



# **Solar Powered Water Quality Monitor and Control system For Fish Farming**

by

Sadman Shakib Rodro (192016005)  
Sheikh Shifat Alam Shipul (192016011)  
Tanjidul Islam (192016002)

A project report submitted in partial fulfillment of the requirements for the degree of  
Bachelor of Science in Electrical and Electronic Engineering

Supervisor: Md. Shahjalal, PhD.  
Assistant Professor

Department of Electrical and Electronic Engineering  
University of Liberal Arts Bangladesh  
688 Beribadh Road  
Mohammadpur, Dhaka -1207,  
Bangladesh.

**13<sup>th</sup> January, 2025**

## DECLARATION

This Final year Capstone Project report is submitted to the Department of Electrical and Electronic Engineering, University of Liberal Arts Bangladesh in partial fulfillment of the requirements for the degree of Bachelor of Science. So, we hereby, declare that this report is based on the work done by us. Materials of work found by other researchers are mentioned by reference. This project report, neither in whole, nor in part, has been previously submitted for any degree.

Name: Sadman Shakib Rodro

Signature:  Date: 13<sup>th</sup> January, 2025

Name: Sheikh Shifat Alam Shipul

Signature:  Date: 13<sup>th</sup> January, 2025

Name: Tanjidul Islam

Signature:  Date: 13<sup>th</sup> January, 2025

## **SUPERVISOR'S CERTIFICATION / APPROVAL**

The Final year Capstone Project report entitled “Solar powered, water quality monitoring and control system for fish farming” is submitted to the Department of Electrical and Electronic Engineering, University of Liberal Arts Bangladesh, Dhaka in partial fulfillment of the requirements for the degree of Bachelor of Science.

MD. Shahjalal, PhD

Supervisor

Assistant Professor

Department of Electrical and Electronic Engineering

University of Liberal Arts Bangladesh

---

Signature

Date:

Prof. Mahbubur Rahman, PhD

Head of Department

Professor and Dean

Department of Electrical and Electronic Engineering

University of Liberal Arts Bangladesh

---

Signature

Date:

## **ACKNOWLEDGEMENT**

We wish to express our deepest gratitude to the supervisor, Md. Shahjalal, for his invaluable guidance, unwavering support, and insightful feedback throughout this capstone project. His expertise, encouragement, and dedication have been instrumental in shaping this final report and our overall academic journey.

We would like to convey our sincere gratitude to our Head of Department, Mahbubur Rahman, for his assistance. Although we had limited interaction, his leadership, and the environment fostered within the department have greatly contributed to the successful completion of this work. We appreciate their efforts in ensuring a productive and supportive academic setting.

We extend our heartfelt appreciation to the Former Head of Department, Mofazzel Hossain, and former supervisor, Mirza Rasheduzzaman for their encouragement and support throughout the project. Their vision and leadership have provided a conducive environment for academic growth and excellence within the Electrical and Electronics Department at the University of Liberal Arts Bangladesh.

We are grateful to all the esteemed faculty of the Electrical and Electronics Department, including Abu Sayeed Ud Doulah, whose expertise and commitment to academic excellence have enriched our learning experience. Their valuable insights and encouragement have been invaluable assets in completing this project.

Furthermore, we would like to acknowledge and appreciate the patience exhibited by our supervisor, Md. Shahjalal, Head of the Department, Mahbubur Rahman, and all faculty members, for their understanding and support during any delays in the project work.

Lastly, we sincerely thank the University of Liberal Arts for providing a conducive environment for academic pursuits and fostering a culture of learning and innovation.

Thank you all for your invaluable contributions and support.

## **Abstract**

This paper addresses the challenge of ensuring optimal conditions for fish survival and growth in the face of a rising human population and dwindling aquatic resources. Fish species require specific environmental conditions, often found in natural waterfronts such as ponds, rivers, and seas. However, with the increasing demand for aquatic animals, it becomes critical to develop sustainable methods for managing these conditions. This report proposes an embedded systems approach to design a solar-powered water quality monitoring and control system tailored for fish farming. The system focuses on controlling key parameters vital for aquaculture, such as temperature, pH, oxygen levels, and total dissolved solids, which are crucial for the health and growth of aquatic organisms. By integrating solar power, the design ensures energy efficiency, making it suitable for sustainable farming practices, especially in off-grid or resource-limited environments. The proposed system continuously monitors water quality in real-time, providing automated adjustments to maintain optimal conditions. The system is integrated with cloud monitoring for access of parameters monitoring remotely. This approach allows for more precise and consistent management of water quality, ultimately improving fish yield and contributing to the future sustainability of aquaculture practices. The paper outlines the design process, key components, and potential impact of this system, demonstrating its relevance in addressing the growing challenges of modern fish farming.

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# Chapter 1: Introduction

## 1.1 Background

Fish farming has become essential to food security in Bangladesh, a country traditionally reliant on its river systems, which are now in decline. As fish and rice are staples of Bengali culture, meeting the rising demand for fish is crucial, especially with increasing poverty and food scarcity. To boost productivity, many fish farmers have turned to chemical interventions, which, while temporarily effective, pose risks to both fish health and the environment. Most farmers lack the resources and technology to create ideal conditions for fish survival, leading to poor water quality, increased disease, and high mortality rates.

Water quality parameters such as pH, temperature, dissolved oxygen, and salinity are crucial for fish health. However, monitoring these conditions requires manual, labor-intensive processes that can be challenging for less-educated farmers and prone to human error. This lack of efficiency, combined with the frequent need for monitoring, significantly affects fish productivity.

Given these challenges, there is a pressing need for an automated system to monitor and control water quality. Such a system could reduce reliance on labor, minimize errors, and improve fish health, leading to lower mortality and higher productivity. By incorporating renewable energy, like solar power, this solution could further enhance sustainability in fish farming. This research seeks to address the current gaps by developing a cost-effective, automated system to support the growing demands of Bangladesh's aquaculture sector, improving both productivity and environmental sustainability.

### 1.1.1 Abbreviations and Acronyms

*DO – Dissolved Oxygen, TDS – Total Dissolved Oxygen Sensor, NaOH – Sodium Hydroxide.*

## 1.2 Problem Statement

The availability of food is declining due to increasing levels of poverty and hunger, while demand continues to rise. To meet this growing demand, fish farmers are turning to various chemical interventions, including pesticides, to boost productivity. However, maintaining optimal conditions for the survival and growth of specific fish species is a complex task that often falls beyond the capacity of individual farmers. The lack of precise environmental control contributes to suboptimal growth conditions and elevated mortality rates in aquaculture.

Effective fish farming requires continuous monitoring and regulation of critical water parameters such as temperature, pH, and salinity to ensure ideal living conditions. However, current monitoring practices necessitate farmers manually checking each parameter using separate sensor kits, which can be particularly challenging for those with limited education. This process is labor-intensive, and inefficient, and increases the reliance on human intervention, which introduces the risk of error. The need for frequent monitoring—often twice a day—not only consumes significant time but also leaves room for even minor mistakes, which can have a considerable negative impact on fish productivity.

### **1.3 Motivation**

Fish and rice are integral components of Bengali culture and livelihood. Bangladesh, once surrounded by over 700 rivers, is now witnessing a significant reduction in its river systems, leading to a growing dependency on fish farming to meet the demand for this essential food source. With rising issues of poverty and hunger, the availability of food is declining while demand continues to grow. In response to this pressure, fish farmers are increasingly relying on chemical interventions to boost yields, often to the detriment of both the environment and the health of the fish. Furthermore, farmers are often unable to provide the precise environmental conditions required for the survival and optimal growth of different fish species.

To ensure sustainable and efficient fish farming, it is imperative to monitor key water parameters such as temperature, pH, and salinity, and to have mechanisms in place to adjust these conditions either manually or through automation. Inappropriate management practices can lead to the proliferation of pathogens, contributing to higher fish mortality. Poor water quality in fish ponds not only increases fish vulnerability to disease but also poses serious public health risks, with contaminated water potentially spreading diseases like giardia, cholera, and typhoid fever.

