

Design Of A Wi-Fi Based Monitoring And Control System For Milkfish Pond Water Quality (Case Study: Pokdakan Tani Sejahtera)

Isa Mahfudi¹, Ayu Andira Fitriani¹, and Hudiono¹

¹Department of Digital Telecommunication Network, State Polytechnic of Malang, Jl. Soekarno - Hatta 9, Malang-Indonesia

Corresponding Author: isa_mahfudi@polinema.ac.id

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Abstract

The Fish Cultivation Group (POKDAKAN) of Prosperous Farmers is one of the groups that cultivate brackish water milkfish in Kedanyang village. Based on the information received from the results of observations and interviews with the pond management, the main problem when cultivating milkfish is that water parameters (pH, Total Dissolved Solid, and temperature) are not monitored properly. Pond farmers cannot monitor every water parameter, whether in good or bad condition, because there is no adequate monitoring and only rely on looking at the color of the pond water. Weather factors are also a challenge during the rainy season, changes in water conditions can occur extremely. Based on the existing problems, the research that will be carried out is to develop existing research by using the necessary parameters such as salt content, water pH, and water temperature as well as to control automatically if there are problems that occur in the pond. By using the test parameters on the system, the pH level is generally within an acceptable range but with occasional fluctuations. Temperature variations tend to be within a narrow range unless there is an isolated drop. The TDS level is stable with occasional deviations, especially the one recorded on June 27 the testing on the website has been successful and the features are working as intended. The success rate of this system is 99.997%.

Keywords: Milkfish cultivation, water quality monitoring, pH, TDS, temperature, automatic control system

1 Introduction

Aquaculture has become an increasingly important source of aquatic food, and its expansion is expected to help meet the growing global demand for fish products [1]. Milkfish cultivation has very good prospects in Gresik Regency, East Java, known as *Kampung Bandeng*; quoted from the East Java Province KOMINFO office, Gresik has a pond area of 28 thousand hectares and a milkfish productivity of 87 thousand tons per year, capable of generating income of up to IDR 1.4 trillion [2]. Kedanyang Village, in Kebomas District, therefore shares this potential [2]. Milkfish (*Chanos chanos*) can live in seawater or in brackish water with muddy soil and a certain salinity, and brackish-water ponds usually follow the ebb and flow of the tide, with water exchange regulated through sluice gates [3]. Milkfish are active fish that can be cultivated at high stocking densities [4], but such culture relies on supplemental feeding, and the limited pond area is prone to the accumulation of nutrients from excreta and uneaten feed that may become toxic [5]. Hence, pond water quality suitability has been widely assessed in Indonesian milkfish and brackish-water ponds [6], and milkfish respond physiologically to environmental change: thermal stress has been quantified through scale cortisol [7], and salinity and temperature changes induce shifts in metabolic pathways [8].

The Fish Cultivation Group (POKDAKAN) of Prosperous Farmers cultivates brackish-water milkfish in Kedanyang Village. Based on observations and interviews with the pond management, the main problem is

that the water parameters (pH, Total Dissolved Solids (TDS), and temperature) are not monitored properly: farmers cannot monitor every parameter, whether in good or bad condition, and only rely on the color of the pond water. Weather is an additional challenge in the rainy season, when water conditions can change extremely; rainwater is cooler and slightly acidic and dilutes the pond, and in shrimp ponds heavy rain has been reported to lower temperature, pH, and salinity and to make dissolved oxygen first rise and then drop markedly [9]. The principles linking these parameters are described in [10]. Such changes matter because poor water quality is one of the causes of stressed fish [?]: low dissolved oxygen and undesirable temperature or pH trigger stress hormones such as cortisol, impair the immune response, and increase susceptibility to infection, so a water quality monitoring program should be maintained [11]. Conventional monitoring, however, is limited in its rapid response to dynamic environmental changes [12].

