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Design of a Smart Biofloc Monitoring and Controlling System using IoT

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ABSTRACT

In this paper, an IoT based real-time monitoring and controlling system have been designed and developed for an eco-friendly aquaculture system namely a biofloc fish farm. Currently, technology has a vital role in improving aquaculture production which leads to attaining sustainable development. The microorganisms in the biofloc fish tank are utilized for detoxifying the toxic waste materials by recycling as well as transforming them into fish food e.g. protein cells. Hence, it not only manages good water quality in the biofloc system but also produces additional feed for the fish. Water quality monitoring of biofloc fish tanks is a significant aspect to guarantee a better environment for producing fish. This paper focuses on developing an IoT based device for biofloc fish tanks to monitor various water quality parameters as well as control water temperature and air pump. Using this device, users can monitor the water quality data received from sensors and control the actuators accordingly from any remote location through the graphical user interface (GUI).

Keywords: Aquaculture, Monitoring, Controlling, Biofloc, Turbidity, Temperature.

1 Introduction

Biofloc aquaculture has been proliferating around the world in recent times. This system allows producing an increased amount of food from the smaller area of land with fewer inputs. In this system, the cost of fish feeds is decreased since the toxic waste nutrients are converted and consumed by fish later on. The use of aggregates of bacteria, algae, or protozoa enhances water quality, ensures waste treatment, and prevents disease in the aquaculture system. The traditional fish farm has a number of issues namely temperature instability, nutrition, water pollution, high maintenance charge, etc. In fish farming, biofloc technology transforms the conventional fish farming process into another infrastructure that utilizes the leftover food by converting it into bacterial biomass. Crab et al. [1] conducted a review of the advantageous effects of the biofloc process and addressed a number of challenges for further research. Hargreves et al. [2] referred to biofloc technology as a technique to enhance ecological control over production. Researchers and engineers designed a variety of monitoring and controlling systems for the fish farm over recent years. Phawa et al. [3] designed and developed an automated biofloc fish farming system. For measurement of the water temperature, a temperature sensor has been used. Arduino board is used for processing and controlling a heater that is placed in the tank. Furthermore, Mahanjan et al. [4] developed an e-monitoring system for the automated fish farming process. This system is integrated with IoT supported system for monitoring the fish farming process where PH sensors, Temperature sensors, TDS sensors, and Gas sensors were used. Noor et al. [5] developed a PIC microcontroller based automatic fish feeding system. The rotational speed of the DC motor controls the pellets in the automated fish feeding system. Another research by Tasin et al. [6] focussed on IoT based monitoring and assessing the quality of river water for saving the ecosystem. The researchers developed an Artificial Neural Network (ANN) based automated device with the help of IoT. Parra et al. [7] developed a wireless sensor network based approach to monitor both the fish behavior as well as water quality in an aquaculture tank using a low-cost sensor system. Their proposed system is capable of monitoring the status of the fish tank, the velocity and depth of feed falling and fish swimming along with the water quality parameters as well. A. Ramya et al. [8] developed another IoT based automated system that can not only monitor the fish farm but also assists the fish farm owners to maintain the fish feeding process. Shaari et al. [9] proposed an integrated system that combines both the automatic feed dispensing as well as distribution process. Kayalvizhi et. al. [10] proposed an automated device integrating sensors such as TDS sensor, pH sensor, Dissolved oxygen and Ultrasonic sensor, and controllers like Raspberry Pi and Arduino board. Chen et al. [11] conducted a thorough experiment on some water quality parameters namely pH, temperature, and dissolved oxygen developing an automated monitoring system that could work wirelessly via the Zigbee sensor network. Further research work by H Hendri et al. [12] demonstrated an automatic fish feeding approach where the turbidity level of water is tested and Arduino Mega was used as a controller. Research by Phillip G Lee et al. [13] focussed on developing bio-filters for monitoring water parameters. The authors made use of video cameras inside the fish tank to check the status and growth of the fish. Garcia-Pineda et al. [14] developed a cost effective automated fish feeding control system using a set of sensors. Bhakti et al. [15] highlighted analyzing water quality by measuring temperature, TDS, turbidity, and pH with various sensors and Raspberry Pi controllers. Mozumder et al. [16] proposed a smart IoT based biofloc monitoring system that uses a number of sensors that collect, store, and analyze the sensed data by using the decision regression tree model for forecasting the water condition. Rashid et al. [17] presented an IoT based water quality prediction system using sensors and carried out a machine learning based analysis for tracing water quality and sending notifications to the user as well. Yang et al. [18] developed a smart prototype system for

