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Pearl Catfish Pond Water Quality Monitoring System Using the ThingSpeak Server

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ABSTRACT

The research is centered around the implementation of an IoT-based water quality monitoring system for Pearl catfish ponds. This system uses ThingSpeak server to monitor pH, turbidity, temperature, and ammonia levels to maintain ideal conditions for fish growth. The data is processed using fuzzy logic which uses two inputs and one output data, namely data from pH and turbidity with output in the form of a percentage of water quality levels. The results are sent in real time to the ThingSpeak server for continuous monitoring. The main objective of this system is to optimize production efficiency and improve fish quality for catfish farmers. The research has successfully developed an Internet of Things (IoT)-based water quality monitoring system for catfish ponds, demonstrating the positive impact of probiotics on both water quality and fish growth. Notably, Fishpond A, which received probiotic treatment, demonstrated notably superior water quality in comparison to Pond B without probiotics. Additionally, fuzzy logic testing indicated a high degree of accuracy, underscoring the system's effectiveness in real-time water condition monitoring.

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1. INTRODUCTION

Catfish is a popular freshwater fish because it is easy to cultivate, and the price is affordable. However, there are obstacles such as lack of water quality in pond water which affects the quality of fish seeds [1]. the development of the fisheries sector in Indonesia has not kept pace with the necessary advancements in science and technology. This harms the fish farming system and often leads to crop failure and fish death before harvest [2].

Changes in physical parameters affect farmed fish growth and health. Each species of farmed fish has specific requirements for water conditions in order to grow optimally. Farmers need to regularly check water conditions in their ponds and treat them accordingly to ensure the right environment for the fish [3]. In practice, fish farmers still manually measure water quality. They have to go to the fishpond and use simple measuring tools. This method greatly influences the effectiveness of fish farming [4]. Good water quality enhances fish growth and survival [5]. Fish growth is influenced by weight, length, age, genetics, parasites, disease, gender, food, water quality, and environment [6].

Water quality factors play an important role in ponds. Therefore, we need a system that is able to combine and provide real-time data on water conditions. This also simplifies the task for breeders by eliminating the need for manual measurements, allowing them to swiftly take action in order to preserve the optimal quality of pond water.

To assess water quality in catfish farming, this study focuses on probiotic technology by measuring temperature, oxygen levels, pH, and ammonia levels to ensure the suitability of water for fish. Understanding each of these parameters will help improve water quality [7]. Previous research explains that pH can be a benchmark in determining the water quality of catfish ponds. Water quality in a catfish pond is determined not only by the pH level but also by the level of turbidity [8].

Water quality assessments usually rely on one or two parameters to determine if the water is good or bad. This does not adequately represent the actual conditions of fish growth. Using a fuzzy logic system helps to improve the assessment of water quality by making it more efficient and accurate [9]. This system will use the Fuzzy Logic method, which is proven to provide a high level of accuracy in decision-making [10].

The author developed a technology to monitor water quality in Mutiara catfish ponds, which allows farmers to take quick action when problems occur in the pond. Using fuzzy logic that can determine accurate quality results. Comparing two ponds: one with probiotics (pond A) and one without Probiotics (pond B). This system monitors sensor parameters in the Mutiara catfish pond then All sensor data results, and water quality results will be processed and sent to the ThingSpeak server.

Ponds for pearl catfish farming need temperatures between 15-35^{0}C, pH levels from 5 to 9, ammonia levels of 0.2 ppm, and turbidity around 0-10% [11] . The research will compare the effect of probiotics on water quality and growth of Pearl catfish in two ponds to see if probiotics can improve water quality and fish growth. This system aims to solve the common problems faced by catfish farmers, such as not paying enough attention to the quality of pond water, which affects the quality of catfish offspring.

2. RESEARCH METHOD

The research method is experimental in nature and employs a quantitative approach [12]. where this research is the result of the author's work. In this research, the mechanism for monitoring the quality of Mutiara catfish ponds. The first stage is designing the hardware for this device. The hardware design can monitor pH, temperature, ammonia, and turbidity levels. Arduino IDE software is used to process data, display sensor readings, and analyze water quality using the Mamdani fuzzy logic method. The processed data is then sent to the ThingSpeak server to monitor catfish ponds.