Therefore, continuous monitoring and control of water quality are essential to ensure optimal growth conditions, reduce mortality rates, and mitigate the spread of disease. Current monitoring systems often require farmers to manually check individual parameters using separate sensor kits. This process is both labor-intensive and prone to human error, particularly for farmers with limited education or technical skills. Additionally, the need for frequent monitoring—sometimes twice daily—can be time-consuming and inefficient, increasing the likelihood of mistakes that could negatively impact fish production.

In light of these challenges, this project seeks to design an automated system capable of monitoring and controlling water quality with minimal human intervention. By leveraging advanced technology, the system is expected to reduce fish mortality, prevent disease outbreaks, and improve growth rates, thus offering a more sustainable and efficient solution for the aquaculture industry.

## **1.4 Objectives**

The objective of this research is to design and develop an integrated monitoring and control system for aquaculture that addresses the critical need for efficiency, sustainability, and enhanced biosecurity in fish farming. The proposed system will leverage automation to regulate essential water quality parameters, including oxygen levels, pH, salinity, and other key factors, to maintain optimal conditions for aquatic species. By implementing a cost-effective and user-friendly platform, this system aims to increase the accessibility of advanced monitoring technologies to a wider range of aquaculture operations, including small- and medium-sized enterprises.

A central feature of the system will be its reliance on solar energy, providing a renewable power source that aligns with global sustainability objectives. This approach reduces dependence on conventional energy sources, thus minimizing environmental impacts and promoting long-term viability. The automated system will also integrate disease prevention mechanisms by continuously monitoring water quality, thereby reducing the incidence of disease outbreaks and improving overall productivity in aquaculture.

This research will further investigate how such an integrated system can contribute to enhanced biosecurity measures, promoting resilience in aquaculture operations. Ultimately, the aim is to offer a scalable solution that increases the efficiency and productivity of fish farming while ensuring environmental sustainability and reducing operational risks.

## **1.5 Organization of Report**

This report outlines the development of a Solar-Powered Water Quality Monitoring and Control System for Fish Farming. It begins by presenting relevant data from previous research and studies, followed by a detailed explanation of the unique approach to designing the proposed system. The system's design is then discussed, including a model block diagram and an overview of the hardware components used in its construction. For clarity, the algorithm for the system is presented through a flowchart.

Subsequently, the report details the results obtained from cultivating Tilapia fish using the system, with a discussion of the findings. Finally, the limitations of the proposed system are acknowledged, and the report concludes with suggestions for future developments to enhance the system's applicability to fish farming.

## **Chapter 2: Literature Review and Methodology**

### **2.1 Research Preliminaries**

Fish farming in Bangladesh is a vital component of food security and economic sustainability. However, the industry faces significant challenges, particularly in water quality management, which directly impacts fish health and productivity. Farmers often rely on labor-intensive, manual methods to monitor essential parameters like pH, salinity, temperature, and dissolved oxygen. These practices are prone to human error, leading to inefficiencies and higher fish mortality rates. Additionally, many fish farmers lack the resources or technical knowledge to maintain optimal water conditions, further exacerbating the problem.

This research aims to address these challenges by developing a solar-powered automated water quality monitoring and control system tailored specifically for fish farming. The system will continuously track key water parameters and automatically adjust conditions in real time to ensure optimal environments for fish growth and health. By integrating solar energy, the system also promotes sustainability, reducing dependence on traditional energy sources and aligning with environmental goals.

The primary objective of this project is to improve fish farming efficiency by minimizing human intervention, reducing fish mortality, and increasing productivity through the use of advanced technology. Previous research highlights the limitations of existing manual monitoring methods and suggests that automated systems offer significant improvements in accuracy and operational efficiency. However, such systems are often costly and complex, making them inaccessible to many small-scale farmers in developing countries. This project builds on existing research to develop an affordable, user-friendly solution powered by renewable energy.

The system will be designed to operate independently, using solar energy to power the sensors and control mechanisms. Data collected from the sensors will be processed in real-time, allowing for immediate adjustments to water conditions. The project hypothesizes that this automated approach will significantly reduce fish mortality, improve water quality, and increase overall productivity in fish farming compared to traditional methods.

The scope of the research will focus on small to medium-sized fish farms in Bangladesh, with particular attention to the core water quality parameters necessary for fish survival. The

project will begin with testing in a controlled environment before being deployed in real-world settings to assess its effectiveness and scalability. Ethical considerations, such as the impact on the environment and adherence to sustainability practices, will be prioritized throughout the development and deployment of the system.

This research is feasible within the given constraints of time and resources, utilizing existing technologies such as water quality sensors, microcontrollers, and solar panels. The project will involve collaboration with local fish farmers to ensure practical application and usability, with the ultimate goal of providing a scalable, sustainable solution that enhances the efficiency and environmental impact of fish farming.

## **2.2 Field-Specific Theories**

A water quality monitoring and control system ensures safe water for fish farming, protects fish from unhealthy aquatic environments, and supports sustainable resource management. It minimizes pollution, improves efficiency, and monitors key water parameters (pH, DO, Temperature, TDS) in aquaculture and also controls those parameters within the desired range. It is important to maintain temperature, pH and dissolved oxygen level as optimal for maximizing growth and less mortality rate.

Existing study examines the effects of water temperature on the growth performance, feed efficiency, and survival rates of Nile tilapia fry reared in a closed-loop aquaculture system. Results indicate that an optimal temperature range of 28–30°C maximizes growth, feed conversion efficiency, and survival rates, while performance falls at below optimal temperatures of 24°C and 32°C. Fish were fed a 35% protein diet, starting at 30% of their body weight and reduced to 20% in the second month, with feeding adjustments every 10 days over a 50-day period. Fry reared at optimal temperatures demonstrated higher growth rates, better feed utilization, and improved resilience, highlighting the importance of precise temperature control in sustainable aquaculture systems [1].

Another study highlights the impact of water pH on the growth performance, feed efficiency, and survival rates of Nile tilapia fingerlings; the result indicates pH range of 6.5 to 8.5 for maximum performance. Growth, survival, and feed utilization significantly decreased at pH levels below 6.0 (acidic) and above 9.0 (alkaline), with extreme pH conditions causing stress, reduced appetite, and higher mortality. Suboptimal pH levels also impaired metabolic processes, making the fish more vulnerable to environmental stressors. The findings

emphasize the importance of maintaining water pH between 7 and 8, along with regular monitoring and adjustments, to ensure sustainable and efficient aquaculture production [2].

Another research indicates that maintaining dissolved oxygen levels between 5 and 7 mg/L is crucial for optimal growth, feed intake, and survival of tilapia. Result indicates that tilapia thrive in waters with oxygen levels above 5 mg/L, supporting efficient respiration and overall health. In contrast, reported that oxygen levels below 4 mg/L lead to reduced feed intake and slower growth rates [3], while another study observed that low oxygen levels significantly decrease the growth and survival of tilapia fingerlings. These findings highlight the importance of effective aeration and water quality management to maintain adequate oxygen levels and promote healthy development in tilapia aquaculture [4] .

Another system offers several strengths, including the ability to monitor water temperature, level, pH, and TDS, while also automating the control of pumps, motors, heating, cooling, and water filling. It operates as a closed-loop system that makes automated decisions when threshold values are reached, but also allows farmers to manage processes manually. The system integrates sensors, a cloud platform, a mobile app, and control devices, all at a low cost of 4500 BDT. However, there are some weaknesses, such as the lack of monitoring for Dissolved Oxygen (DO), Electrical Conductivity (EC), and Ammonia levels. Additionally, the system does not incorporate a self-sustaining renewable energy power solution [5].

A study on the use of Biofloc Technology (BFT) in shrimp farming explores its effects on water quality, shrimp health, and overall productivity. BFT systems effectively reduce Total Ammonia Nitrogen (TAN) through microbial processes, improving water quality and minimizing toxicity. The research delves into the microbial dynamics within biofloc systems, highlighting the role of beneficial bacteria and other microorganisms in nutrient recycling and the creation of microbial biomass, which serves as an additional food source for shrimp. This contributes to faster shrimp growth, higher survival rates, and lower feed costs. The system also strengthens disease resistance by boosting the shrimp's immune response, resulting in healthier animals and enhanced farm productivity. Furthermore, BFT reduces environmental impact by minimizing waste discharge and water exchange, offering a more sustainable and cost-effective approach to shrimp farming. [6].