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classifying dead and live fish species and evaluating feeding decisions using the deep learning approach. However, this system could not address composite data in aquaculture. Dzulqornain et al. [19] proposed an automated IoT based approach and implemented the machine learning algorithm for the prediction of the quality of water in the biofloc tank. The proposed approach uses some parameters such as pH, temperature, turbidity, and total dissolved solids, and the sensor data was stored in the cloud. However, the process was manual. Ahmed et al. [20] implemented a prototype of a biofloc farm monitoring system taking into consideration of the chemical properties of water and controlling the pumps as well. A mobile application was used for real-time monitoring and controlling as well. However, the system performance was not evaluated.

From the thorough review of related literature, it is obvious that the water quality is based mainly on some crucial water parameters namely pH, temperature, turbidity, total dissolved solids, etc. In this work, an IoT based system has been developed which has real-time monitoring data on water quality and these data are ultimately sent to the cloud. Furthermore, the temperature of the water tank is controlled along with the air pump as well.

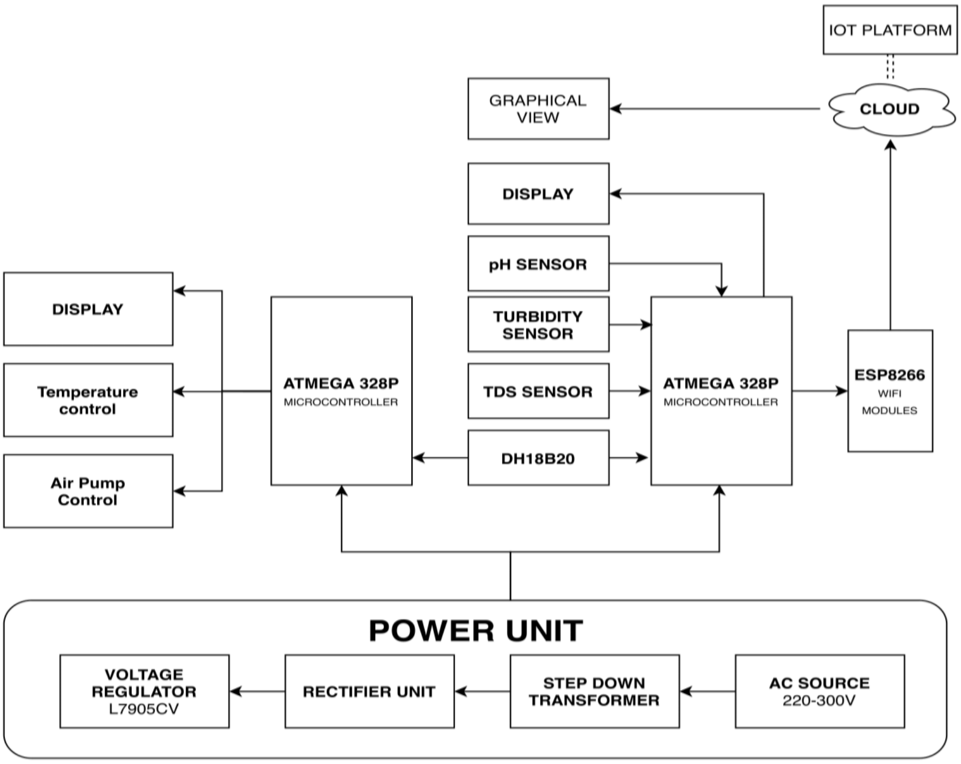


Fig. 1 System block diagram.

