

IoT-Based Real-Time Monitoring System For Enhancing Shrimp Pond Management: A Case Study In Deli Serdang, North Sumatra, Indonesia

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ABSTRACT

Monitoring shrimp ponds involves observing and measuring key environmental factors that influence shrimp health and growth. This study was conducted at a shrimp pond on Jalan Paluh Merbau, Tj. Rejo, Kec. Percut Sei Tuan, Deli Serdang Regency, North Sumatra, Indonesia. Traditionally, air humidity and water temperature are monitored manually by taking water samples for laboratory analysis or using litmus paper. These conventional methods are time-consuming and prone to inaccuracies, potentially compromising shrimp health. To address these challenges, this research implemented an Internet of Things (IoT)-based monitoring system to automate the measurement of air humidity and water temperature. The system utilizes DHT11 and DS18B20 sensors, integrated with an ESP32 module, to continuously collect data and automatically transmit it to Google Sheets for real-time monitoring. This IoT approach enables shrimp farmers to easily track water quality parameters, enhancing the accuracy and efficiency of pond management. A two-day testing phase demonstrated stable environmental conditions, with humidity levels recorded at 86.5% to 87.78% and water temperatures ranging from 27.55°C to 28.06°C. These readings were within the ideal thresholds for optimal shrimp growth, showcasing the system's effectiveness in maintaining suitable pond conditions. This research will contribute significantly to more efficient, accurate, and sustainable shrimp farming practices.

Keywords: Internet of Things (IoT), Pond Monitoring

INTRODUCTION

Aquaculture, the production of aquatic organisms such as fish and crustaceans, is critical for global food security and a crucial protein source [1]. Shrimp farm production is significant. Many factors determine shrimp farm productivity, such as having more shrimp seedlings, knowing the proper shrimp farming techniques, having plenty of water in the pond's water plain, and finding the best location for the land. These productivity-determining components - physical capital, human capital, natural resources, and technological know-how - can be used in a more complex and realistic economy. Since these highly influence production, it is difficult to determine the development of pond farmers' income. Pond water pH is positively correlated with temperature, total alkalinity, and carbonate, and negatively correlated with orthophosphate, bicarbonate, and total organic matter (TOM). To anticipate changes in pH, pond water quality maintenance should be carried out from day 96 to harvest. [2]. Aeration is essential for maintaining DO levels in shrimp farming. This study found that different DO setpoints did not affect growth or productivity but increased costs without benefits, except for morning and afternoon DO variations [3]. The real-time monitoring display and Android Telegram notification system have proven effective in the automated water quality monitoring of the Vannamei prawn pool in Pamandati, South Konawe District, Southeast Sulawesi, Indonesia [4]. The sensors used for monitoring were thoroughly evaluated in both controlled and real-world environments. The sensors demonstrated high accuracy in controlled settings with standard solutions, providing readings that closely matched reference values. However, challenges emerged during real-world testing, where environmental factors caused deviations in sensor accuracy [5][6]. An integrated IoT system requires compatible sensor and actuator devices, supported by proper circuit design and reliable communication networks [7]. The Internet of Things (IoT) offers a revolutionary way to address challenges in modern aquaculture. Quamonitor is an IoT-based tool developed to monitor vannamei shrimp pond water