2.1. Hardware Design

2.1.1. Block Diagram

To optimize planning goals, it is crucial to concentrate the discussion on the planned design within the system block diagram. A block diagram is a graph that shows how information or signals flow from input to output in a system. These diagrams help in understanding and analyzing systems in a more scientific and structured way [12]. The following is a block diagram of the pearl catfish pond water quality monitoring system:

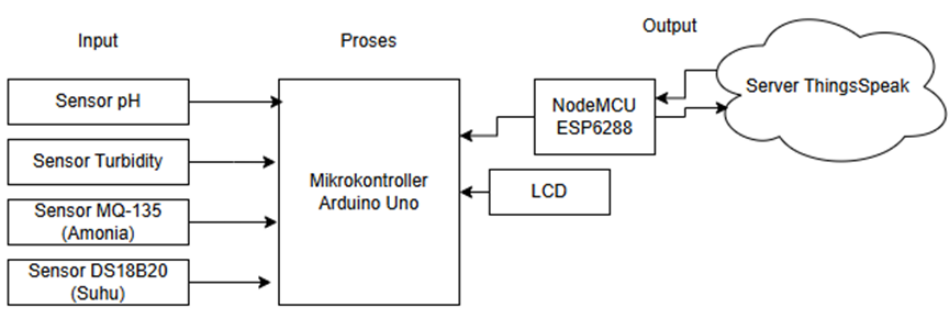

Figure 1. Block Diagram

The diagram shows an IoT water quality monitoring system with sensors, microcontrollers, and servers organized into input, process, and output parts. There are four sensors connected to the microcontroller: a pH sensor for measuring the pH level of the Pearl catfish pond, a turbidity sensor for measuring the water's cloudiness, an MQ-135 sensor for measuring ammonia levels, and a temperature sensor for measuring the pond's temperature. These sensors measure water quality parameters and send the data to the microcontroller for further processing.

In the process section, the microcontroller processes the data received from these sensors. After processing, the microcontroller uses Node MCU to send data to the

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ThingSpeak server and display the measurement results on the connected LCD. Data sent to the ThingSpeak server allows monitoring and analyzing water quality parameters and results of the Pearl catfish pond on the ThingSpeak platform. This system allows for real-time monitoring and analysis of water quality to ensure the best conditions for raising Pearl catfish.

2.1.2. Circuit Schematic

A circuit schematic is necessary to identify the components, sensors, and actuators used in water quality monitoring systems for catfish ponds. Hardware design is the process of creating a circuit layout for all the components of a device. This ensures that the device functions well as a monitoring tool [13]. Circuit schematics are also used to find out the wiring connected to each component or sensor, making installation easier.