The Internet of Things (IoT), extensively discussed for smart-city applications [13], has therefore been adopted in aquaculture; a recent systematic review examined how IoT enhances the accuracy and capability of real-time monitoring, along with its technical, operational, and economic barriers [14]. Anggraeni *et al.* [15] built a web-based monitoring system for vaname shrimp ponds measuring salt level, pH, and turbidity to replace the traditional method of tasting the water with the tongue by a system that is easy to reach and more accurate. It ran well, although data on production increase could not be obtained because it takes longer; however, the error or delay percentage was not explained, so it is unclear whether the system is at least 90% successful or needs further treatment, and it only monitors without control, relying on farmers to handle problems [15]. For milkfish ponds, Fakhriyah *et al.* developed an Arduino-based pH, TDS, and salinity device whose design was valid and relevant, but which shows readings locally on an LCD [16]. Boonsong *et al.* [17] used a 900 MHz Wireless Sensor Network (WSN) to send temperature, dissolved oxygen, and pH to the operator via a cloud platform and router gateway, while Abdullah *et al.* combined a WSN with a Wi-Fi module in a brackish-water shrimp farm and obtained data as reliable and accurate as a commercial device [18]. A NodeMCU-ESP8266 node with a DS18B20 sensor showed that water temperature and dissolved oxygen are negatively correlated [19], which is relevant to aeration control, and in the Surabaya area Pratama *et al.* monitored pH, temperature, and TDS of a vannamei pond through a website and Android application integrated with a solar-based aerator, reporting 98.57% accuracy [20].

Beyond monitoring, automatic control has also been explored. Daud *et al.* designed an automatic control for koi fish pond water quality that reads normal or abnormal pH and temperature; in seven tests, tests 3 and 4 were normal while tests 1, 2, 5, 6, and 7 were abnormal and needed treatment, so the water pump was turned on [21]. Controlled the aerator and feeder with predefined fuzzy rules on temperature, pH, dissolved oxygen, and hardness, increasing shrimp survival by 33.3% compared with conventional aquariums [22]. Implemented user-defined “if this then that” rules on a NodeMCU-based smart aerator with an average trigger-to-start latency of 159 ms [23].

Communication technology also matters: in an agricultural monitoring experiment, Wi-Fi offered a much higher throughput than ZigBee and LoRaWAN but a poorer power consumption [24], and the suitable protocol depends on coverage area, power budget, and data rate [25]. Because the sensor node here connects to a local Wi-Fi network, Wi-Fi is a practical, low-cost choice, and its energy demand can be met by a battery charged by a solar panel, as in solar-based aerator systems [20]. Salt content is represented by TDS: as most dissolved solids are ions, TDS relates to salinity and conductivity, although the conversion factor varies among waters, so it is best regarded as an approximate indication of mineralization [26]. Based on these studies, the researchers designed a “Wi-Fi-Based Water Quality Monitoring and Controlling System for Milkfish Ponds (Case Study: Pokdakan Tani Sejahtera)” to address the partners’ problem that pH, temperature, and dissolved salt content cannot be monitored intensely and properly. Pond managers can monitor water quality remotely through a smartphone on the website, control the aerator manually or automatically, and the system automatically carries out treatment based on the input parameters, without the owner having to come to the pond. The system uses a pH sensor, a Dallas (DS18B20) temperature sensor, and a TDS sensor, with an Arduino Uno connected to an ESP8266 that sends the data to the website in real time and switches the aerator. Compared with the monitoring-only system of [15], it adds automatic aerator control and reports the measurement error of each sensor against a reference instrument; compared with the standalone milkfish device of [16], it adds remote web access and real-time data logging. The work follows the design science research paradigm [27], in which a new artifact, here a device and a website, is designed, built, and evaluated.

2 Method

2.1 Research Design

The type of research that will be carried out is research on the development of Science and Technology. Where this study develops pre-existing research. The Design Science Research (DSR) study paradigm has attracted a lot of attention in the last 20 years, particularly because it may help firms become more innovative and support the urgently needed change of society toward sustainability. In this study, a device and website were produced to provide ease for pond managers in monitoring and controlling pond water quality to minimize fish deaths.

