT, it refers to a system that uses IoT technologies to monitor and display data collected which is pH and temperature from sensors via a mobile application of the water at aquatic farm of tilapia and catfish.

By using an IoT platform, data can be monitored and displayed via a mobile phone app and then used to analyse the behaviour and effect of pH and temperature of water towards surrounding conditions [17-19]. A water quality monitoring system has been successfully developed using designed hardware, software, and architecture. The experiment was carried out in a fishpond to evaluate the performance of water quality monitoring system equipment. Water quality parameter obtain

i. The range of temperature by time start morning to night: 28 - 31 °C
ii. The range of temperature by weather in cloudy, rainy, and sunny day: 29 - 30 °C
iii. The range of pH by time start morning to night: 6.3 -7.011.
iv. The range of pH by weather in cloudy, rainy, and sunny day: 6.6 – 6.9.

Fig. 4. Complete set of the IoT system of the project

3.1 Data Display

Figure 5 shows the sensors monitoring performed by the Blynk mobile application using a digital gauge meter. For this project, the digital gauge meters display the temperature and pH values measured by each sensor. The data pins out in each widget can be customized by the user, and they can be freely chosen to display the data from the sensors. Furthermore, different colours can be used for each parameter to make the user interface more visually appealing and easy to monitor.

Fig. 5. Data displayed in the Blynk app gauge meter

3.2 Data Analysis

During the field test, which tested in various condition like cloudy, rain and sunny day. Besides, it also tested in the morning, noon, evening, and late night. This test is made to know the position of pH readings and water temperature in the fish cage. As we know, fish are always gasping at night and early morning. After the test, ESP32 continuously sends values to the cloud, which are then retrieved by the Blynk mobile application [19]. The data was analyzed using a super chart created by Blynk. Each parameter is constantly updated to show the values attained each day. Figure 6 shows the live data analysis of the water.

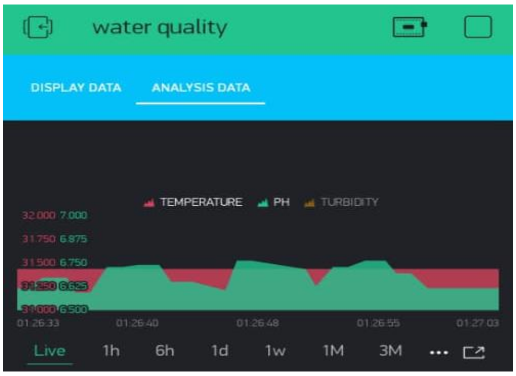

Fig. 6. Live data analysis of the water

3.3 Temperature of Water

Figure 7 shows the graph analysis for temperature of the water based on time and weather. The data shows the continuous evolution of the different values in real time regarding the environmental factor by measuring the water temperature. According to the data received from the Blynk app, the highest temperature of 31°C is recorded. This is because on that time is in the evening and sunny which is hot that indeed sunlight radiates directly to the surface of the water. However, the lowest temperature that been captured is at night which is 28.938°C. Same goes to at morning and rainy the temperature of water also at low reading. Based on observations, in the morning and evening or at other times when the water temperature drops, tilapia fish will easily gasp on the surface of the water to get air. This means that when the water temperature drops from the normal level, the oxygen value in the water will also drop.