The study examines how Biofloc Technology (BFT) can enhance water quality, promote shrimp growth, and minimize environmental impact. It highlights the crucial role of microbial communities within BFT systems, particularly the beneficial bacteria that assist in nutrient

recycling and ammonia removal, thereby improving water conditions. This process not only supports shrimp health and survival but also offers a cost-effective approach by decreasing the need for water exchange and reducing feed costs. Furthermore, the paper underscores BFT's environmental sustainability, as it helps limit waste discharge into surrounding ecosystems. Overall, the study demonstrates the potential of BFT as an effective and sustainable farming method, with significant benefits for the shrimp aquaculture industry. Positive results were observed in shrimp farming through the implementation of biofloc technology, which involved monitoring essential water quality parameters [7].

A novel system was designed to monitor and regulate key water quality parameters in aquaculture, including temperature, pH, dissolved oxygen, water level, foul odor, and ammonia concentrations. This system incorporated an Arduino microcontroller, which served as the central processing unit to collect and analyze data from various sensors installed in the water. The sensors continuously monitor the environmental conditions in real-time, ensuring that water quality remains within optimal ranges for aquatic life. The Arduino microcontroller processes the data received from the sensors and makes necessary adjustments to maintain ideal conditions. For communication and remote monitoring, the system is integrated with a GSM modem, enabling real-time transmission of data to the system operators or aquaculture managers via mobile phones or computers. This allows for instant notifications of any critical changes, such as abnormal temperature fluctuations, increased ammonia levels, or a decrease in dissolved oxygen, which could affect the health of the aquatic species. In addition to providing valuable data for immediate action, the system also enables remote access, reducing the need for constant physical presence in the facility. This is especially useful for large-scale aquaculture operations, as it helps ensure that water quality parameters are consistently monitored and controlled without the need for manual interventions. Overall, this technology improves the efficiency and sustainability of aquaculture practices by offering a more automated, precise, and responsive approach to water quality management. [8] .

Several papers propose an IoT-based solution to improve efficiency and productivity in aquaculture. It presents a system that collects data from sensors (pH, temperature, TDS), analyzes it using machine learning, and makes decisions with the help of AI, sending notifications to users [9]. Another paper proposed solar powered system that will monitor the parameters along with IOT [10].

A review paper highlighted that water quality monitoring could reduce stress, improve biosecurity, and potentially lower the occurrence or severity of pathogens, [11] while several studies also emphasized the benefits of fish farming and its alignment with Sustainable Development Goals (SDGs) [12] [13].

While these systems monitor key parameters, they are unable to control them directly, requiring manual intervention for parameter adjustments. One of the papers proposed an automated system designed to maintain optimal water temperature using an Arduino-controlled heater [14].

An additional system integrated an automatic fish feeder powered by a peristaltic pump to enhance feeding efficiency [15].

The proposed solution in this paper will not only monitor but also control key parameters. Furthermore, the system will be powered by a solar panel. However, controlling TDS is not feasible with this system, as reducing TDS requires methods like water changes or Reverse Osmosis (RO) filtration [16].

Studies highlight the importance of monitoring water temperature, pH, and dissolved oxygen for optimal tilapia growth. The optimal water temperature for Nile tilapia is 28-30°C, pH should be between 6.5 and 8.5, and dissolved oxygen levels must remain between 5-7 mg/L. The proposed system in this paper not only monitors but also controls key parameters, and is powered by solar energy for improved sustainability.

## **2.3 Methods**

The rising demand for fish consumption, driven by global population growth, has placed increasing pressure on aquaculture systems to maximize productivity. Ensuring optimal water quality is critical to reducing fish mortality and rising yields. This study aims to develop an automated system to monitor and control key water quality parameters, including pH, temperature, total dissolved solids (TDS), and dissolved oxygen (DO), to create an environment conducive to the healthy growth of tilapia, the species chosen for this experiment.

### *2.3.1. Data Collection and Literature Review*

The first phase of the research involves a comprehensive literature review to collect secondary data on the optimal water conditions required for tilapia. Tilapia is chosen due to

its widespread use in aquaculture, high tolerance to varying environmental conditions, and its ability to thrive in a range of water qualities. These traits make tilapia an ideal species for testing water quality control systems. Scientific articles, aquaculture reports, and previous studies are examined to determine the appropriate thresholds for parameters such as pH, temperature, TDS, and DO. This secondary data will provide baseline survival and growth conditions for tilapia, which will serve as a reference for designing the control mechanisms in the system.

### *2.3.2. System Design and Sensor Integration*

Based on the findings from the literature review, an automated water quality monitoring system will be designed to measure and control the critical parameters. The system will use sensors connected to an **Arduino microcontroller** to monitor water quality in real time. The following sensors will be integrated:

- **pH Sensor:** Monitors the acidity or alkalinity of the water.
- **Temperature Sensor:** Measures the water temperature, ensuring it stays within the optimal range for tilapia.
- **Total Dissolved Solids (TDS) Sensor:** This sensor tracks the concentration of dissolved solids, providing an indicator of overall water quality.
- **Dissolved Oxygen (DO) Sensor:** This sensor measures the amount of oxygen dissolved in the water, a crucial factor for tilapia's survival.

The sensors will be calibrated to standard units for end users (farmers) to ease interpretation and ensure that the data collected is accurate and actionable.

### *2.3.3. Data Monitoring and Parameter Control*

Once the system is operational, the Arduino will act as the central hub for processing sensor data. The collected data will be continuously analyzed to ensure that water quality parameters remain within the predefined thresholds identified during the literature review for tilapia. If any of the monitored parameters deviate from the optimal range, the system will automatically trigger control mechanisms to correct the imbalance. The following devices will be used to adjust water conditions:

- **Aerator:** Increases the concentration of dissolved oxygen if levels fall below the required threshold.

- **Buffer Ejector:** Adjusts the pH by adding chemicals to balance the water's acidity or alkalinity.
- **Heater:** Maintains the water temperature within the desired range. Since the system is designed for Bangladesh, where a cooler is not typically required due to the country's warm climate, only a heater will be used to maintain optimal temperatures.

These control mechanisms will be pre-programmed into the Arduino's code, ensuring that the system responds immediately and automatically to any fluctuations in water quality.

#### *2.3.4. System Testing and Data Analysis*

Data analysis will be conducted once the design is complete and the system is deployed in a practical aquaculture setup. Tilapia will be used as the test species, and sensor readings will be monitored over time. The choice of tilapia is strategic, as it is one of the most farmed fish species globally, known for its adaptability to varying water conditions. Tilapia's resilience makes it an ideal subject to test the efficiency and precision of the monitoring and control system. The system's effectiveness will be measured by tracking the growth and health of the tilapia, with a specific focus on metrics such as **fish size** and **mortality rate**. Fish yield, measured by size, will be compared with the system's control of water quality parameters to assess how well the system maintains optimal conditions and its impact on productivity.

#### *2.3.5. Solar-Powered Sustainability*

To make the system environmentally friendly and accessible in off-grid or remote locations, the entire system will be powered by **solar energy**. Solar panels will supply power to the sensors, Arduino controller, and associated devices (aerator, heater, and buffer ejector). This renewable energy source ensures that the system remains operational even in areas with limited access to electricity, promoting sustainability and reducing operational costs for fish farmers. By harnessing solar power, the proposed system aims to provide a sustainable solution for aquaculture, reducing the environmental footprint of fish farming while improving its productivity.

### **2.4 Summary**

A final evaluation will be conducted after completing the system design, deployment, and testing phases. The system's success will be measured based on its ability to maintain water quality parameters within the optimal range for tilapia, reduce fish mortality, and improve

overall fish yield. Comparisons will be drawn between the outcomes of the system-controlled environment and manual monitoring and control practices in aquaculture. Additionally, the system's ability to function reliably in off-grid locations, powered solely by solar energy, will be critically assessed to ensure long-term sustainability and scalability.