2 System Design

Fig. 1 illustrates the system block diagram. In this diagram, the power unit is comprised of an AC voltage source which is transformed into a DC voltage source with the help of a rectifier. The device is comprised of Atmega 328P microcontroller, Node MCU, pH Sensor - pH-4502C, Temperature sensor - DH18B20, turbidity sensor, TDS sensor, LCD Monitor, and Air pump. Atmega 328P is used with ESP8266 module that links the embedded device to the internet and gathers the relevant data from temperature (DS18B20), analog pH, TDS, and turbidity sensors. These sensed data go to the microcontroller. Depending on the water quality and water temperature in the tank, the microcontroller sends a trip signal to the relay. Then the heating rod, as well as the water pump, is both turned ON. The Atmega 328P acts as a sensor node assuring continuous data transmission through ESP8266. Moreover, the received data are transmitted to the web server “Thinger.io”. Air pumps are also one of the key parts of the developed system to supply oxygen which is controlled as well. Adding the GUI (Graphical User Interface) is another essential part of the Thinger.io application.Three Atmega328P are used for carrying out a number of tasks. The developed device not only controls temperature and air pump, but also monitors the quality of water and processes the analog data. Fig. 2 shows the circuit diagram. Fig. 3 represents the flow chart. The temperature sensor (DS18B20) detects the water temperature and displays it on the monitor. If the temperature becomes less than the value set by the user, then the microcontroller sends a trip signal to relay for turning ON the heating rod as well as the water pump. If the temperature of the water becomes equal to the set value, it resends the trip signal to the relay for switching ON the heating rod and turning OFF the water Pump. Users are allowed to fix the value of temperature and the entire procedure is repeated. Also, both air pumps are initiated. If the first pump is turned ON, then the second pump is turned OFF. After a preset amount of "X" delay, the first air pump is turned OFF and the second air pump is also turned ON and the entire procedure is repeated. A user can fix the time value "X". Data received from the sensors is in the millivolt range. In the biofloc aquaculture system, the range of analog pH is from 0 to 14, the TDS sensor is from 50 to 2000 ppm, Turbidity is from 0 to 3000 NTU and DS18B20 sensor is from -55 to 155 degrees Celsius. If the received data from the sensor fulfills the program condition, then the display shows the data which are sent to the cloud.