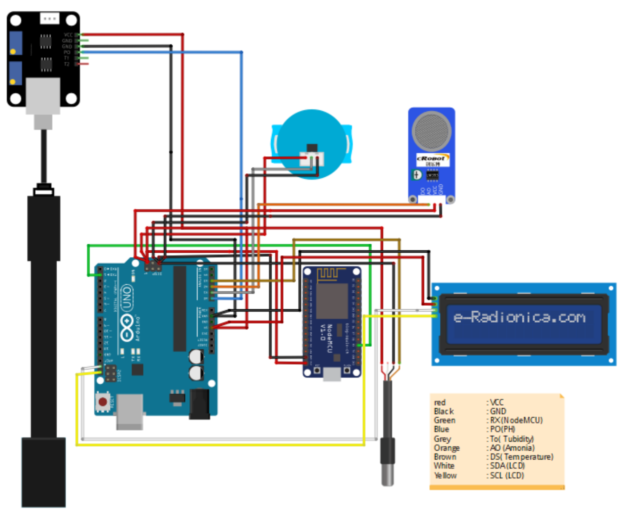

Figure 2. Wiring diagram of system

The device's schematic design explanation: The voltage source comes directly from the electricity supply connected to the Arduino. The Arduino UNO provides a 5-volt power supply for all connected sensors, as it serves as the main microcontroller. The pH sensor is connected to pin A0 on the Arduino Uno. The turbidity Sensor on pin A1 of Arduino Uno measures water turbidity in pond. MQ-35 sensor connected to Arduino Uno pin A2 measures ammonia levels in catfish pond water. Arduino Uno's A3 pin is used to connect a temperature sensor for detecting water temperature in the catfish pond. The MCU node is connected to the Arduino Uno and sends data from the Arduino to the ThingSpeak server. The device also has an LCD that acts as a monitor, allowing users to directly view data.

2.2. Software Design

After designing the hardware, the next step is software design. It is an important stage that guides the creation of a program. When creating a program using the Arduino IDE, the program will be uploaded to the microcontroller. This stage ensures that the program runs well and meets needs [14]. The following is a flowchart of software design as in Figure 3.

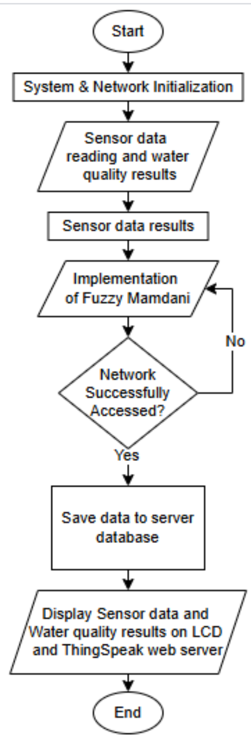

Figure 3. Flowchart of Software design system

The system flow diagram above shows the process of determining the water quality value of a catfish pond. Starting with system and network initialization, make sure the network is connected to the internet. Then read the sensor data programmed in the Arduino IDE software. After the results of the sensor data come out, the fuzzy logic that has been programmed in the Arduino IDE software is used to determine the results of the water quality. There are three stages in fuzzy logic processing, namely fuzzification, inference and defuzzification. Finally, the water quality value of the catfish pond is determined. NodeMCU sends processed data from Arduino Uno using Arduino IDE software. The NodeMCU checks the connection to the cloud. If the cloud is not connected, NodeMCU will try to reconnect the network. If the cloud is accessible, the data will be displayed on the ThingSpeak server and can also be monitored on the programmed LCD.

2.2.1. Fuzzy Logic Method

Fuzzy logic is crucial for decision support when complex conditions require more nuanced answers than just "yes" or "no." This happens because of uncertainty in data or information received during data processing [15]. The fuzzy logic approach is used because it represents an approachable and essential mathematical concept in reasoning [16]. The data undergoes preprocessing using fuzzy logic before being sent to the ThingSpeak server. In this study, the Mamdani fuzzy logic method was employed for data processing. Where Fuzzification transforms crisp values into fuzzy sets by means of fuzzy membership functions [9]. The reason for using Mamdani fuzzy logic is that it employs rules based on linguistic logic (If-Then), which are easy for humans to understand. These rules often resemble the way humans think when making decisions.

In the fuzzification stage, pH and turbidity are the inputs, and water quality is the output. The pH and Turbidity variable is shown on the horizontal axis and the degree of membership is shown on the vertical axis.

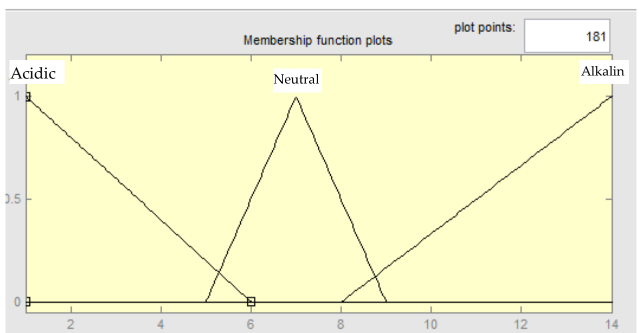

Figure 4. pH Membership Set

Table 1. pH Membership Function

fuzzy variables	fuzzy set	Domain	membership function
pH	Acidic	[1 – 6]	linear down
	Neutral	[5 – 9]	triangle.
	Alkaline	[8 – 14]	linear up.

