Smart IoT Based Monitoring System for Fish Breeding

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ABSTRACT

Water quality in breeding tank plays a significant role when breeding the fish because optimal water quality is significant as these environmental changes will affect young fish to grow successfully. In order to ensure an optimal water quality in the fish breeding tank, an automatic and IOT based monitoring system is essential to replace the conventional monitoring which is done manually. In this paper, Jade Smart 1.0 was developed as a IoT based monitoring system of water quality in the breeding tank which consists of three identical boxes equipped with ESP32 as microcontroller, pH sensor, water temperature sensor and water turbidity sensor. This smart monitoring system is capable to digitally collect, store and display the water quality data in real-time through web and mobile phone applications. Jade Smart 1.0 was tested with three different points known as point A, point B and point C, in real local fish breeding tank in Seremban 2, Negeri Sembilan. Point A was located at the incoming water source, point B, at the corner of the tank opposite of the incoming water and point C, at the corner opposite of point B. The result showed that the average pH level at three locations for water depth of 10cm was pH 6.48 and at water depth of 20cm, dropped to pH 6.40. The maximum difference was 2.6% while the minimum difference was 0.6%. For water temperature at three locations at the water depth of 10cm, the average reading was 28.6°C while for water depth of 20cm, the average reading dropped to 28.3°C. The maximum difference of 1.7% and minimum difference of 0.3% were found. Next, for water turbidity, the location A measured an average of 3.3NTU while location B and location C measured an average reading of 9.8NTU and 9.9NTU respectively.

1. Introduction

There are many factors that contribute towards fish breeding success, such as the tank capacity, water temperature, pH level, oxygen demand and fish diet [1-3]. These factors were also mentioned by Ohrem *et al.,* [4], regarding the design requirements for robot to detect and prevent biofouling

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which can affect fish health. The project's main interest is to monitor the pH value of water in the breeding tank, the water temperature, and turbidity of the water. The breeding tank's pH level needs to be monitored because pH level changes are particularly significant on young fish. Too acidic or alkaline water can interfere with the fish body functions that can leave the fish vulnerable to disease and stress [5-6]. Moreover, the weather in Malaysia is hot and humid, and sometimes with a heat wave. This heatwave may influence the water temperature of the incoming water to the tank and the water inside the tank. Monitoring the water temperature helps to notify the user if the water is too hot for the fish. Lastly, the turbidity of water determines the water visibility. If the water is too cloudy which means high turbidity, it will affect the fish ability to search for food and to navigate [7]. A fish breeding tank is a large tank that can hold up to 1000 litre of water. If reading is only done at a point in the tank, it would not be sufficient to assume the measurement of the water quality in the tank. More than one point of measurement is needed to take the average reading of water quality inside the tank. Besides, water depth also plays a role when taking the measurement. This report will show the results of the data collected and discuss the importance of the number of measurement locations and water depth. With current Industrial Revolution (IR) 4.0 technology, this report is about creating a device that can monitor and send the data collected to the server using the Internet of Thing (IoT) with ease. A more efficient, sustainable, as well as safer and easier risk management can be achieved by implementing IoT in the aquaculture industry [8, 9]. This creation of device will help local fish cultivators monitor the water pH level, temperature, and water turbidity thus a corrective action can be implemented when necessary.

2. System Components and Methodology
2.1 Suitable pH Level for Fish Breeding

As toxic (NH_3) and non-toxic (NH_4^+) forms, the pH of water determines the amount of total ammonia. By increasing the pH, the ammonium ion (NH_4^+) is transformed into ammonia gas (NH_3), which increases the concentration of toxic ammonia in water. Therefore, pH is a determining factor in the risk of fish and shrimp being poisoned with ammonia. In his paper, Mustapha (2019) [10] summarises the effects of pH variation on warm water such as Tilapia and Catfish in the following table, the desired ranges of 6.5 pH to 9 pH level for fish breeding.

2.2 Method of Monitoring The pH level – Gravity pH Analog Sensor

DF Robot Analog pH Sensor Kit is specifically designed to measure the solution's pH value and to reflect the acidity or alkalinity. The onboard voltage regulator chip is compatible with 5V and 3.3V main control boards and operates at a wide voltage supply of 3.3V to 5.5V. Features include filtered output signal from hardware, low jitter, and uniform size and connector, convenient for mechanical structure design. The pH of this sensor covers a wide range of uses in chemistry, medicine, agriculture, aquaponics, aquaculture, and water testing in the environment. The pH is usually a number ranging from 0 to 14. Under standard thermodynamic conditions, pH=7 means the solution is neutral; pH>7 means the solution is alkaline.