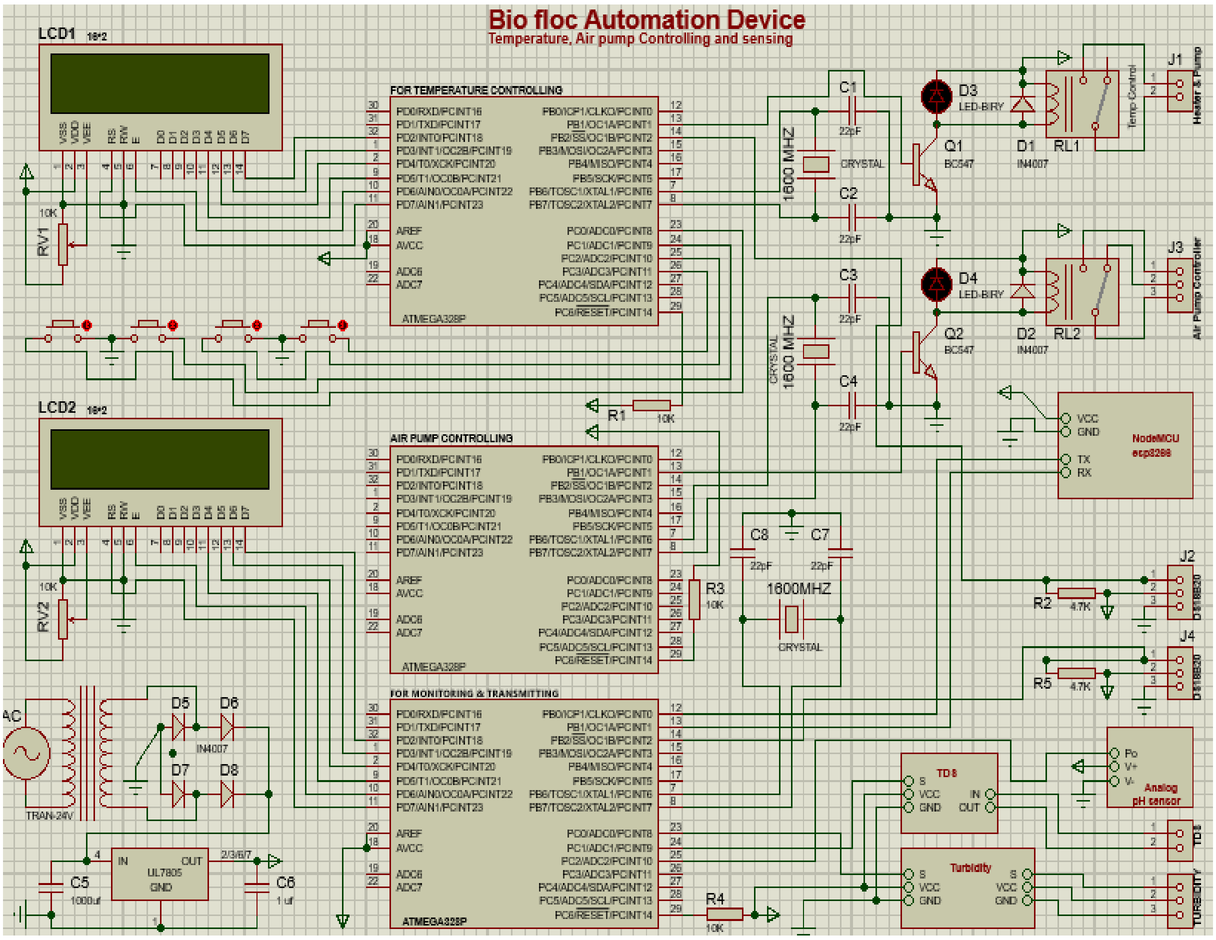


Fig. 2 Circuit diagram.

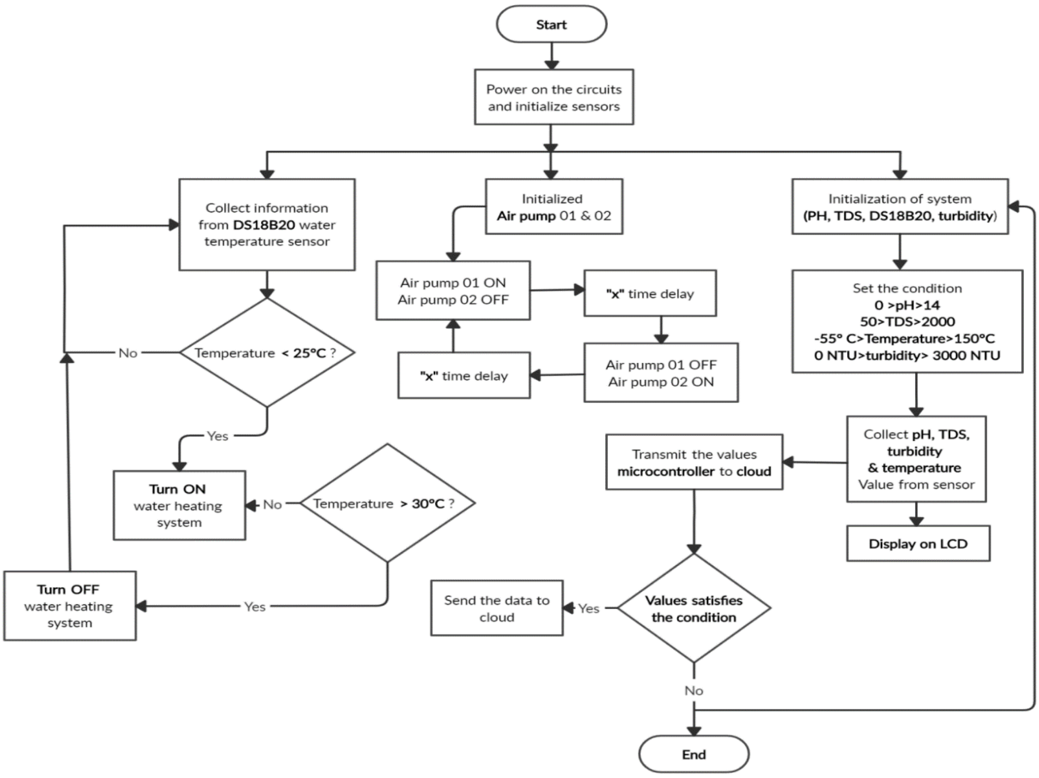


Fig. 3 Flow chart.