2.2 System Design

The system was designed to monitor key water quality parameters, including pH, Total Dissolved Solids (TDS), and Temperature. The hardware components used included pH sensor, temperature sensor, TDS sensor, and a microcontroller unit (MCU), specifically the NodeMCU ESP8266, which was chosen for its Wi-Fi capabilities. The sensors were calibrated to ensure accurate readings, and the MCU was programmed to collect data from the sensors at regular intervals.

The data collected by the sensors was transmitted wirelessly via Wi-Fi to a cloud server, where it was stored and processed. The processed data was then made accessible through a web-based interface, which provided real-time visualization and historical data tracking. The system also included automated controls, where predefined threshold for pH, TDS, and temperature triggered corrective actions, such as adjusting water flow or aeration to maintain optimal water quality. An explanation of the system design can be seen in figure 1.

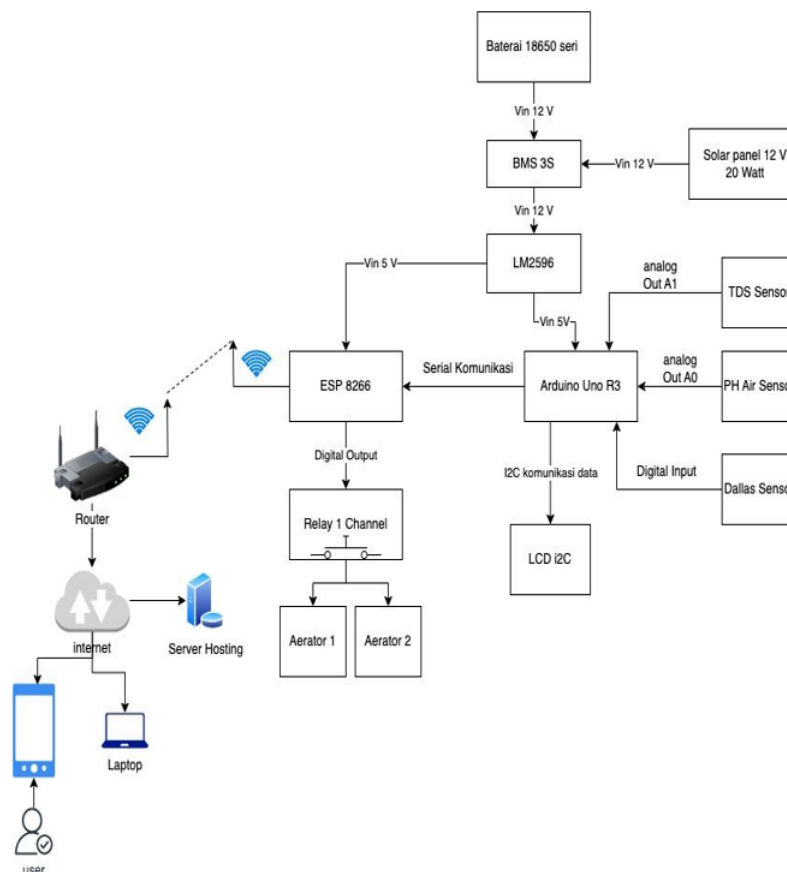


Figure 1: Diagram Block System

2.3 Implementation

The implementation phase involved setting up the system in a real-worlds milkfish pond environment. The sensors were strategically placed in different areas of the pond to capture comprehensive water quality data. The NodeMCU ESP8266 microcontroller was connected to these sensors and configured to transmit data to the cloud server via a local Wi-Fi network. The web-based interface was developed using HTML, CSS, and JavaScript, with a back-end powered by a PHP server to handle data storage and retrieval. Figure 2 shows the implementation of the system.