2.3 Method of Monitoring Water Temperature - DS18B20

There are two types of sensors to measure the temperature which are DHT11 and DS18B20. DHT11 is a type of sensor to measure the temperature in the air. The sensor can also measure the humidity in the air. However, the sensor is unsuitable to be used in this project because the sensor is

not submersible in water. The scope of this project is to measure the water temperature. DS18B20, is a more suitable sensor for this project because it allows measurement to be taken in the water as the sensor is submersible in water. The DS18B20 uses 1-wire interface which means it requires only one port pin for communication. The sensor can measure temperature from -55 °C to 125 °C with ±0.5°C Accuracy from -10°C to +85°C. The sensor needs to be connected to 4.7k ohm resistor to keep the data transfer stable.

2.4 Method of Monitoring Water Turbidity

The gravity Arduino turbidity sensor produced by DFRobot, was used to measure the turbidity in this project. It assesses water quality by measuring turbidity, or the opaqueness of the water. It measures light transmittance and scattering rate, which fluctuates with the quantity of total suspended solids (TSS) in water, to identify the suspended particles in water [11]. The amount of liquid turbidity rises as the 11 TTS rises. Water quality in rivers and streams, wastewater and effluent measurements, control instruments for settling ponds, sediment transport studies, and laboratory measurements can employ this turbidity sensor. This liquid sensor can produce both analogue and digital signals.

2.5 Microcontroller – ESP32

The ESP32 chip is widely used in numerous fields, according to recent research studies. A microcontroller may be used with a broad range of environmental monitoring sensors [12], whether it's to monitor air pollution or to directly monitor LPG leaks [13]. The article [14] shows how to utilise ESP32 as a control system to support wireless networks. ESP32 is a low-cost, low-power system-on-a-chip microcontroller that has built-in Wi-Fi and dual-mode Bluetooth. Espressif Systems, a Shanghai-based Chinese firm, designed and developed the ESP32, which is produced by TSMC using their 40 nm process. It is the ESP8266 microcontroller's replacement.

2.6 Internet of Things (IoT) – Blynk

Blynk is an Internet of things (IoT) company which provides a platform for building mobile (IOS and Android) applications that can connect electronic devices to the Internet and remotely monitor and control these devices [15-16]. It is important to incorporate modern technologies in the design process of a product as it can be beneficial to lots of people [17]. For many vertical applications, IoT solutions are built for environmental monitoring and control, health monitoring, monitoring of vehicle fleets, industrial monitoring and control, and home automation.

3. System Framework and Design
3.1 Solution Method and Algorithm

As illustrated in Figure 1 and 2, all three devices, Device A, Device B and Device C, began with reading of the pH sensor, water temperature sensor, water turbidity sensor values and the data collected were then processed by the microcontroller, ESP32 to convert raw data to informative values. Once the intended parameters had been recorded, the data were sent to the Blynk server with separate authentication token for each device. The difference between the authentication token allows the Blynk server to differentiate the data coming from each device. The authentication also allows encrypted connection between the device and the server. As shown in Figure 3, to find