3 System Setup

A biofloc fish tank was selected for the purpose of experimentation which can contain 10,000 litres. Fig. 4 illustrates the entire setup.

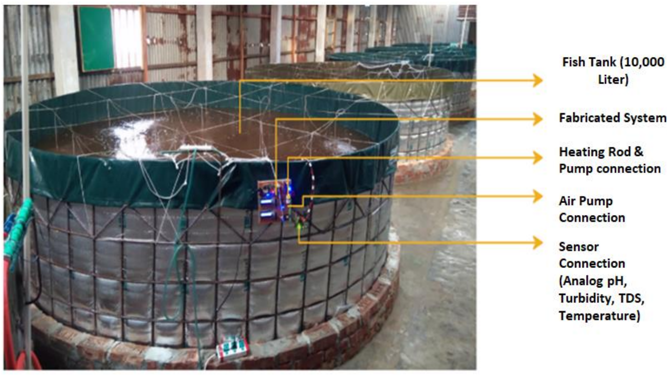


Fig. 4 Device setup.

Fig. 5 demonstrates the entire hardware setup which has a power supply unit, sensor unit, capacitor, relay, as well as a control unit. There are air pumps, a heating rod, and ESP8266 in the controlling unit. Fig. 6 shows the complete sensor connection in the biofloc tank. There are two LCD displays that present the measured value.

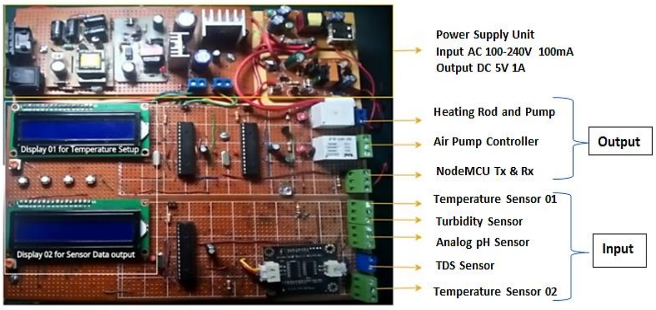


Fig. 5 Hardware setup.

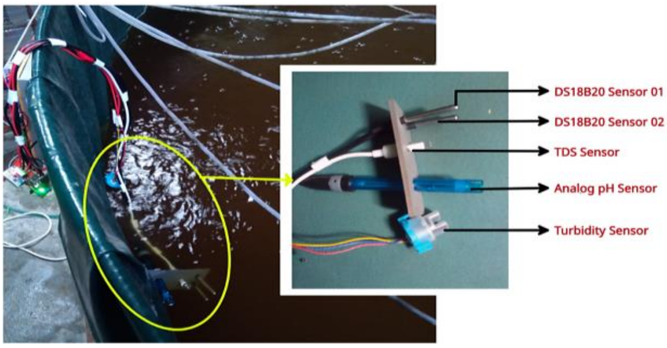
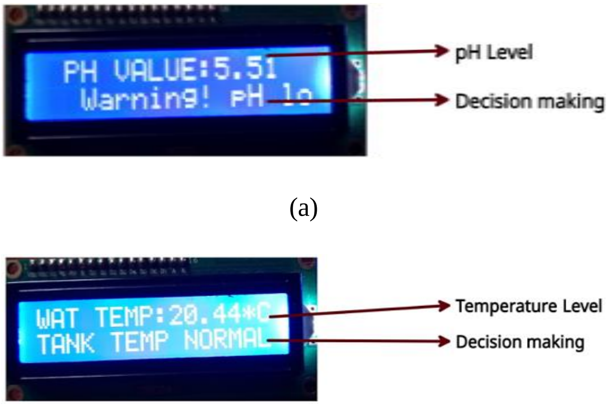


Fig. 6 Sensor connection in tank.