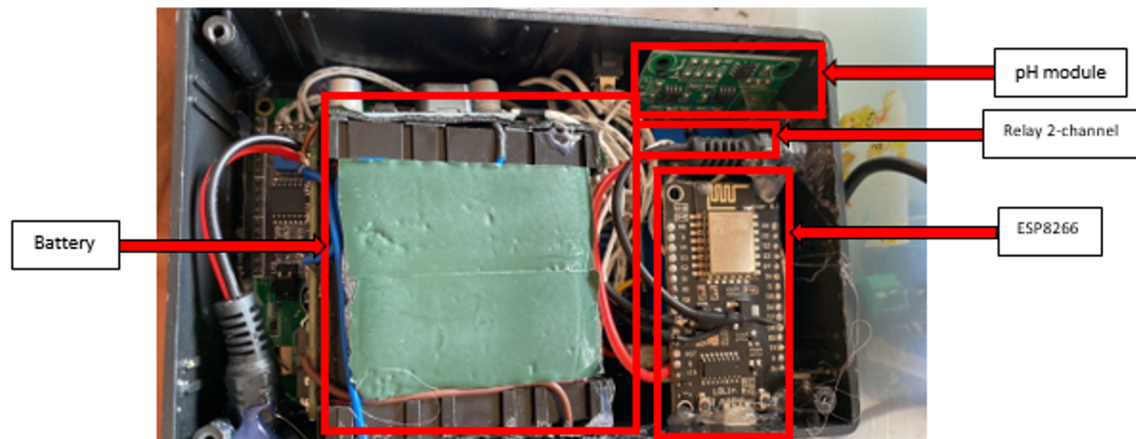


Figure 2: Implementation of Device

2.4 Test Parameters

In this study, the test parameters start by determining the independent and the dependent variable in the system, then continue with the testing technique. Each will be explained as follows:

2.4.1 Independent Variable

The following are the types of independent variables used in this study:

- Sensor Type:
 1. pH sensor
 2. Temperature sensor
 3. Total Dissolve Solid (TDS) sensor
- Communication Method
 1. Wi-Fi
- Microcontroller Platform
 1. Arduino Uno
 2. ESP8266
- Type of Display
 1. Website

2.4.2 Bound Variable

The following are the types of bound variables used in this study:

- Measurement Accuracy: Difference between sensor reading and reference value
- System Reliability: Total time the system is not operating due to faults or failures in the system.
- Ease of Use: Ease of data interpretation.

2.4.3 Testing Technique

1. Testing the functional of each sensor individually.
2. Testing the overall functionality of the system under real conditions.
3. Testing the results of system conformity on the website.
4. GET data.
5. POST data.

3 Result and Discussion

In this section, it is explained the results of research and at the same time is given the comprehensive discussion. Results can be presented in figures, graphs, tables and others that make the reader understand easily [28], [29]. The discussion can be made in several sub-sections.

3.1 Result of Sensor Test

In this sub-chapter, analysis of the result of the sensor.

3.1.1 The Result of Temperature Sensor

The manual thermometer served as the reference for the measured values, which were taken from the temperature sensor's. The results of DS18B20 temperature test are shown in the following table 1.

Table 1: Result of Temperature Sensor Test

Testing to-	Thermometer (°C)	Temperature Sensor (°C)	Error (%)
1	27.5	27.50	0
2	27.5	27.56	0.002
3	27.6	27.60	0
4	27.5	27.50	0
5	27.4	27.70	0.01
6	27.4	27.45	0.001
7	27.3	27.30	0
8	27.5	27.64	0.005
9	27.5	27.50	0
10	27.3	27.35	0.001
Average			0.001

$$\begin{aligned}
 \text{Temperature accuracy percentage} &= 100\% - \text{Average error percentage} \\
 &= 100\% - 0.001\% \\
 &= 99.999\%
 \end{aligned}$$

Data collection was carried out with 10 experiments at a time limit of 30 minutes. The test uses a water thermometer as a comparison alt. A repetition of 10 experiments provides an average accuracy of the distance detected by the DS18B20 temperature sensor with the comparator used.

Based on the results of the comparison that has been carried out, it can be seen that the percentage of sensor success in taking and sending data is 99.999%. These results show that the temperature sensor is consistently able to pick up and transmit data very close to perfection.