the average values of pH value, water temperature and water turbidity of the three devices, Device B would retrieve the data from Device A and Device C on the server and calculate the average value on the microcontroller. The average values were then sent back to the server to be displayed and stored.
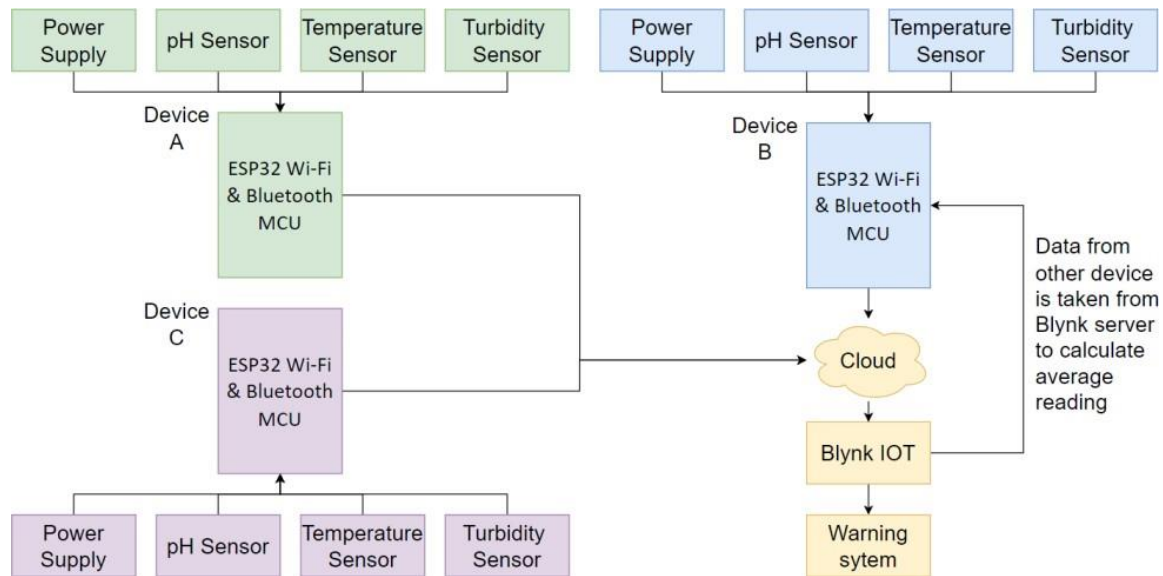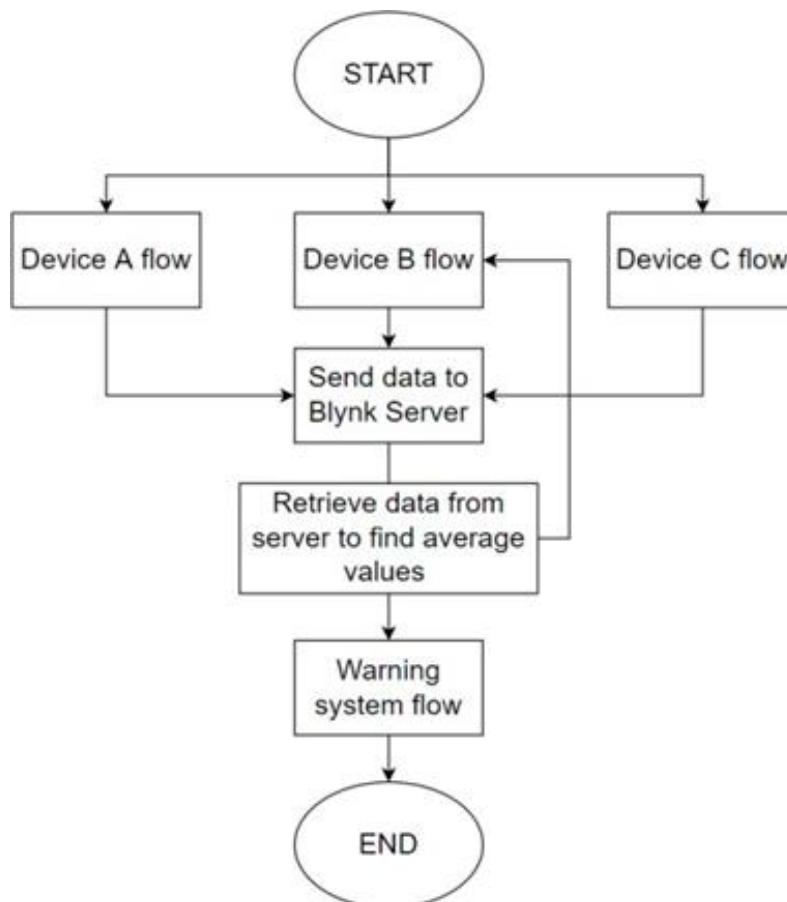