quality, focusing on pH, temperature, and salinity. Using the ADDIE model, the system is supported by WiFi, MQTT, and Node Red for real-time monitoring via Android. Testing showed low error rates: 0.29% for pH, 1.7% for temperature, and 0.41% for salinity, indicating successful and effective performance [8]. The Internet of Things (IoT) has become a global benchmark for smart object communication, transforming real-world objects into interconnected devices [9]. Internet of Things (IoT) has significantly impacted both industry and private life, offering cost-effective solutions for life sciences research through remote environmental data collection. However, despite its potential, the full integration of IoT in natural sciences remains uncertain, indicating room for further development and exploration [10]. This study explores IoT applications in aquaculture, highlighting its role in productivity, sustainability and resilience. Bibliometric analysis of 428 publications (2012-2024) revealed a growing interest in water quality monitoring, disease prevention, and resource efficiency. Key themes include advanced systems, health monitoring, and predictive tools, with suggestions for future research on AI interoperability and integration [11]. A pond water monitoring device based on sensors and Arduino microcontroller was developed by M.M.Islam, 2023 [12] [13] to measure pH, temperature, and turbidity in ponds of Jamalpur District, Bangladesh. The data was sent to ThingSpeak IoT cloud platform and analyzed using 10 machine learning algorithms to monitor the water quality in real-time. The Internet of Things (IoT) has great potential for real-time monitoring. The article introduces an IoT framework designed to efficiently monitor and control various parameters of the water environment [14]. Traditional water quality monitoring in aquaculture tanks is limited by the lack of real-time data, leading to inefficient feeding practices, reduced productivity, and environmental risks. Addressing these limitations requires innovative solutions for continuous and accurate water quality assessment [15]. Perception-related challenges include barriers that discourage aquaculture farmers from using IoT systems. As a potential solution, the literature suggests that policy makers should intervene by promoting the benefits of using IoT systems and providing incentives to encourage the adoption of such technologies [16]. Chiu, Min Chie et al 2022 [17] developed a smart aquaculture monitoring and control system using IoT devices. The system collects and analyses data, and an artificial intelligence-based deep learning (DL) model is used to predict the growth of California Brass fish. The important cultivation parameters for freshwater aquaculture include water temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), and salinity levels [18]. The need to ensure future food security and estuarine water quality concerns are driving aquaculture expansion into coastal waters. A thorough evaluation of new aquaculture sites needs to be conducted prior to large investments in infrastructure and labor. Measurements of water temperature, salinity and dissolved oxygen are important to assess site suitability and the risk of harmful algae [19]. Water quality is a crucial factor in shrimp farming, where production is greatly affected by water conditions. Challenges such as population growth, pollution and global warming have impacted fisheries, especially freshwater shrimp. This research monitors pH, temperature, TDS, EC, and salinity in real-time, overcoming the limitations of manual systems in water quality monitoring.[20][21]. Rapid developments in the utilization of Internet of Things (IoT) technology to monitor water quality in real-time. The integration of IoT in aquaculture enables accurate and continuous monitoring of important parameters such as pH, temperature, DO, salinity and TDS, overcoming the limitations of manual systems. Several studies have developed Arduino and sensor-based devices to monitor water quality in real-time, with notifications via mobile apps. The application of IoT not only improves production efficiency, but also reduces environmental risks through more integrated and continuous monitoring. The implementation of this technology requires compatible sensor and actuator devices and reliable communication network support. Further research is directed towards the integration of artificial intelligence (AI) and improved interoperability of IoT devices for more accurate and efficient prediction of water conditions. Although IoT technology offers many advantages, research shows that adoption by farmers is still low due to lack of knowledge, high costs, and resistance to technological change [4]. Literature also mentions that government policy support and technology education are needed to accelerate IoT adoption among small and medium-sized farmers [17]. Based on the preceding context, the problem formulation in this study revolves around how the design and deployment of a comprehensive Internet of Things (IoT) system can assist farmers in monitoring water quality in real-time with greater accuracy and

lower costs compared to traditional methods. The primary objective of this research is to design and propose an integrated IoT system that emphasizes cost efficiency and enhanced accuracy in water quality monitoring for shrimp farming. The proposed system aims to address the limitations of conventional manual monitoring methods, which are often characterized by the lack of real-time capabilities, inadequate detection of environmental parameter fluctuations, and limited predictive analysis of water conditions. By leveraging precise sensors and robust communication networks, the system is expected to significantly enhance the productivity and sustainability of shrimp farming operations. Previous studies have shown that IoT applications in shrimp farming are generally fragmented, with monitoring systems typically focusing on individual parameters such as pH, temperature, or dissolved oxygen (DO) without comprehensive integration [4]. [15]. In contrast, this research proposes a fully integrated IoT platform capable of simultaneously monitoring various critical water quality parameters, including temperature, humidity, pH, and Total Dissolved Solids (TDS). This comprehensive approach is designed not only to improve real-time data accuracy but also to reduce operational costs, thereby enhancing both production efficiency and environmental sustainability in shrimp aquaculture.

METHODE

The design and manufacture of prototypes of air humidity and water temperature monitoring devices were carried out in the laboratory of the Mechanical Engineering Study Program, Faculty of Engineering, University of Muhammadiyah Sumatra Utara, while testing the tools was carried out in a shrimp pond located on Jalan Paluh Merbau, Tj. Rejo, kec.percut sei tuan, deli Serdang district, North Sumatra, Indonesia as Fig 4.