Three fuzzy sets are defined within the pH variable: Acidic, Neutral, and alkaline. The acidic fuzzy set is represented by a decreasing linear form, the neutral fuzzy set is represented by a triangular form, and the alkaline fuzzy set is represented by an increasing linear form [17].

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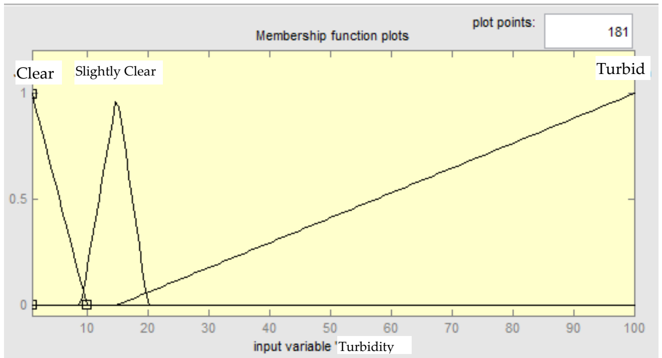


Figure 5. Turbidity Membership Set

Table 2. Turbidity Membership Function

fuzzy variables	fuzzy set	Domain	membership function
Turbidity	Clear Slightly Clear Turbid	[0 - 10] [9 - 20] [19 - 100]	linear down triangle. linear up.

The Turbidity variable is defined in three Fuzzy sets: Clear, Slightly Clear, and Turbid. The variable is represented using a decreasing linear format for Clear, a triangular format for Somewhat Clear, and an increasing linear format for Turbid. An overview of the Fuzzy set for the turbidity variable can be seen in Figure 5.

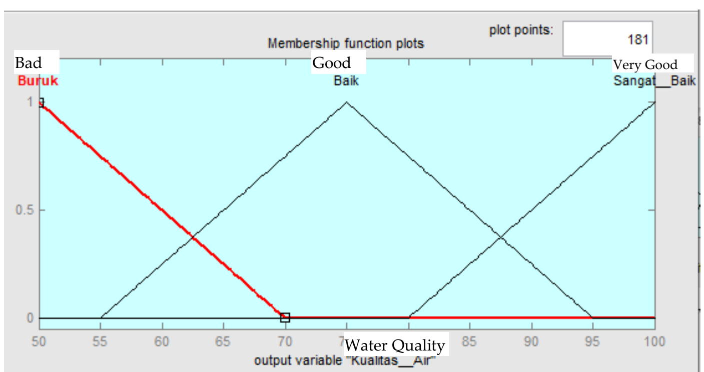


Figure 6. Water Quality Membership Set

Table 3. Turbidity Membership Function

fuzzy variables	fuzzy set	Domain	membership function
Water Qyality	Very Good Good Bad	[80 - 100] [55 - 95] [50 - 70]	linear down triangle. linear up.

The Water Quality variable is defined as three Fuzzy sets, namely Very Good, Good and Bad. The Water Quality variable is represented by three different fuzzy sets. The Very

Good Fuzzy set has a descending linear shape, the Good Fuzzy set has a triangular shape, and the Bad Fuzzy set has an upward linear shape.