Fig. 1. System block diagram

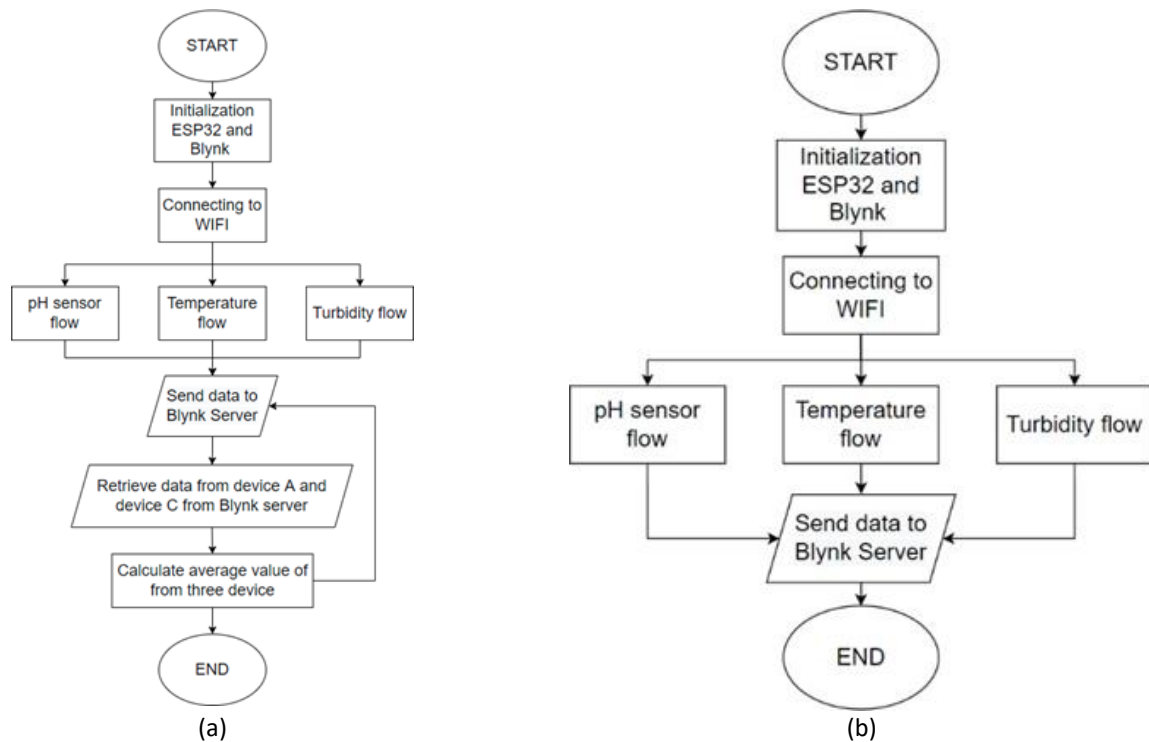**Fig. 2.** Flowchart for overall system

Fig. 3. (a) Flowchart for device B (b) Flowchart for device A and C

3.2 Schematic Diagram

Figure 4 illustrates the schematic diagram of device A and device C. There are three sensors connected to the ESP32. All the sensors voltage input is connected at 5V output pin on the ESP32, and the ground pin of each sensor is connected to the ground pin on the ESP32. Temperature sensor output analog pin is connected to GPIO 32 on the ESP32. Next, pH sensor output analog pin is connected to GPIO 35 and turbidity sensor output analog pin is connected to GPIO 33.
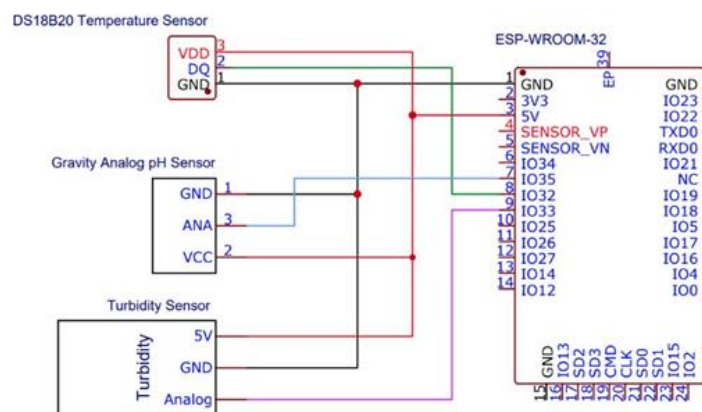
Fig. 4. Schematic diagram for device A and device C

Device B was equipped with three red LEDs which required additional resistor as shown in Figure 5. All the sensors voltage in, ground and analog output pin were connected similar to device B and device C. There were three LEDs; the first LED for pH warning, the cathode of the LED was connected to ground pin on ESP32 while the anode of the LED was connected to 220ohm resistor, and then connected to GPIO 25. The same goes for ground pin and resistors for temperature warning LED and turbidity warning LED but each was connected to GPIO 26 and GPIO 27 respectively.
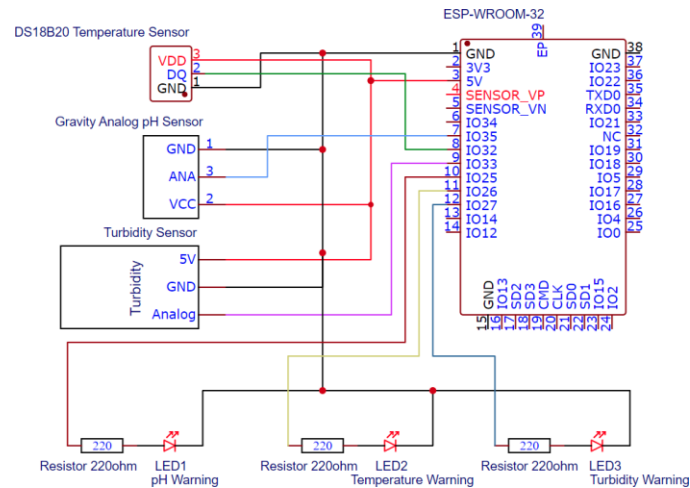
Fig. 5. Schematic diagram for device B