### 3. System Design

#### 3.1 System Overview (Model Block Diagram)

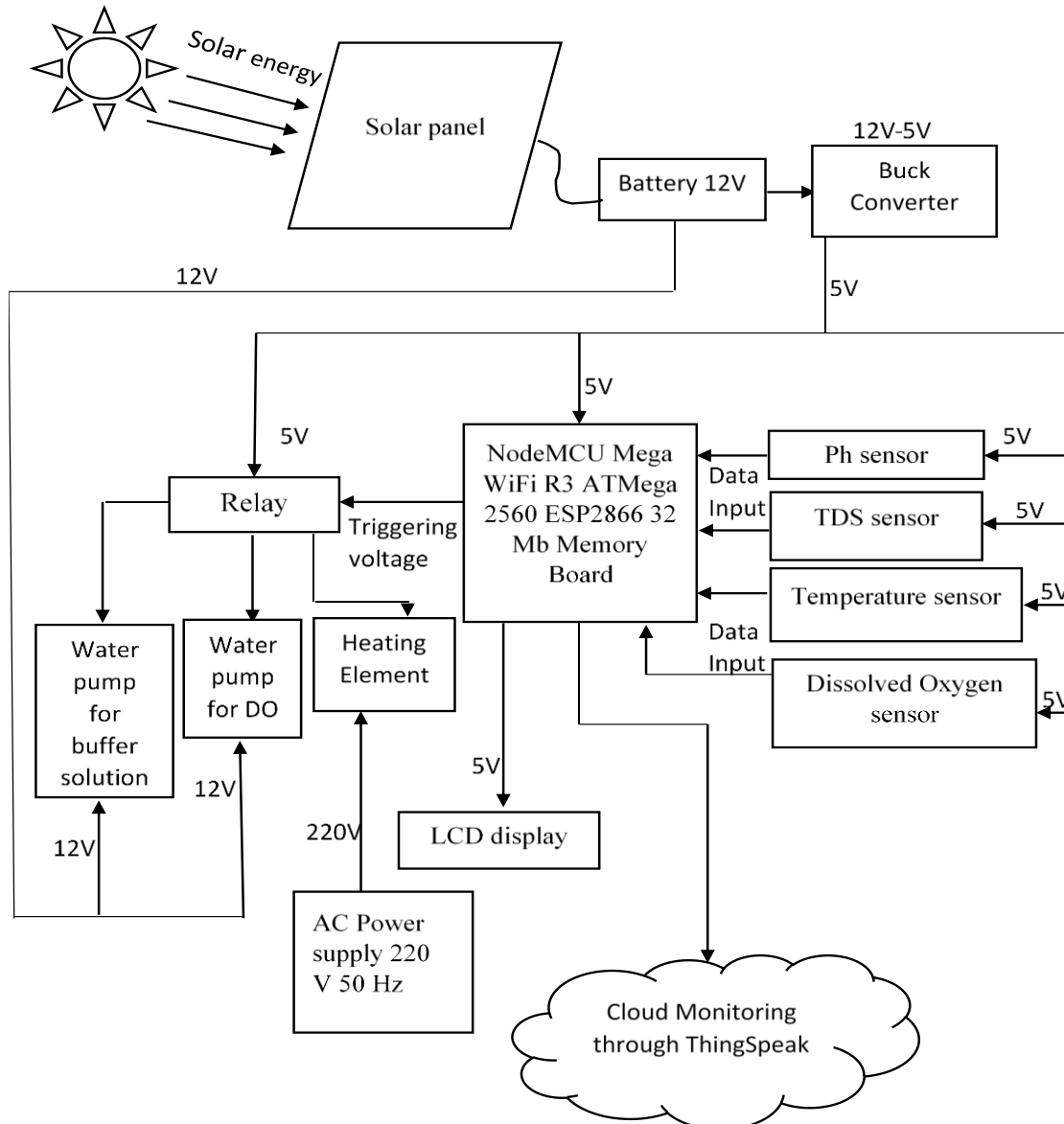


**Fig 3.1: Model Block Diagram**

The figure 3.15 shows the block diagram for the bio floc system that was designed to monitor and control parameters for fish farming. The whole system is runed by renewable energy with just one exception. Firstly, the 20-watt solar panel is being charged by the solar energy, which then charged up a 12 V battery. The bio floc system primarily is runed by 12V and 5V supplies. A buck converter is used to step down 12 V DC voltage from the battery to 5V. 5V

supply is required to run our sensors, LCD, microcontroller, and trigger our relay switches. Secondly, the buck converter supplies the 5V to turn on the pH sensor, temperature sensor, TDS sensor, and Dissolved Oxygen sensor. The sensors turn on and send the data to the microcontroller Arduino, which is also powered up by 5V from the buck converter. The Arduino reads the data and supplies a trigger voltage of 5V to the relay switch according to the conditions provided. The buck converter powers the relay. Arduino also powers up an LCD with a 5V supply to monitor the water parameters on site. Lastly, the control system is run directly by a 12V supply from the battery. The battery powers up all the controllers through a relay switch. When the conditions provided are not matched the parameters controllers are powered up including a 12V DC water pump to eject buffer solution for pH control and a 12V DC water pump is used as an aerator to control the dissolved oxygen percentage in water. The whole Bio floc system is run by solar energy generated power except for the heating element which is run by AC power. A 500-watt AC-powered heater is used to control the temperature of the water for fish farming, as it provides sufficient power to regulate the water temperature during the experiment. The use of a DC heater was not considered, as DC heating elements typically require larger current draws and complex voltage regulation systems, which could add unnecessary complexity and inefficiency to the design. In contrast, AC heating elements are more efficient and easier to control with standard relays. A Node MCU Mega Wi-Fi R3 ATmega 2560 ESP2866 32Mb memory board has been used as a controller here, which has ESP 8266 integrated into it, so no additional power is required for cloud monitoring.

## **3.2 Hardware Requirements**

### *3.2.1 PH Sensor*

The PH4502C sensor is designed to measure pH values within the range of 0 to 14, making it suitable for a wide range of applications in laboratory and industrial environments. The sensor's circuitry requires precise calibration through a potentiometer, while a buffer solution is employed for fine calibration to ensure accurate readings. To achieve reliable results, the probe must be handled with care to prevent contamination between liquids, as this can lead to significant inaccuracies in the pH readings. Additionally, the sensor's performance can be affected by factors such as temperature and ionic strength of the solution being tested, necessitating careful environmental control during measurements.



**Fig 3.2: PH4502C Sensor**

### *3.2.2 Temperature Sensor*

The DS18B20 is a digital, one-wire temperature sensor capable of measuring water temperature with an accuracy of  $\pm 0.5^{\circ}\text{C}$ . This sensor is equipped with a unique 64-bit serial code, which enables the use of multiple DS18B20 sensors on a single 1-Wire bus. This feature allows for easy integration and control of many DS18B20 sensors by a single microprocessor, even when they are distributed over large areas. The DS18B20's one-wire interface simplifies wiring and reduces the number of required connections, making it ideal for applications where space and wiring complexity need to be minimized.



**Fig 3.3: DS18B20 Temperature Sensor**

### *3.2.3 Total Dissolved Solids (TDS) Sensor*

The TDS (Total Dissolved Solids) sensor is used to measure the concentration of soluble solids in water, typically expressed in parts per million (ppm) or milligrams per liter (mg/L). The sensor's electrodes detect conductive particles, such as metals and ions, that are dissolved in the water. A low TDS value typically indicates cleaner water, while a higher TDS value suggests the presence of more dissolved solids, potentially affecting water quality. According to water quality standards, a TDS value above 300 ppm generally indicates poor

water quality, while values below 300 ppm are considered acceptable for most uses. Drinking water usually has a TDS value around 150 ppm, which is considered optimal for human consumption.



**Fig 3.4: TDS Sensor**

#### *3.2.4 Dissolved Oxygen (DO) Sensor*

The gravity-analog Dissolved Oxygen (DO) sensor measures the concentration of dissolved oxygen by detecting the amount of oxygen that diffuses through a permeable membrane and undergoes a chemical reduction reaction. To ensure accurate readings, the sensor's membrane cap requires the addition of a 0.5 mol/L NaOH solution, which helps maintain the correct chemical environment for the reaction. The DO sensor has an oxygen detection range from 0 to 20 mg/L, making it suitable for a variety of water quality applications, such as monitoring aquatic ecosystems and industrial processes. Notably, the galvanic probe used in this sensor eliminates the need for polarization time delay, allowing for faster and more reliable measurements of oxygen levels in the solution. This feature ensures that the sensor delivers real-time, continuous data, which is particularly useful in dynamic environments where oxygen levels fluctuate rapidly.