4 Results Analysis

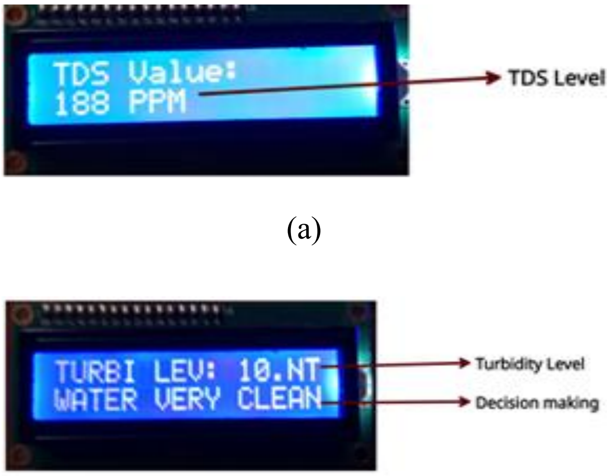
For controlling water temperature, the experiment is conducted with the help of a heating rod. The relay remains normally open (NO). Based on the temperature, trip signals are sent from the microcontroller (Atmega328P) that ground the relay through an NPN transistor (BC547). Thus, the heating rod is turned ON and the user can easily set the time delay. The experimental result demonstrates that if the temperature of the water becomes less than 25° Celsius, then the microcontroller sends the trip signal which turns ON the heating rod as well as the water pump. If the water temperature becomes 30° Celsius, then the relay becomes tripped again and the heating rod as well as the water pump becomes ultimately turned OFF. The temperature sensor (DS18B20 sensor) senses the water temperature. The received dataset was recorded at room temperature. The timing of the air pump is also controlled by setting the 'X' time delay. The experimental results were received successfully.

In this work, an analog pH sensor, Turbidity sensor, TDS sensor, and Temperature (DS18B20) sensor were used for sensing the quality of water in the fish tank. For biofloc fish farming, a pH value of less than 7.0 is preferable. From the measured pH values, the system takes the data from the pH sensor as well as calculates it which is shown in LCD (16*2) display. Simultaneously, these data are sent to the Thinger.io webserver. When the pH value becomes more than the reference level (more than 8), then the water becomes alkane. However, when the level is less than 6.8, then the water becomes acidic. As soon as the water turns acidic, a warning message is shown on the display. Users can check the data by monitoring the level and subsequently taking the required action. Fig. 7(a) shows the pH level while Fig. 7(b) represents the level of water temperature on the LCD monitor.



(b)

Fig. 7 Measuring water quality (a) pH value and warning message (b) water temperature.



(b)

Fig. 8 Water quality data (a) TDS level (b) Turbidity level.

TDS sensor measures the amount of total dissolved solids in water. The TDS data is gathered using a TDS sensor and sent to the TDS module which transmits the data to the microcontroller. Then the TDS sensor values are seen in the LCD display. In this work, a turbidity sensor is also used to measure the purity of the water. LCD display shows the measured values of turbidity as the water becomes very clean. Fig. 8(a) and Fig. 8(b) illustrate both the TDS level and turbidity level of water.

Table 1 shows the experimental data of measurements taken from the biofloc fish tank over 15 hours. These data changed according to time indicating the changes in water quality parameters.

It is apparent that the value of pH is changing from 5.5 to 6.8. It represents that the water is transforming from acidic to alkane condition. When the pH value is below 7, it means that the water is acidic. Furthermore, from Table 1, it can be seen that the amount of dissolved solid varies from time to time. Also, the temperature of the water depends on the weather and environment. The minimum temperature recorded was 23 °C which was observed in the early morning and the highest one was 31°C which was observed in the midday. Moreover, the turbidity values change from time to time based on the cleanliness of the water.