3.3 Experimental Setup

Device A, device B and device C final assembly can be seen in Figure 6. There were three points; point A, point B and point C in the tank in which the data were collected with each device at each point as shown in Figure 7. Point A was at the incoming water to the tank, Point B was at the corner of the tank opposite of the incoming water and point C was at the opposite corner of point B. The pH probe and water temperature probe were submerged in the water and the turbidity sensor floated on the water. The data were then uploaded to the Blynk server and displayed in the Blynk application and website.

Fig. 6. Component assembly for device A, B and C

Fig. 7. Experimental setup at the breeding tank

4. Result and Discussion

4.1 Water pH Level

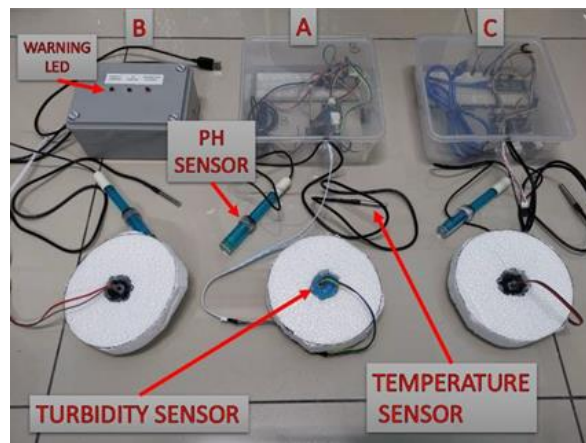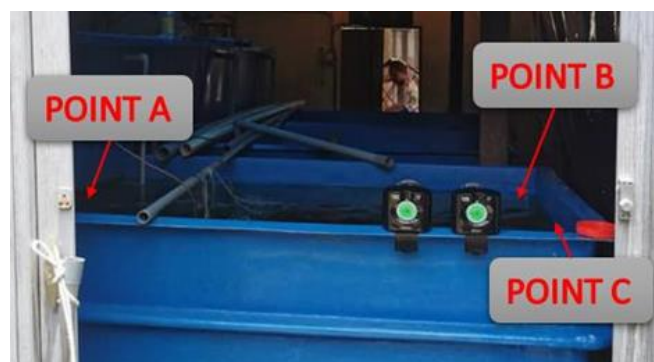The desirable pH level of the tank is 6.5 [18]. While doing the data collection, a manual pH check was done to compare the accuracy of the devices. The manual pH check resulted with 6.4. The experimental result for all points A, B and C were monitored at the water depth of 10 cm below the water level as shown in Figure 8. Point A which was located at the incoming water showed an average of 6.61 pH level which is in the desirable range of water ph. Contrary to point B and point C, the water pH level differed from the reading at point A with differences around 0.2 at average reading of 6.41 pH level for point B and 6.42 pH level for point C. The average reading of point A, B and C was at 6.48 pH level. Overall, the data collected within 30 minutes are acceptable with the range of +- 0.4 for each device. As seen in Figure 8, the average pH values of three locations slightly increased from 6.46 pH to 6.55 pH after 28 minutes. The pH values became more alkaline, increased by 0.09 which is 1.3% increment. The increase is caused by the pH sensor which is susceptible to external sources of electrical interference. Micro-voltages entering the water from unnatural sources such as pumps, solenoid valves, or other probes/sensors cause this interference. Therefore, the fluctuating pH reading was due to multiple pH sensor probe and water temperature probe being submerged in the water.
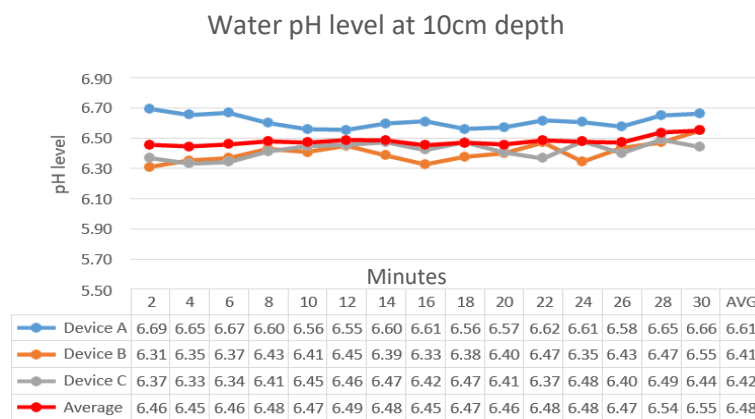
Water pH level at 10cm depth