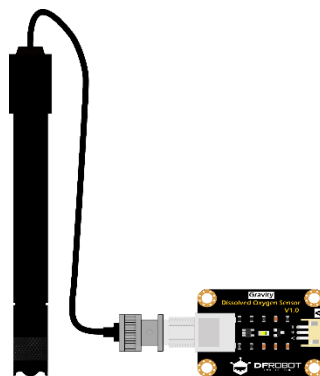


**Fig 3.5: DO Sensor**

### 3.2.5 NodeMCU Arduino

The NodeMCU Arduino ATmega 2560, combined with the WiFi-enabled ESP8266 R3 microcontroller, is responsible for receiving numerical data from the connected sensors and processing it accordingly. The processed data is then displayed on an LCD screen for user interaction, while the microcontroller also sends control signals to manage devices, turning them on or off as required. Compared to the Arduino Uno, the NodeMCU ATmega 2560 offers significant advantages, including a larger number of I/O pinouts and greater memory capacity, making it better suited for handling more complex tasks, especially in projects with multiple sensors and actuators. Additionally, the microcontroller features a higher processing speed, which ensures faster data processing and responsiveness. The integrated ESP8266 WiFi module allows the microcontroller to transmit sensor data to the IoT cloud platform, such as ThingSpeak, enabling remote monitoring, data logging, and real-time analysis. This wireless connectivity allows users to access the data from any location, further enhancing the versatility and convenience of the system.



**Fig 3.6: Arduino mega AT2560 + WiFi ESP8266**

### 3.2.6 Aerator Pump

An air pump is used to introduce air bubbles into the water, supplying oxygen necessary for maintaining adequate levels of dissolved oxygen. This process facilitates gas exchange, allowing carbon dioxide to leave the water while oxygen enters, which is essential for the survival of aquatic organisms. By ensuring proper oxygenation, the air pump helps maintain a healthy environment for fish and other aquatic life. A 12-volt DC air pump is employed for this task, and its operation is controlled via a relay, which turns the pump on and off as needed. The relay is managed based on an algorithm that continuously monitors the dissolved oxygen concentration, ensuring that it remains above the minimum threshold required for

optimal aquatic life. If the oxygen levels fall below the defined value, the relay activates the pump to restore the oxygen concentration. Additionally, the system can be fine-tuned to adjust the air pump's operation based on environmental factors such as water temperature, which may affect oxygen solubility.



**Fig 3.7: Aerator Pump**

#### *3.2.7 Buffer Ejector*

A 12-volt water pump, connected to a reservoir tank and a spray nozzle, is designed to inject a buffer solution into the system when the pH levels are detected to be outside the predefined range. The **bicarbonate buffer solution** is commonly used in fish culture systems to help maintain pH stability. This buffer works by neutralizing both hydrogen ions ( $H^+$ ) and hydroxide ions ( $OH^-$ ), ensuring that the pH remains within the optimal range for aquatic life. The bicarbonate buffer is ideal for maintaining stable water conditions, as it closely mirrors the natural buffering systems found in freshwater and marine environments. By preventing drastic pH fluctuations, the buffer helps to create a stable environment, which is critical for fish health and overall water quality. The pump is automatically activated when the pH exceeds the set thresholds, injecting the appropriate amount of buffer solution to restore balance. Through real-time monitoring and automatic adjustments, the system ensures that the water's pH stays within the optimal range for fish culture.



**Fig 3.8: Sodium Bicarbonate Buffer Solution**

### *3.2.8 Water Heater Coil*

An AC water heater will be employed to maintain the water temperature within the optimal range for fish growth, preventing it from falling below the required conditions. The heater plays a crucial role in ensuring that the temperature remains stable, as it is the only component in the system powered by AC, emphasizing its importance in maintaining precise control. A 100-watt heater coil has been selected, as it provides sufficient power to regulate the water temperature during the experiment. The use of a DC heater was not considered, as DC heating elements typically require larger current draws and complex voltage regulation systems, which could add unnecessary complexity and inefficiency to the design. In contrast, AC heating elements are more efficient and easier to control with standard relays. The operation of the water heater is controlled by a relay, which is triggered by the Arduino microcontroller based on temperature readings. When the temperature drops below the defined threshold, the microcontroller activates the relay, turning on the heater coil to restore the desired temperature. This process is continuously monitored, ensuring that the system responds quickly to any temperature fluctuations, which is essential for the optimal health and growth of the fish.



**Fig 3.9: Water Heater Coil**

### *3.2.9 Solar Panel*

This solar panel is a high-efficiency photovoltaic module designed for reliable power generation in a variety of applications. It has a maximum power output of 20 watts, with an open circuit voltage of 22.4 volts and a short circuit current of 1.23 amperes. When operating at its peak, the panel delivers 17.4 volts at maximum power voltage and 1.15 amperes at maximum power current. Its compact size, measuring 490 mm by 350 mm by 25 mm, makes it ideal for installations where space is limited, and its light weight of 1.3 kg adds to its portability. Rated for an irradiance of  $1000 \text{ W/m}^2$  and designed to function at an air mass (AM) of 1.5, it operates efficiently under standard conditions of  $25^\circ\text{C}$ . With Grade A cells, this solar panel ensures long-term performance and high reliability, making it suitable for applications such as charging devices, powering small appliances, or serving as part of a larger off-grid solar system.



**Fig 3.10: Solar Panel**

### 3.2.10 Solar charge controller

A 20A solar charge controller will be utilized to regulate the charging of a 12-volt battery from the solar panel. The charge controller ensures efficient energy transfer by regulating the flow of electricity from the solar panel to the battery, preventing damage caused by overcharging. It maintains a constant voltage and current supply, which not only safeguards the battery from potential damage but also optimizes the charging speed for maximum efficiency. The controller typically features a built-in MPPT (Maximum Power Point Tracking) or PWM (Pulse Width Modulation) algorithm, depending on the model, which maximizes energy harvest from the solar panel. By continuously monitoring the battery's charge level and adjusting the power delivered, the controller ensures that the battery is charged at the optimal rate without overcharging or deep discharging, both of which can shorten battery life. Additionally, the controller protects against other potential hazards such as reverse polarity, short circuits, and overcurrent, providing an extra layer of safety for the entire system. This protection mechanism not only extends the lifespan of the battery but also ensures a reliable and stable power supply for the system, especially in off-grid applications.



**Fig 3.11: Solar charge controller**

### 3.2.11 Buck converter

The LM2596 DC-DC buck converter will step down the 12-volt battery supply to 5 volts for powering sensors, Arduino Mega, and other pieces of equipment. The adjustable potentiometer must be adjusted to set the output at 5 volts precisely.



**Fig 3.12: Buck Converter**

### 3.2.12 Battery

A 12-volt 1.3 Ah lead-acid rechargeable battery supplies power to the whole system, excluding the water heater coil. The battery is sufficient to meet the system's power requirement while maintaining a compact size.



**Fig 3.13: 12-volt battery**

### 3.2.13 Relay

A 4-channel relay board with 5 volts and 12-volt trigger options will allow access to switching up to 250 VAC and 30 VDC of 10 Ampere current. The relay board will have 5 bolt trigger inputs from the Arduino. It will act as the switch for the water heater coil, buffer ejector, and Aerator pump.



**Fig 3.14: 4 Channel Relay**

### 3.3 Control Unit

The controlling unit design manipulates three essential factors for enhanced fish survival and growth. Temperature, pH, and dissolved oxygen control have been proposed in this design. The data from the sensors will be used as feedback for biasing the controlling components of the three factors as per requirement.