5 Real-time monitoring

Real-time monitoring was carried out for pH, TDS, and water temperature levels. In this work, a cloud IoT Platform named Thinger.io was used. By using the IoT Platform, any user can observe the water quality parameters from anywhere in the world. The server shows the stored real-time data. Users can also download the data if necessary. Fig. 9 illustrates the graphical representation of the real-time data for pH whereas Fig. 10(a) illustrates the exact value anytime in an instant using the Gooch chart. Likewise, Fig. 11 illustrates the graphical representation of TDS values in real-time while Fig. 10(b) shows the Gooch chart. Also, Fig. 12 illustrates the real-time temperature data of tank water whereas Fig. 10(c) represents the gooch chart of temperature data.

Table 1 Sensor output during the experiment in the biofloc system.

Time in hours	pH	Temperature (°C)	Turbidity (NTU)	Total Dissolved Solid (PPM)
7:00 AM	6.7	23	7	220
8:00 AM	6.7	23	7	223
9:00 AM	6.8	24	8	227
10:00 AM	6.5	25	8	222
11:00 AM	6.0	27	7	230
12:00 PM	5.8	30	7	229
01:00 PM	5.5	31	8	233
02:00 PM	5.5	31	7	228
03:00 PM	5.4	30	8	227
04:00 PM	5.7	28	8	230
05:00 PM	5.9	26	7	234
06:00 PM	6.1	25	7	230
07:00 PM	6.5	25	8	237
08:00 PM	6.8	25	8	237
09:00 PM	6.9	24	7	240

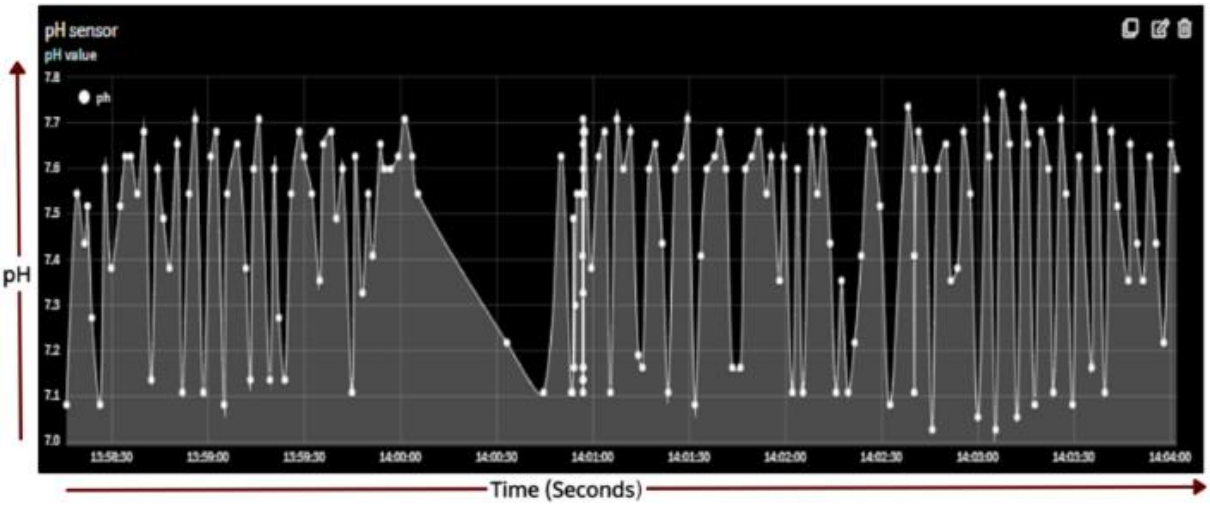
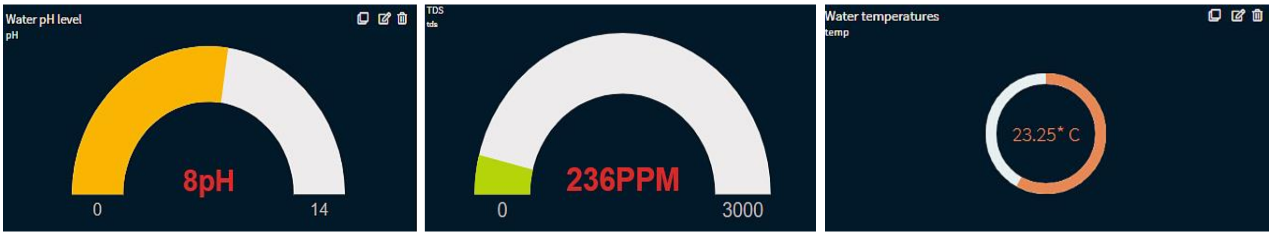


Fig. 9 Real-time graph of analog pH.