Minutes	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	AVG
Device A	6.69	6.65	6.67	6.60	6.56	6.55	6.60	6.61	6.56	6.57	6.62	6.61	6.58	6.65	6.66	6.61
Device B	6.31	6.35	6.37	6.43	6.41	6.45	6.39	6.33	6.38	6.40	6.47	6.35	6.43	6.47	6.55	6.41
Device C	6.37	6.33	6.34	6.41	6.45	6.46	6.47	6.42	6.47	6.41	6.37	6.48	6.40	6.49	6.44	6.42
Average	6.46	6.45	6.46	6.48	6.47	6.49	6.48	6.45	6.47	6.46	6.48	6.48	6.47	6.54	6.55	6.48

Fig. 8. Data collected of pH level at 10cm below water level

4.2 Water Temperature

According to Hsiao [19], the optimal water temperature for fish growth ranges from 18 to 30°C. Figure 9 shows the parameter of water temperature at 10 cm of depth. Point A which is the incoming water inlet had lower temperature than point B and point C, at the average of 28.5°C. Point B and point C had average reading of 28.6°C and 28.7°C respectively. Overall, the average reading for all device locations was 28.6°C. Meanwhile, the fluctuation occurred for the temperature in the breeding tank is affected by the outside of the tank temperature. The water in the tank may quickly heat up or cool due to this temperature difference. As found in the literature, the fluctuation in temperature which is outside the preferred range will weaken the immune system of the fish thus they are less resistant to disease or parasite [20]. Therefore, the goal of this study was to maintain the temperature within the preferred range suitable for the species of Jade Perch originated from Australia which is bred at a local farmer in Negeri Sembilan.
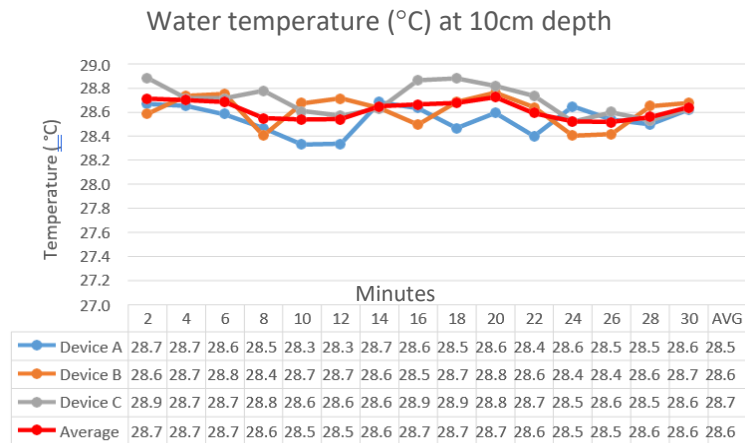
Water temperature (°C) at 10cm depth

Minutes	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	AVG
Device A	28.7	28.7	28.6	28.5	28.3	28.3	28.7	28.6	28.5	28.6	28.4	28.6	28.5	28.5	28.6	28.5
Device B	28.6	28.7	28.8	28.4	28.7	28.7	28.6	28.5	28.7	28.8	28.6	28.4	28.4	28.6	28.7	28.6
Device C	28.9	28.7	28.7	28.8	28.6	28.6	28.6	28.9	28.9	28.8	28.7	28.5	28.6	28.5	28.6	28.7
Average	28.7	28.7	28.7	28.6	28.5	28.5	28.6	28.7	28.7	28.7	28.6	28.5	28.5	28.6	28.6	28.6