### 3.3.1 Algorithm

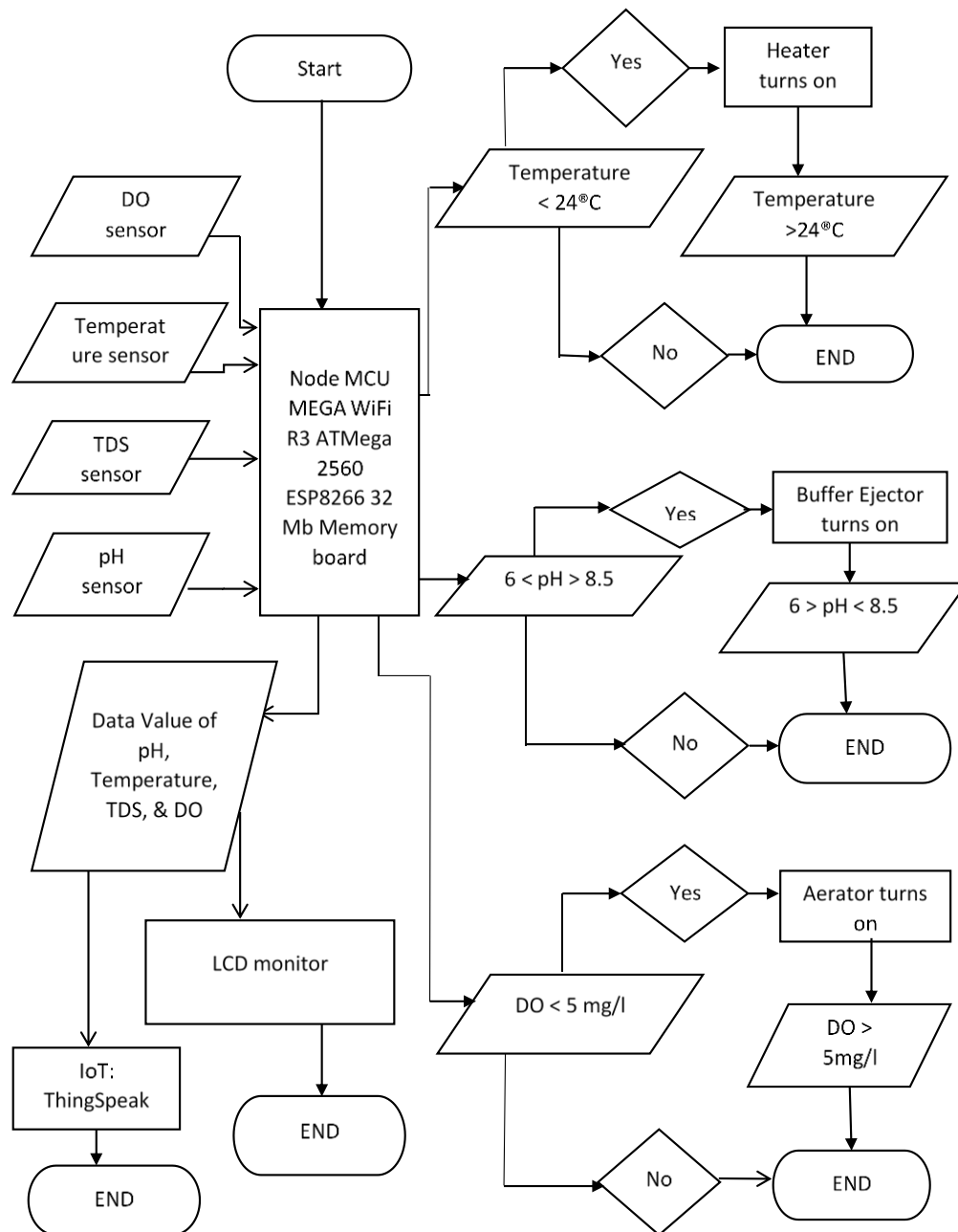


**Fig 3.15: System Algorithm**

The figure 3.15 shows the algorithm for the Biofloc system to monitor and control water quality for fish farming. Initially, the controller Arduino and the sensors power up, and the sensors start sending the data to the Arduino every 20 seconds. The Arduino then reads the data and takes necessary actions required according to the conditions provided to it, which are as follows, for the temperate reading if the temperature is less than 24°C then the heating element is turned on, and it heats the water until it is greater than 24°C and turns off once the

temperature reached its condition provided value. For the pH reading if the pH is less than 6 and greater than 8.5 the buffer ejector turns on and continues to eject buffer solution until the pH reading is greater than 6 and less than 8.5. For the dissolved oxygen reading if the dissolved oxygen is less than 5 mg/L the aerator turns on and keeps running until the dissolved oxygen reaches a greater value than 5mg/l. For onsite monitoring, a LCD is provided, which shows the pH, temperature, TDS and DO values. For remote monitoring, the integrated ESP8266 in the Arduino board sends data to ThingSpeak.

## **Chapter 4: Results & Discussion**

### **4.1 Experimental Setup**

To develop a bio floc system running completely on renewable energy solar energy was chosen as the equipment to transform solar energy into electrical power is easily available and easy to use. A solar panel of 20 watts is used to charge a 12 V battery to run the whole system of bio floc through a solar charge controller. It takes 1.56 hours for the solar panel to completely charge the battery. The system consists of various sensors and parameter control equipment, which primarily runs on 12 V and 5V. A buck converter is used to step down 12 V from the battery to 5 V to run the sensors, relay, and Arduino. The 12V supply is used to run the buffer ejector and aerator.

For monitoring the water quality 4 parameters are monitored in this system, which are as follows: pH, temperature, TDS, and DO. To monitor the following parameters 4 sensors are used, which are as follows: pH sensor (PH4502C), temperature sensor (DS18B20), TDS sensor, DO sensor, and LCD. A 5 Volt power supply by a buck converter powered all these sensors. To monitor the parameters on site we are using a 16×2 I2C LCD and for remote monitoring we are using the Arduino board with integrated ESP 8266 (Node MCU Mega WiFi R3 ATmega 2560 ESP2866 32 Mb Memory Board), which sends all monitored parameter values to Mathworks -ThingSpeak.

All of the sensors were calibrated and verified before they were used to monitor the parameters of the water.

The pH sensor probe is dipped in the water for reading data. A pH meter was used for calibration and verification of a pH sensor. Firstly, a buffer solution of known pH 6.86 at 25 °C was used and measured appropriately with a pH meter. Secondly, the probe was submerged into the solution and the variable resistor of the pH sensor was varied until the desired reading was seen in the serial monitor of Arduino IDE. Lastly, a buffer solution of known pH 4.01 at 25 °C was used to verify the sensor functionality, and the reading was taken successfully for the verification of calibration for the pH sensor.



**Fig 4.1: pH Determined Buffer Solution & pH meter**

The temperature sensor did not require calibration but was verified using a thermometer. A thermometer was submerged into the water and the reading was recorded before the sensor probe was submerged. After that, the probe was submerged and the reading from the sensor was recorded and matched with the temperature reading from the thermometer for calibration.

A TDS meter was used to confirm that the TDS sensor did not need to be calibrated. Before the sensor probe being submerged, a TDS meter was immersed in the water and the reading was noted. Following the probe's submersion, the sensor's measurement was recorded and compared to the TDS reading from the TDS meter to calibrate it.



**Fig 4.2: TDS & Thermometer**

For the calibration of the DO sensor single point calibration method was used. Firstly, we need to prepare the probe by using a 0.5 mol/L NaOH solution as the filling solution for a new dissolved oxygen probe. To fill the membrane chamber with NaOH, unscrew the membrane cap and fill it about 2/3 full with NaOH solution. Keep the probe vertical while screwing the cap back to avoid bubbles and a small overflow of the solution is acceptable but avoid overfilling to minimize excess overflow. It is required to close the NaOH-filled membrane cap should be closed tightly after filling to prevent air from affecting the solution. Secondly, to carry out the single-point calibration, wet the probe in pure water and shake off

excess water drops. After that, expose the probe to maintain proper airflow wait for the output voltage to be stable, and record the voltage reading once it is stabilized. This is the saturated dissolved oxygen voltage at room temperature. After recording the voltage from the air, prepare a cup of purified water to make saturated oxygen water by using an eggbeater to continuously stir for 10 minutes to saturate the dissolved oxygen. Once it is done stop stirring the water and put the probe after the bubbles disappear. After placing the probe, keep stirring slowly while avoiding any bubbles and once the output voltage is stable, record the temperature and voltage. Lastly, use the sample code provided for single-point calibration with a baud rate of 115200. Upload the code and observe the serial monitor for the DO reading at the current temperature.