The results of this calculation provide information regarding the reliability and quality of the sensor's performance. This information has significant implications for the further development and use of systems involving these sensors. Overall, the results indicate that both sensors have good capabilities in carrying out their tasks.

3.1.2 The Result of TDS Sensor

The manual TDS meter served as the reference for the measured values, which were taken from the TDS sensor. The results of the TDS test are shown in the following table 2.

Table 2: Result of TDS Sensor Test

Testing to-	TDS Meter (ppm)	TDS Sensor (ppm)	Error (%)
1	307	307	0
2	330	329	0.003
3	300	299	0.003
4	380	377	0.007
5	306	309	0.009
6	240	239	0.001
7	238	237	0.004
8	307	307	0
9	300	299	0.003
10	337	335	0.005
Average			0.003

$$\begin{aligned}
 \text{TDS accuracy percentage} &= 100\% - \text{Average error percentage} \\
 &= 100\% - 0.003\% \\
 &= 99.997\%
 \end{aligned}$$

Data collection was carried out with 10 experiments at a time limit of 30 minutes. The test uses a water thermometer as a comparison alt. A repetition of 10 experiments provides an average accuracy of the distance detected by the TDS sensor with the comparator used.

Based on the results of the comparison that has been carried out, it can be seen that the percentage of sensor success in taking and sending data is 99.997%. These results show that the temperature sensor is consistently able to pick up and transmit data very close to perfection.

The results of this calculation provide information regarding the reliability and quality of the sensor's performance. This information has significant implications for the further development and use of systems involving these sensors. Overall, the results indicate that both sensors have good capabilities in carrying out their tasks.

3.1.3 The Result of pH Sensor

The manual pH meter served as the reference for the measured values, which were taken from the pH sensor. The results of the pH test are shown in the following table 3.

Table 3: Result of pH Sensor Test

Testing to-	pH Meter	pH Sensor	Error (%)
1	7.67	7.11	0.07
2	7.48	7.48	0
3	7.92	7.95	0.003
4	7.92	7.95	0.003
5	7.92	7.95	0.003
6	7.86	7.85	0.001
7	7.84	7.85	0.001
8	6.80	6.78	0.002
9	6.65	6.67	0.003
10	7.45	7.47	0.002
Average			0.003

$$\begin{aligned}
 \text{pH accuracy percentage} &= 100\% - \text{Average error percentage} \\
 &= 100\% - 0.003\% \\
 &= 99.997\%
 \end{aligned}$$

Data collection was carried out with 10 experiments at a time limit of 30 minutes. The test uses a water thermometer as a comparison alt. A repetition of 10 experiments provides an average accuracy of the distance detected by the pH sensor with the comparator used.

Based on the results of the comparison that has been carried out, it can be seen that the percentage of sensor success in taking and sending data is 99.997%. These results show that the temperature sensor is consistently able to pick up and transmit data very close to perfection.

The results of this calculation provide information regarding the reliability and quality of the sensor's performance. This information has significant implications for the further development and use of systems involving these sensors. Overall, the results indicate that both sensors have good capabilities in carrying out their tasks.

3.2 System Test Result

The 10-day test results, from 20 June 2024 to 29 June 2024, were conducted at intervals of every 30 minutes, providing a detailed and comprehensive overview of the performance of the systems being tested. Each of these intervals provided specific and consistent data, allowing for in-depth analysis of changes and patterns occurring over the period. With devices and systems pre-configured, testing will begin on June 20, 2024. Data is collected automatically every thirty minutes and stored in a structural database to facilitate further analysis. It collects data for 24 hours a day, ensuring that time is not missed and all relevant variables can be thoroughly observed.