Fig. 9. Water temperature at 10cm below water level

4.3 Water Turbidity

As we can see from Figure 10, point A at the incoming water had the lowest turbidity at 3.3 NTU in average. As the water circulates around the tank, the water turbidity increases at point B at 9.8 NTU and point C at 9.9 NTU. The average reading at 5:02pm for the three locations was 7.6NTU while at 5:30pm, the average reading of the locations was 7.8NTU. This increment is minimal at 2.6%. and the water turbidity changes are because the water inside the tank is constantly being replaced by incoming water source, meanwhile the excess water is removed. Overall, the water turbidity of the tank was 7.6 which is acceptable for fish breeding environment.
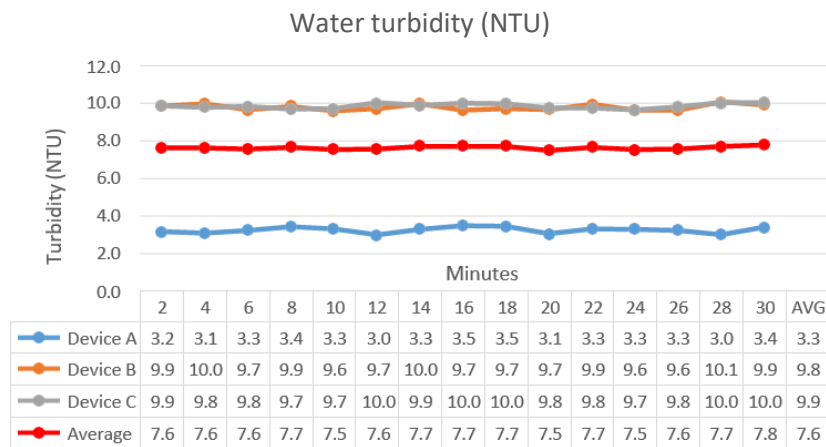
Water turbidity (NTU)

Minutes	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	AVG
Device A	3.2	3.1	3.3	3.4	3.3	3.0	3.3	3.5	3.5	3.1	3.3	3.3	3.3	3.0	3.4	3.3
Device B	9.9	10.0	9.7	9.9	9.6	9.7	10.0	9.7	9.7	9.7	9.9	9.6	9.6	10.1	9.9	9.8
Device C	9.9	9.8	9.8	9.7	9.7	10.0	9.9	10.0	10.0	9.8	9.8	9.7	9.8	10.0	10.0	9.9
Average	7.6	7.6	7.6	7.7	7.5	7.6	7.7	7.7	7.7	7.5	7.7	7.5	7.6	7.7	7.8	7.6

Fig. 10. Turbidity level at the water surface

4.4 User Interface – Blynk Application

Figure 11 highlights the user interface of this smart monitoring system. There are two tabs at the top of the page. The first tab shows the average reading of the three devices. This tab is configured to have a real-time monitoring graph so that the user can see the reading and it allows the user to see the previous collected data at 1 hour, 6th hour, 1 day, 1 week, 1 month until a maximum of 3 months. These data can also be exported to CVS format for data analytics to figure the trend and spike from time to time. The next tab that appears in the Blynk app is point-based reading to see specific reading at point A, point B and point C.
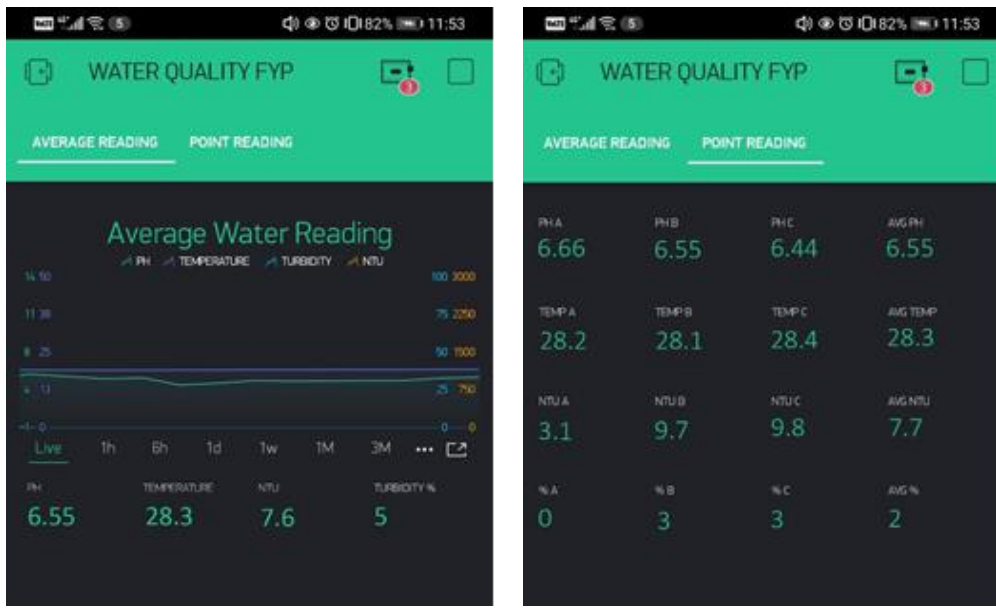
(a)   (b)