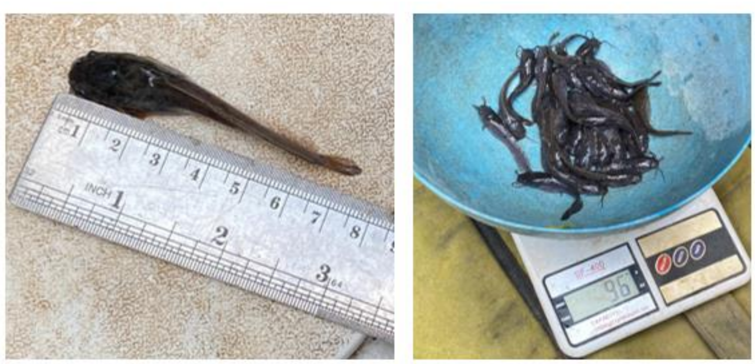
There are several important factors that must be taken into account. Among them is the crucial matter of transforming input values into output values through the fuzzy inference stage. This fuzzy inference stage is a way to formulate a mapping from the given input to output [18]. Fuzzy rules are determined through inference. During the fuzzification stage, the collected data in the form of pH and Turbidity set membership values will be processed using fuzzy rules[19].

Table 4. Fuzzy Rules

Rule	Input pH	Input Turbidity	Output Water Quality
Rule 0	Acidic	Clear	Good
Rule 01	Acidic	slightly clear	Bad
Rule 02	Acidic	Turbid	Bad
Rule 03	Neutral	Clear	Very Good
Rule 04	Neutral	slightly clear	Very Good
Rule 05	Neutral	Turbid	Bad
Rule 06	Alkaline	Clear	Good
Rule 07	Alkaline	slightly clear	Good
Rule 08	Alkaline	Turbid	Bad

2.3. Perparation Catfish And Pond

This research was conducted in the catfish ponds of the Macan Kumbang area, which focused on the nursery stage of 1-month-old Mutiara catfish. Using two ponds measuring 2.5 x 2.5 meters prepared for this study, namely pond A which was given probiotics and pond B without probiotics.



(a) (b)

Figure 7. Initial length and Initial weight of catfish

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The pearl catfish that were put into each pond were 100 fish. In Figure 7, the initial length of the fish was 7 cm and the average weight of the fish was 3.7 grams and will be monitored for 14 days.

3. RESULTS AND DISCUSSION

3.1. Device Design Results

The system starts by creating a tool to monitor the water quality of Pearl catfish ponds using IoT technology and a NodeMCU shown in (a) Figure 8. This process consists of two main parts: hardware assembly and software design. At the hardware assembly stage, different components are assembled to form a monitoring system. A pH sensor measures acidity in the water of the Pearl catfish pond. A turbidity sensor measures water clarity and a temperature sensor measures the water temperature. An MQ-135 sensor is used to monitor ammonia levels in the Mutiara catfish pond. The NodeMCU and microcontroller processes the data from all these sensors. The water quality monitoring tool can be seen in (b) Figure 8.

(a) (b)

Figure 8. water quality monitoring system tools

The sensor programming software is designed using the Arduino IDE. Fuzzy Logic creation is also programmed in the Arduino IDE, as shown in Figure 9. The NodeMCU has a built-in Wi-Fi module for sending data to the server and monitoring it in real-time on the web through the ThingSpeak server and an LCD screen. The monitoring display on the ThingSpeak server can be seen in Figure 10.

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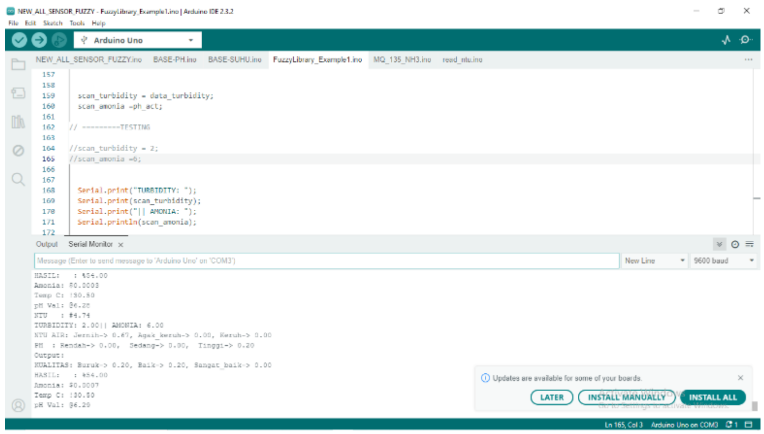

Figure 9. Arduino IDE Software Programming

Figure 10. ThingSpeak Webserver Monitoring Results

This ThingSpeak web server makes it easier to monitor fishponds in real time and can save the data. The author saves the data using Excel data to make the data collection process easier.