Fig. 1. ESP32 DevKit V1 Module - Microcontroller with Integrated WiFi and Bluetooth

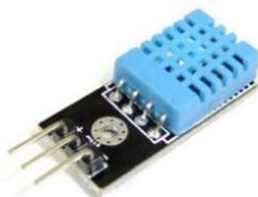


Fig. 2. DHT11 Temperature and Humidity Sensor Module - Digital Output for Environmental Monitoring



Fig. 3. DS18B20 Waterproof Temperature Sensor - Stainless Steel Probe for Water and Environmental Monitoring

This research begins with preparing tools and materials consisting of several main components. The ESP32 microcontroller was used as the main controlling unit in the shrimp pond water quality monitoring system. The ESP32 was chosen because it has superior specifications, including a 32-bit dual-core processor and integrated WiFi and Bluetooth connectivity, enabling real-time sensor management. Some of the main sensors interfaced with the ESP32 include: DSB18B20 to measure water temperature, DHT11 to measure air temperature and humidity, pH Sensor to measure water acidity, and Turbidity Sensor to detect water clarity. In addition, Portable WiFi is used as a medium for internet connectivity in remote locations that are generally far from conventional internet network infrastructure. Portable WiFi allows flexible and real-time data transmission to the cloud platform. Next, the device was installed in the field. All sensors are connected to the GPIO (General Purpose Input Output) found on the ESP32 microcontroller at this stage. Each sensor is installed strategically in the pool to optimize measurement accuracy. The DSB18B20 sensor is placed in the pool's center to measure the water temperature evenly. In contrast, the DHT11 sensor is installed in an open area to monitor the air temperature and humidity accurately. The pH sensor is positioned in a part of the pond prone to changes in water quality, and the Turbidity Sensor is placed near the water inflow and outflow to monitor fluctuations in clarity in real-time. After the device installation, the next step is testing the connection between the ESP32 and the Portable WiFi. This test aims to ensure that the data collected by the sensors can be properly transmitted to the cloud platform. The connectivity test includes checking the stability of the WiFi signal throughout the pool area, testing the data transmission from ESP32 to the cloud directly, and verifying data access via mobile devices or computers in real-time. The good connection test results ensure the system is ready to monitor optimal water quality. The next stage is real-time data collection performed by each sensor. The DSB18B20 sensor accurately measures the water temperature, the DHT11 monitors the air temperature and humidity, the pH Sensor measures the acidity or basicity of the water, and the Turbidity Sensor detects the clarity of the water. The data collected by these sensors is then processed by the ESP32 and transmitted in real-time to the cloud platform via a Portable WiFi network. This allows the farm manager to monitor the water condition of the shrimp pond directly and remotely, without the need to be present at the physical location. The next stage is data storage and monitoring once the data has been successfully transmitted to the cloud. Data stored on the cloud platform can be accessed anytime through a computer.

Software Design (Software)

In the design of this tool describes the creation of a Google Sheet to send data on experimental results, as for the steps to create a Google Sheet as follows: Open Google Sheet Create a new spreadsheet and name the spreadsheet and also the sheet as needed (for example: "Humidity and temperature monitoring") and sheet sheet (for example: "Humidity and temperature monitoring_Sheet") as in Fig.4 Fill in the columns, rows to read the values obtained in the test. Record and Save Google Sheets Project Name, Google Sheets ID, Sheet Name on NotePad or similar, as shown in Fig 5. Fill in the columns, rows to read the values obtained in the test

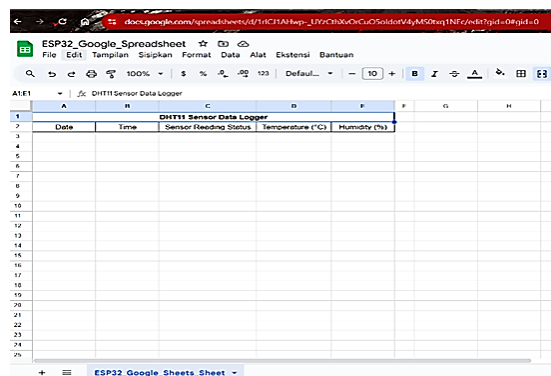


Fig. 4 Creating a New Spreadsheet

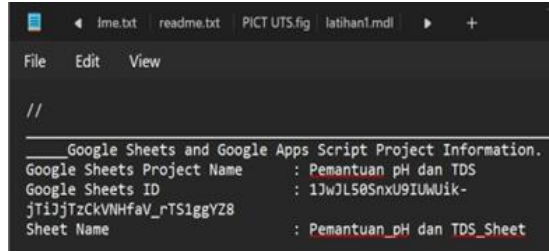


Fig. 5 Saving Data to NotePad

After that, activate Google Apps Script by clicking Extensions > Apps Script then create a Google Apps Script code to read the data, as shown in Fig. 6