After the calibration and verification process is done, sensors are ready to function for the monitoring system. The pH sensor reads the pH values, the temperature sensors read the temperature values, the TDS sensor reads TDS values, and the DO sensor reads the dissolved oxygen of water. Arduino then reads the data and displays the current parameter readings on the LCD for on-site monitoring. Arduino also uploads the current parameter readings to ThingSpeak for remote monitoring through the integrated ESP8266 in the board.

Fish farming requires good control of the parameters of water for the fish to be healthy and enhance the water quality. To control the parameters, a buffer solution of sodium bicarbonate with a pH of 8 was used. After reading the data from the pH sensor, if the reading is out of the range from the predefined pH value being  $6 < \text{pH} < 8.5$ , then the Arduino sends a triggering voltage of 5V to the relay switch and turns on the water pump working as a buffer ejector to eject buffer solution and control the pH value until it is in the predefined range. Secondly, a 12V water pump is used as an aerator to control the dissolved oxygen, which turns on when Arduino reads the data from the DO sensors and the dissolved oxygen of water is less than the predefined value, which is  $\text{DO} < 5 \text{ mg/l}$  and sends a 5V triggered voltage to the relay switch. Lastly, the temperature is controlled by a water heater coil, which is powered by a 220 V AC supply and turns on by a triggering voltage of 5V from the Arduino to the relay switch when the Arduino reads an out-of-range value from the predefined range value being  $\text{Temperature} < 24^\circ\text{C}$  from the temperature sensor.

We are not controlling the TDS parameter for our design as TDS has a steady or longer effect on the tank water due to the smaller number of fish used for experimentation.

A 120-liter fish tank was filled with water and an area in the tank was enclosed by submerging a net for the sensor probes and control system equipment to avoid fish coming in contact with the probes and other equipment. Considering the practical situation when the water heater coil and buffer ejector are turned on, the aerator is programmed to turn on in parallel to disperse evenly and bring the water temperature and pH under equilibrium at a quicker rate.

## 4.2 Experimental Results

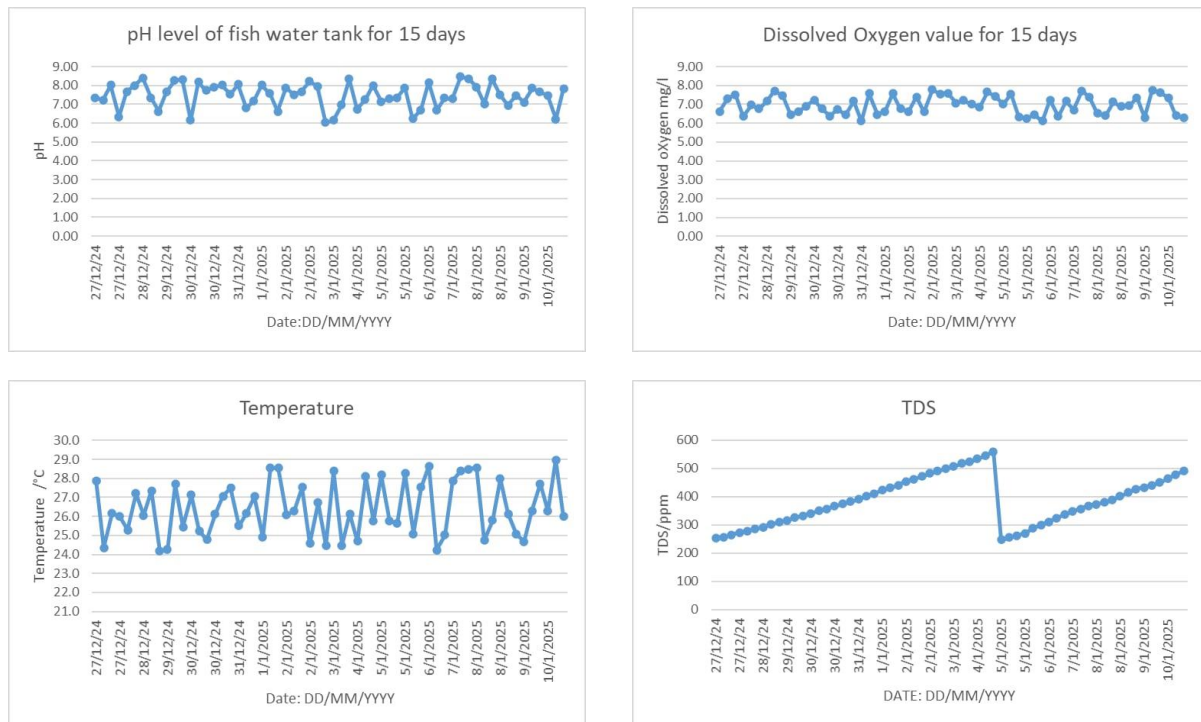


**Fig 4.3: Graphical representation of water quality parameters during Tilapia farming**

A 5-day test run was conducted to avoid any malfunction or disruption before recording data from the onsite monitoring system such as failure of the temperature probe. Figure 4.3 shows the controlled parameters for 15 days during Tilapia farming. All of the readings above were monitored at 6-hour regular intervals through the onsite monitoring system LCD. The data were recorded and graphs were plotted for each parameter. The monitoring system has shown dynamic sets of data with respect of time and the controlling system functioned accordingly to counteract any outlier condition of water in the tank for optimal fish growth. Lastly, the TDS was monitored but not controlled using any automatic system. When the TDS value of the water exceeded the normal range of 550 ppm, the water was changed manually to keep the ideal condition in range. To check the mortality rate of the fish, two tanks were filled up with 10 fish each aging approximately 1 month old. The first tank was monitored and

controlled by conservative knowledge and the fishes lived only for a couple of days. On the other hand, the second tank with solar powered monitoring and control system had only one casualty in 20 days and the rest survived as long as the experiment lasted.

### **4.3 Cloud Monitoring**

The integration of Internet of Things (IoT) technology with remote embedded systems has revolutionized the monitoring of environmental parameters, particularly in water quality assessment. By embedding sensors in water sources, real-time data on critical parameters such as pH, turbidity, temperature, and dissolved oxygen can be remotely collected, analyzed, and accessed, facilitating better decision-making in water management.

In this study, the ThingSpeak IoT cloud platform is utilized for data collection, storage, and visualization. ThingSpeak stands out due to its open-source, flexible, and scalable architecture, making it ideal for both small- and large-scale environmental monitoring projects. The platform's unique ability to aggregate data from a diverse range of sensors and present it through customizable, real-time graphical visualizations enables researchers to monitor water quality with ease. The intuitive interface simplifies data interpretation, offering a clear view of water conditions at a glance.

One of the defining features of ThingSpeak is its live data streaming capability, which allows for the continuous transmission of sensor data, ensuring up-to-the-minute updates on water quality parameters. This real-time functionality is important for detecting and addressing rapid changes in water conditions, such as those caused by pollution events or environmental disturbances. Additionally, ThingSpeak's alerting system is highly configurable; users can set threshold-based notifications for specific parameters, ensuring timely alerts when water quality deviates from predefined acceptable limits. Alerts are sent via email or SMS, providing immediate notifications to stakeholders for prompt action.

The platform's scalability and compatibility with a wide range of sensors further enhance its utility. ThingSpeak supports the deployment of numerous sensor nodes across large geographic areas, allowing for the comprehensive monitoring of multiple water sources simultaneously. Its ability to handle large datasets and integrate with external services, such as MATLAB for advanced analysis, adds to its uniqueness and versatility in research and practical applications.

Data collection on Thingspeak of pH, temperature, TDS, and DO was initiated while conducting a control unit functionality test. Therefore, changes beyond the desired range have been observed in graphical representation. The figure 4.4 shows a demonstrative data record on the field charts for remote monitoring.