3.2. Sensor Data Testing and Calibration

A tool or a system can be considered to be functioning properly when it has been tested according to its intended purpose and specifications. The test results display the final planning outcomes, confirming that the hardware functions correctly and can be operated through the user interface [20].

This testing aims to ensure that the tool that has been created is accurate and can be used in real-time. Testing is conducted by taking multiple sensor samples and comparing the corresponding test results with a digital meter. This ensures that the sensor can operate effectively under specific conditions.

Table 5. Sensor Data Testing and Calibration

No	Sensor	Sensor Value	Digital Meter Value	Error (%)	Accuracy (%)
1.	pH	6,64	6,69	0,75	99,25
2.	Turbidity	1,83	1,84	0,54	99,46
3.	Temperature	31	30,5	1,6	98,4
4.	Ammonia	0,000486	0,0005	2,8	97,2

Table 2 shows the comparison between the pH sensor test and the pH meter. The pH value from the sensor is 6.64, and the pH value from the pH meter is 6.69. From these results after calculating the error of the pH sensor from the device made, it is 0. 75% with 99.25% accuracy. When comparing the Turbidity sensor and the TDS Meter, the turbidity of the pond water was measured as 1.83% by the turbidity sensor and 1.84% by the TDS Meter. The turbidity sensor had an error of 0.54% and an accuracy of 99.46%. The temperature sensor reads 31^{0}C, while the temperature meter shows 30.5^{0}C. This means there is a 1.6% calculation error, but the accuracy is 98.4%. The ammonia sensor has a value of 0.000486, while the gas meter value is 0.0005. The calculation error is 2.8%, and the accuracy is 97.2%. The results of these four sensors were taken from several samples taken in the catfish pond. The samples taken are averaged and the values for the four sensors are obtained.

3.3. Fuzzy Logic Method Testing

Fuzzy Logic testing aims to assess the percentage of errors in the microcontroller design. The test involves a comparison between the system defuzzification results and the Matlab simulation results. The percentage of errors found was 0.351% with an accuracy of 99.649%. Data from Fuzzy Logic testing results can be found in Table 6. Apart from that, data delivery testing aims to evaluate system performance when connected to the internet.

Table 6. Sensor Data Testing and Calibration

No	Water Quality Value (%)	Matlab simulation results	Error (%)	Accuracy(%)
1.	93,67	94	0,351	99,649

3.4. Test result

After testing all sensors and fuzzy logic, the next step is to test the entire tool by collecting data from water quality monitoring tools in two fishponds, pond A and pond B. Pond A was given probiotics, while pond B was not. Data collection was carried out for 14 days with 7 data samples taken. Data collection is carried out every 2 days. Data is obtained in table 7 for pond A and table 8 for pond B.

Table 7. fish pond A results data

No.	Testing (Day -)	Temperature Sensor	pH Sensor	Turbidity Sensor	Ammonia Sensor	Water Quality (%)	explanation
1.	1 - 2	31	6,6	1,75	0	93,67	Very good
2.	3 - 4	30,5	9,02	23,88	0,00012	94,93	Very Good
3.	5 - 6	32,68	8,78	8,32	0,00028	93,67	Very Good
4.	7 - 8	28,94	5,46	3,63	0,00035	95	Very Good
5.	9 - 10	30,5	6,58	3,37	0,00048	53,98	Bad
6.	11 -12	31	6,79	12,58	0,00049	82,17	Good
7.	13 - 14	28,7	7,45	3,75	0,00049	57,72	Bad