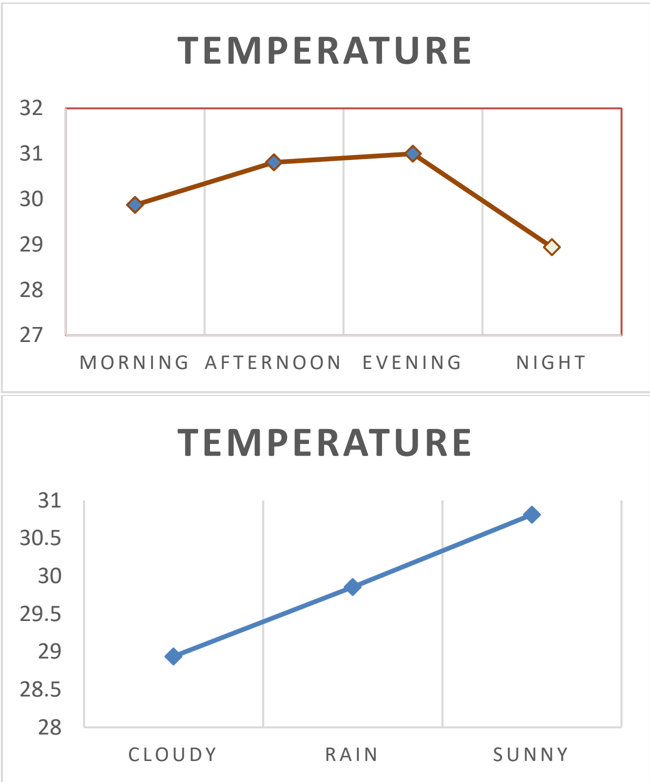

Fig. 7. Graph of water temperature based on time and weather

3.4 pH of Water

Figure 8 shows the graph analysis for pH of the water based on time and weather. By measuring the water pH, the data shows the continuous evolution of the different values in real time regarding the environmental factor [20]. This possible pH reading was measured using a pH sensor at the specified time because it wanted to make a difference and a relationship with the water temperature at that time. According to the Blynk application data, the lowest pH is around 6.3 and the highest pH is 7.011. As we know which fish will change attitudes such as gasping when the value of temperature or pH exceeds normal levels. However, after a long period, they become less aggressive as they can easily adapt to the varying environment especially tilapias.

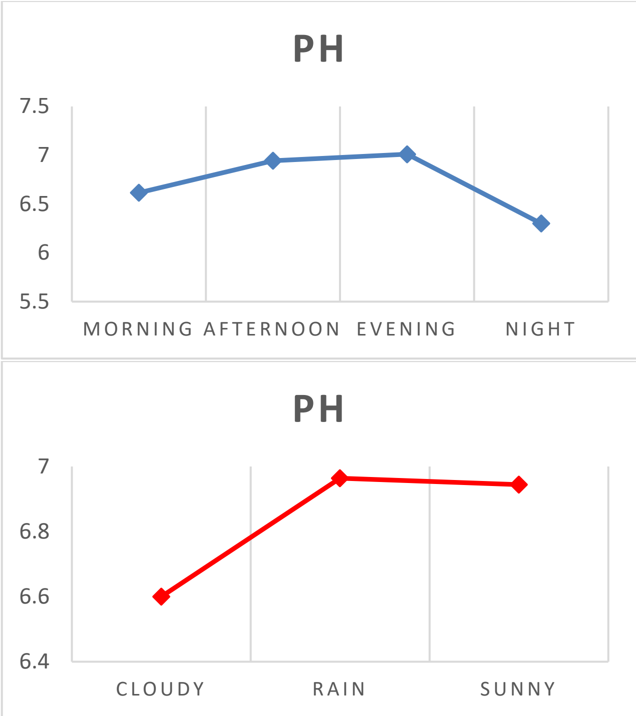

Fig. 8. Graph of water pH based on time and weather

4. Conclusions

This research presents a prototype design and implementation of a remote monitoring system using IoT technology to monitor water quality in aquaculture. The test results show that the system worked properly and was capable of measuring water parameters such as pH and temperature. Furthermore, this mechanism is also supply by Solar-powered and capable of monitoring for 24 hours without human intervention. The mainboards used in this project are the Arduino Uno as microcontroller and the ESP32 for transmitting data to the cloud. The cloud function used in this project is Blynk cloud, which is hosted by Blynk and can store data, processing data, and sending notifications to mobile devices. Following that, the Android mobile application which is Blynk app will be used for this project can view all historical data, change the logging interval, and request logging from the microcontroller in real time via the cloud server.

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