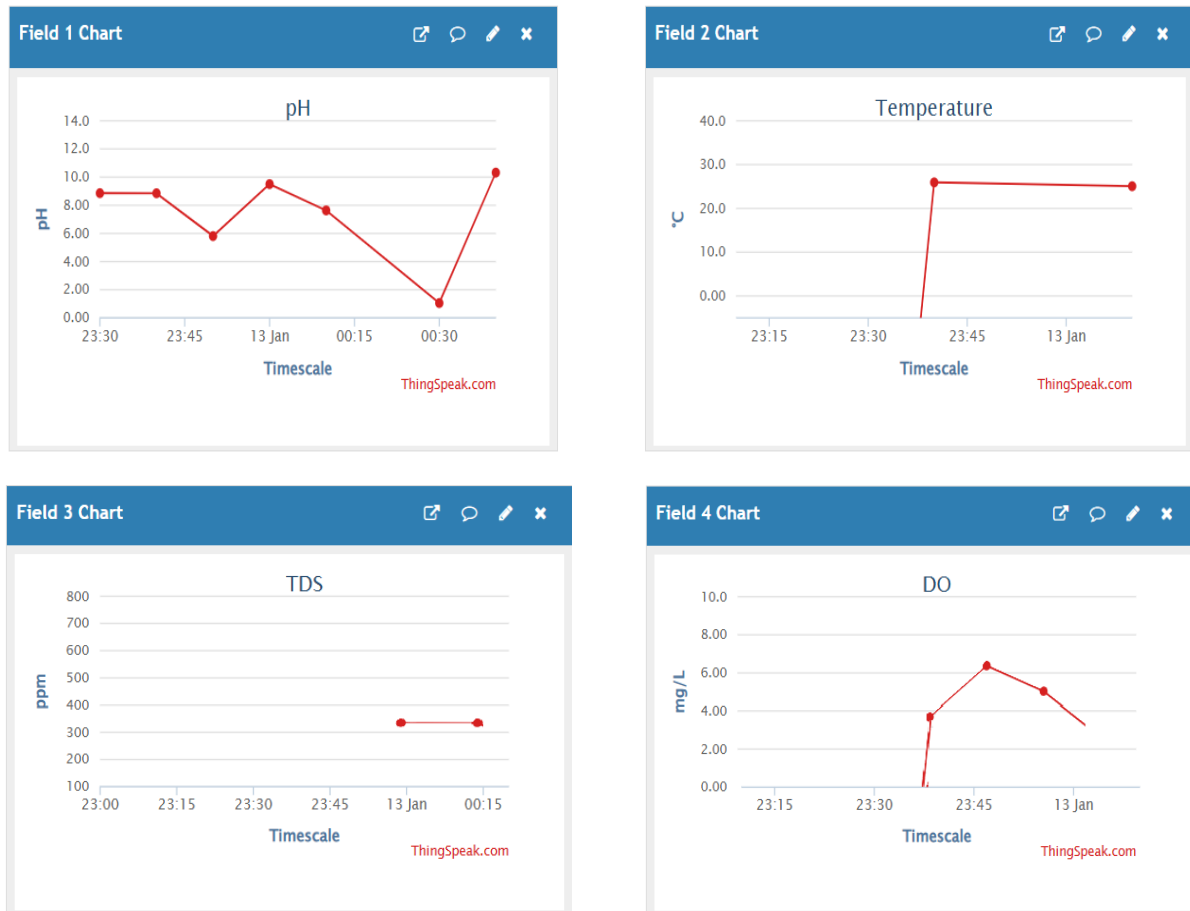


**Fig 4.4: IoT Monitoring system data: ThingSpeak**

In conclusion, ThingSpeak offers a robust solution for remote, real-time water quality monitoring, with features such as live data streaming, customizable alerts, and seamless scalability. Its open-source nature, coupled with ease of integration and use, makes it an invaluable tool for both academic research and environmental management.

#### 4.4 Discussion

The results of this experiment indicate a successful overall maintenance of water quality within the fish tanks. The key parameters for water quality consistently stayed within acceptable ranges, with only occasional instances of anomalous spikes. These spikes triggered the control system to engage and correct the conditions. The system's response was effective in managing these deviations and maintaining stable water quality.

One of the key challenges observed was with the TDS sensor, which exhibited a delayed initialization time before providing accurate readings. Additionally, occasional fluctuations in the pH readings, causing brief activation of the control system were observed. However, despite these fluctuations, the system was able to present major numbers of correct readings, ensuring that the pH remained within the optimal range for fish health. The temperature sensor, on the other hand, demonstrated a high level of stability and accuracy throughout the experiment. The only issue observed was a loss of connection between the probe and the sensor circuit, likely due to the lower-quality construction of the components. While this did not lead to significant data inaccuracies, it occasionally required troubleshooting to restore full functionality.

The Total Dissolved Solids (TDS) readings showed little to no variation, suggesting that the tank's filtration and water renewal systems were functioning as expected without introducing significant changes in water composition. The dissolved oxygen (DO) levels, however, proved to be the most critical parameter. The DO concentration regularly dipped below 6 mg/L, which triggered the aerator to activate and bring the levels back up to the desired threshold. The control system effectively managed this, ensuring that oxygen levels remained optimal for the well-being of the aquatic life.

In conclusion, the experimental system performed well in maintaining water quality, with minor issues that were promptly addressed, allowing for consistent environmental conditions.

## **Chapter 5: Conclusion**

### **5.1 Limitations**

The proposed design aims to assess the impact of environmental conditions on tilapia survival in an enclosed system. During experimentation and data collection, it was noted that the sensors occasionally displayed anomalous readings. This discrepancy suggests that the use of low-cost components may compromise measurement accuracy. Additionally, the system has been specifically configured to monitor and regulate parameters suited to tilapia. As a result, it is not possible to cultivate other fish species without first modifying the software to accommodate the unique requirements of different species.

Furthermore, direct salinity measurements were not incorporated into the system. Instead, past research has demonstrated a strong correlation between total dissolved solids (TDS) and water salinity, allowing TDS sensors to demonstrate salinity content approximation in water. The system currently supports one-way temperature control through heating, as the climate in Bangladesh typically remains within the optimal temperature range for tilapia survival. However, additional cooling mechanisms will be necessary in hotter climates to maintain suitable water temperatures.

### **5.2 Scope of Further Developments**

The "Solar-Powered Water Quality Monitor and Control System for Fish Farming" offers significant potential for expansion and commercial application. Future developments could include the integration of advanced algorithms and machine learning to automate parameter adjustments, making the system adaptable to various fish species and farming environments. IoT capabilities could be extended to include cloud-based data storage and analytics, enabling remote monitoring, predictive maintenance, and data-driven decision-making.

The system could also incorporate high-accuracy sensors for precise water quality monitoring, with future sensor advancements reducing hardware complexity. Adaptive thermal management solutions would optimize energy use, ensuring temperature regulation in diverse climates.

Improvements in renewable energy technologies, such as more efficient solar panels and energy storage, could enhance system sustainability. The design could also be scaled to accommodate larger aquaculture environments, integrating automated feeding and waste

management. Additionally, AI-driven user interfaces could simplify system management, improving operational efficiency for fish farmers.

### **5.3 Summary**

The "Solar Powered Water Quality Monitor and Control System for Fish Farming" presents an innovative and sustainable solution for monitoring and maintaining optimal water quality in fish farming environments. The system integrates solar power for energy efficiency and utilizes real-time data updates via an LCD and the Thingspeak cloud platform, ensuring continuous monitoring of key water parameters such as temperature, pH, dissolved oxygen, and turbidity. These parameters are crucial for the health and growth of fish, and the system ensures they remain within desirable ranges.

The control mechanism of the system plays a critical role by automatically initiating corrective actions whenever water quality conditions deviate from the desired thresholds, thereby preventing potential risks to the fish population and ensuring a stable environment for growth. The system has shown robust functionality in experimental trials, demonstrating reliable updates and control interventions during instances when parameters exceed the optimal range.

While the system has proven effective, the report acknowledges certain limitations, such as the scope of the monitored parameters and the scalability of the system for large-scale operations. However, the design lays a solid foundation for future improvements, including the potential for integrating more sensors, enhancing the control system, and expanding compatibility for various fish species in diverse farming conditions.

The integration of solar power enhances sustainability and reduces operational costs, making this system a viable option for both small-scale and large-scale fish farming operations. With further development and refinement, this system has the potential to significantly contribute to the growth of sustainable aquaculture, promoting efficient and environmentally friendly practices in indoor fish farming.

In conclusion, the proposed system demonstrates both experimental success and future potential, offering a valuable tool for improving water quality management and supporting the sustainable growth of fish farming industries.

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