Fig. 11. (a) Blynk application interface average reading tab (b) Point reading tab

Furthermore, the data collected can also be viewed on a computer web browser. The Blynk interface is available for access on a webpage by entering the authentication token of all devices. However, the graph widget on the Blynk interface is not working properly but we can still see the values displayed. As shown in Figure 12, the interface is similar to the Blynk application on mobile phone.
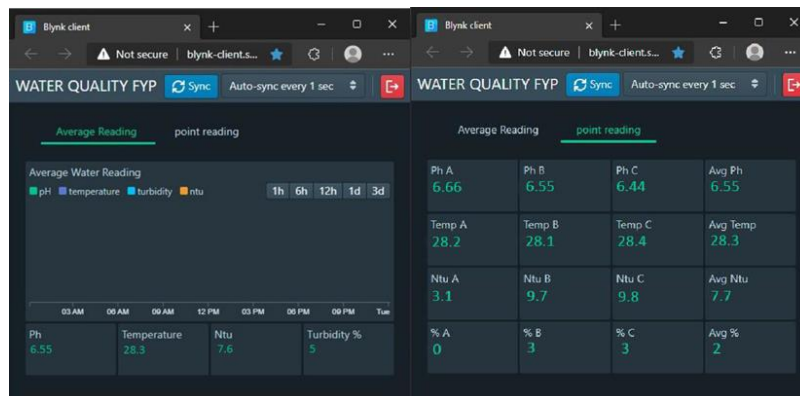

Fig. 12. Web version of Blynk interface

4.5 Warning System

For the pH level of water, the limit is set when the pH level exceeds more than 8 pH level and when the reading of pH level dips below 6 pH level which can be dangerous to fish [2]. As shown in Figure 13, when the pH probe is put into pH 10 buffer solution, the red LED will light up for 1 second. Next, when the pH probe is put in pH 7 buffer solution, the LED will turn off. Lastly, the pH probe is put into pH 4 buffer solution and the red LED will light up again. For temperature, the limit is set to 40°C because the heat wave in Malaysia may stress the fish and could cause death. The temperature probe is put into 100°C water of boiling water and the temperature LED lights up. Lastly, for turbidity, the limit is set when the NTU reading is above 100 NTU. When the turbidity sensor was tested in muddy water, the turbidity sensor recorded 3000 NTU and the warning LED lighted up.

Fig. 13. The embedded warning system

5. Conclusions

The present study was inspired by the problem faced at a real fish farm in Negeri Sembilan in which a species of Jade Perch originating from Australia is bred. The farmer needs to manually record the pH level, temperature as well as other parameters to avoid harm to the fish which causes low breeding successful rate.

In this paper, the results shown are based on the actual fish breeding tank in which the developed smart monitoring system known as Jade Smart 1.0 was successfully implemented. Three identical devices were built and assembled successfully employing ESP32 as microcontroller and three sensors which were pH sensor, water temperature sensor and water turbidity sensor. The data collected were then sent to Blynk server using Wi-Fi. The collected data were stored on the server and can be retrieved and exported into CVS format for further data analysis.

6. Recommendations and Future Works

There are a few recommendations that can improve the project starting with the wire length limitation. The wire length used in this project is not long enough to measure at lower depth such as for water depth of 1 meter and thus it is not able to reach the centre of the breeding tank. This limitation did not allow the data collection to be conducted at deeper water depth or position the sensors at the center of the tank. Besides, currently there is no sensor that can measure ammonia in the water and the dissolved oxygen sensor probe for Arduino is too expensive. These are two parameters that play significant roles when monitoring water quality for fish breeding. For future work, it is crucial to embed the ammonia and oxygen sensors to be integrated with this existing IOT system and to connect with ESP32 for data collection as well as monitoring the water quality in the breeding tank. Lastly, another future work is to take data measurement in the morning, evening, and night to compare the readings and see the overall trends of data collected throughout the day.

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