(a) (b) (c)

Fig. 10 Gooch chart for (a) pH, (b) TDS, and (c) Water temperature.

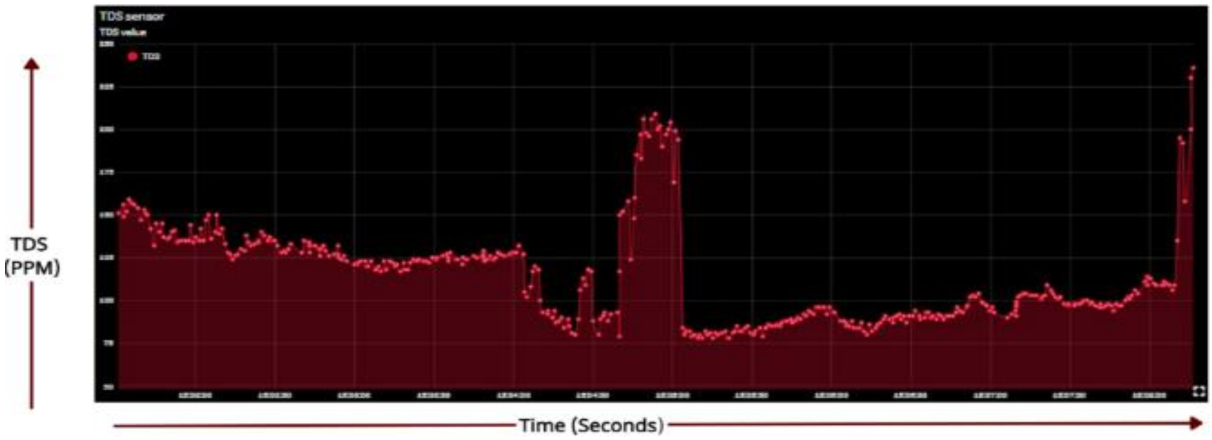


Fig. 11 Real-time graph for TDS.

Fig. 12 Real-time graph of Temperature data

The figures given above represent the quality monitoring data of water parameters via visual and graphical representation while the gooch chart presents instant values. The experimental data are sent to the user's device for continuous monitoring of water quality and taking necessary action. Users can easily monitor the data received from sensors and control actuators with the help of a Graphical User Interface from any remote location. Thinger.io is used as an IoT platform for monitoring and controlling via a web server and an Android app. This device is connected to this interface via an IP address and the calibrated data is sent from the device. This Webserver and android Graphical user interface (GUI) is visible to the user from anywhere. It helps the user not only monitor the real-time data but also control the actuators using this app as well.

6 Conclusion

Biofloc Fish farming has been flourishing over recent years despite increasing prices, unavailability of workers, and the hassle of manual and regular water management. It is a crucial and exigent task to monitor the quality of water in a biofloc fish tank. The proposed automated and IoT based system can effortlessly and efficiently monitor the water quality parameters and does not need people on duty. It can be easily installed and located inside water. The smart system proficiently analyses and monitors the water quality data in real time while decreasing production costs and human reliance, enhancing productivity and sustainability. Also, the controlling device controls the air pump and temperature in accordance with the requirement. The entire system functions by an IoT based platform via a wireless network and send the monitored data very fast. By analyzing the received data, users can take action immediately. Future work of this research work involves including more sensors like dissolved oxygen sensors (DO) and ammonia sensors to monitor more parameters of water. The quality of water can be further predicted using a suitable machine learning algorithm as well.

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