3.2.1 Graph Data Result

- pH graph data

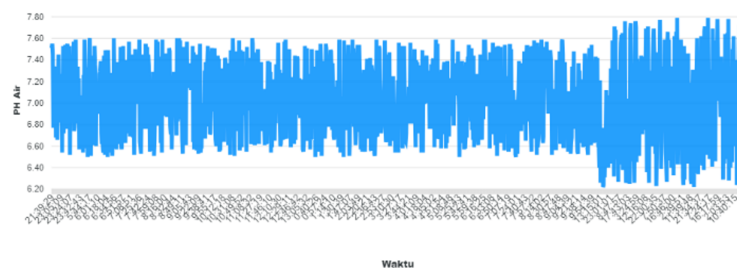


Figure 3: pH Graph Data

- Temperature graph data

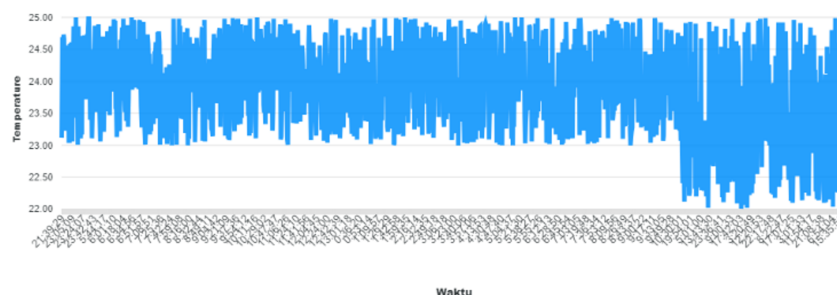


Figure 4: Temperature Graph Data

- Total Dissolve Solid (TDS) graph data

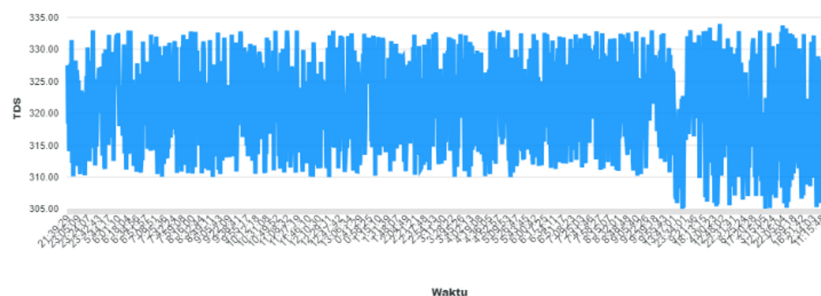


Figure 5: TDS Graph Data

The graph data from Figures 3, 4, and 5 illustrates the data that has been obtained, namely for a stable pH, but at 22 p.m. at 16.02, it decreased to 6.22 and so on the pH was stable in the range of 6.22-7.80. The temperature remained stable in the range of 23-25 degrees, but on the 23rd at 11.26 a.m. the temperature decreased to 22.02 degrees and then stabilized in the range of 22-25 degrees. Then for TDS, it was stable in the value range of 310-333ppm, but on the 22nd the TDS value dropped to a value of 305.94, then stabilized with a value range of 305-333ppm.

4 Conclusion

By showing the average pond water temperature of 27 °C, The Total dissolved solids (TDS) of pond water of 305 ppm, and the average pH of 7.85. The average value of each sensor has successfully reached 99.997% which can be said that the test of the sensor is almost perfect. From the data obtained in real-time via the website, the test results from 20 June 2024 to 29 June 2024 show the variation of pH, temperature, and TDS values within the period. The following is a summary of the measurement results: The pH value tended to fluctuate between 6.23 to 7.65 during the test period. The average pH value was 6.996, indicating that the water was in a neutral to slightly alkaline condition. The water temperature ranged from 22.02°C to 24.91°C. The average temperature value was 23.718°C, which is relatively stable and indicates environmental conditions that do not experience extreme temperature changes. TDS values ranged from 305.22 ppm to 333.4 ppm. The mean TDS value was 316.702 ppm, which shows the variation in solute concentration in the water during the test period.

Overall, The data in the website shows the water condition of milkfish ponds requires careful management to ensure that water quality parameters remain within the optimal range for the health and growth of milkfish.

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