Table 8. fish pond B results data

No.	Testing (Day -)	Temperature Sensor	pH Sensor	Turbidity Sensor	Ammonia Sensor	Water Quality (%)	explanation
1.	1 - 2	30,5	6,19	4,33	0,0001	93	Very good
2.	3 - 4	30,5	8,93	5,31	0,00018	93,67	Very Good
3.	5 - 6	32,67	8,91	9,37	0,0003	93	Very Good
4.	7 - 8	27,52	5,25	0,79	0,00037	94	Very Good
5.	9 - 10	28,58	8,27	10,41	0,000506	52,6	Bad
6.	11 -12	30,5	9,07	13	0,00053	78,22	Good
7.	13 - 14	28,5	8,86	4,95	0,00048	52,49	Bad

Data collection results indicate that overall, the water quality in pond A is better than pond B. The fuzzy logic results from the water quality monitoring tool demonstrate that, on a daily basis, pond A has a higher percentage of better water quality compared to pond B. However, there were still several days during the data collection period when both ponds experienced poor conditions. The weather is less favorable, such as heavy rain. Rainwater can affect the water quality in both ponds, causing the daily percentage change to vary. However, the impact is more noticeable in pond B, which does not use probiotics. Differences in water quality every day are influenced by weather factors, causing fluctuations in pH values and water turbidity. To see the differences between the two ponds, see Figure 11. where there is a graph of the results of water quality in the fish pond, the blue bar graph is the information for pond A and the orange bar graph is the information for pond B.

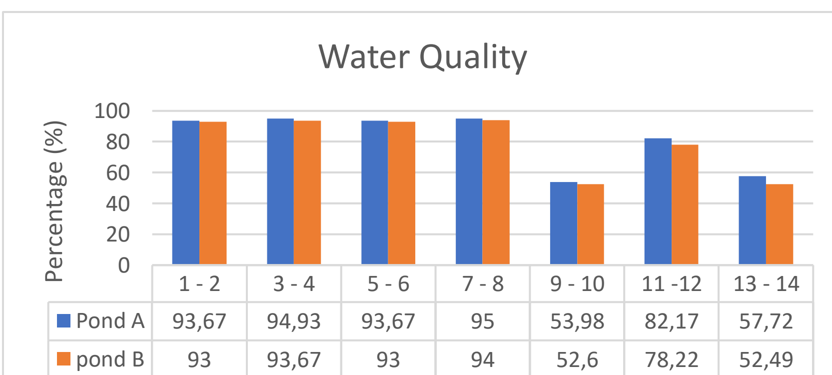

Figure 11. Comparison of water quality percentages

This quality is strengthened by the fish in the fishpond. Catfish in fishpond A are longer and heavier than in fishpond B, where they are smaller and heavier. This shows that pond A, which was given probiotics, has good water quality compared to pond B without probiotics. It can also be seen in the table 9 which is the final result of the growth of the length and weight of the fish that the author has measured and weighed.

Table 9. Turbidity Membership Function

Pond Name	Fish length growth	Fish weight growth	Life sustainability (%)
A	10 Cm	4,56 Grams	100
B	8 Cm	4 Grams	100

4. CONCLUSION

This research shows success in designing an IoT-based catfish pond water quality monitoring system using NodeMCU and the ThingSpeak server. Data from the microcontroller was successfully sent to the ThingSpeak server accurately. The test results indicate that the pH sensor has an error of 0.75% and an accuracy of 99.25%. Similarly, the turbidity sensor shows an error of 0.54% with an accuracy of 99.46%. The temperature sensor has a 1.6% error and a 98.4% accuracy. The ammonia sensor has a 2.8% error and a 97.2% accuracy. Data from several catfish pond samples shows consistent results. Fuzzy logic testing on the system shows an error percentage of 0.351% with an accuracy of 99.649%. Fishpond A, which received probiotics, had better water quality than fishpond B, which did not receive probiotics, during the 14-day data collection period. Fishpond A has consistently better water quality than fishpond B, despite fluctuations in pH levels and water turbidity caused by weather conditions like heavy rain. Fish grow better in pond A because of the improved water quality, resulting in increased length and weight compared to pond B. In conclusion, the IoT-based water quality monitoring system effectively measures and monitors water conditions in real-time. Time, and the use of probiotics significantly improves water quality and catfish growth.

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