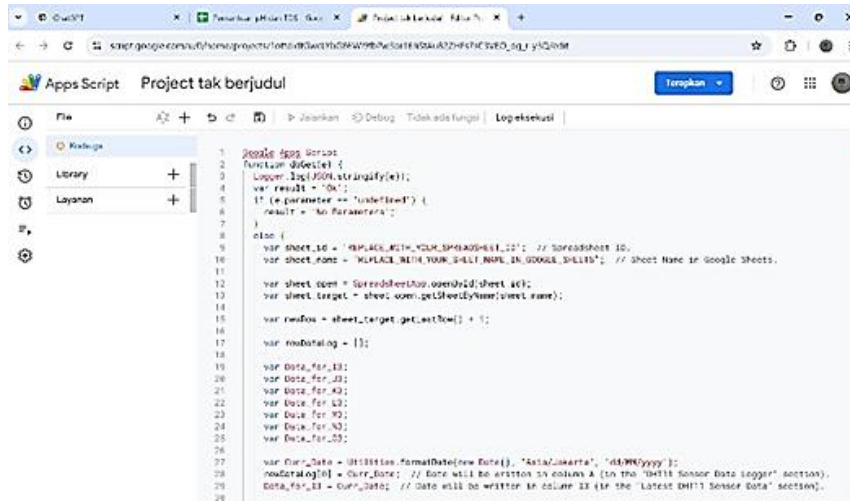


Fig. 6 Creating Google Apps Script Code

- After that, save the code by clicking > Apply > New Deployment > Select type then click Web application > Select anyone access > click apply. Then copy the web URL > click done, like Fig 7



Fig. 7 URL Web

- After the Web URL is copied then add the URL as in Fig 8. After that, try the URL that was copied earlier, if there is no problem in the code.

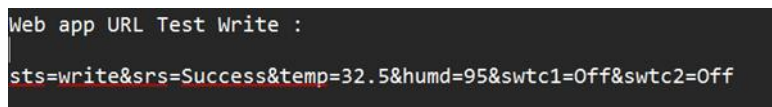


Fig 8 URL Pembacaan Data

script.googleusercontent.com/macros/ecno:u...

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Ok, Switch_2 Written on column G, Sensor Reading Status Written on column C,
Temperature Written on column D, Switch_1 Written on column F, Humidity Written on
column E
```

	A	B	C	D	E	F	G
1	DHT11 Sensor Data Logger						
2	Date	Time	Sensor Reading Status	Temperature (°C)	Humidity (%)	Switch 1	Switch 2
3							
4	12/09/2024	11:34:53	Success	32.5	85	Off	Off

Fig. 9 Readable Apps Script

- App Script then the result will be as shown below
- CodeSelesai.

RESULT AND DISCUSSION

The testing of the monitoring system and its sensors in the shrimp pond aimed to verify the proper functioning of the sensors and the successful transmission of data. The testing process involved reading the measurement results displayed on the prepared Google Sheet. In this study, the monitoring of air humidity and water temperature was conducted at the shrimp pond located on Paluh Merbau Street, Tj. Rejo, Percut Sei Tuan District, Deli Serdang Regency, North Sumatra, Indonesia, as illustrated in Fig. 11-13 Fig 11 shows the relationship between time of day (WIB) and water temperature and relative humidity (RH) in shrimp ponds. The distribution of the data indicates that water temperature tends to increase with time from morning to noon, reaching a peak around 2:00 pm, then decreasing again in the afternoon. In contrast, relative humidity (RH) showed the opposite trend, where values were higher in the morning, decreased as water temperature increased, and increased again in the afternoon. This phenomenon occurs because an increase in air temperature increases water evaporation, thereby reducing relative humidity. The decrease in water temperature in the afternoon results in an increase in relative humidity as water vapor in the atmosphere is again condensed. This pattern shows the natural thermodynamic interaction between temperature and humidity in the pond ecosystem.



Fig. 10 Research location

Figure 12 illustrates the relationship between time (WIB), water temperature (°C), and relative humidity (RH%) during the second testing phase at the shrimp pond. The graphical data distribution demonstrates a clear diurnal pattern in water temperature, which gradually increases from the early morning, reaching its peak around 14:00 to 15:00 WIB. This upward trend is

primarily driven by solar radiation, which intensifies as the sun rises, contributing to the gradual warming of the pond water. The maximum temperature is typically sustained for a brief period before it begins to decline steadily towards the late afternoon as solar intensity diminishes [1].

In contrast, relative humidity (RH%) exhibits an inverse trend compared to water temperature. The morning hours are characterized by high RH levels, coinciding with lower water temperatures and reduced rates of evaporation. As water temperature rises during midday, the rate of evaporation from the pond surface accelerates, resulting in a significant reduction in ambient moisture content and, consequently, a decrease in relative humidity. This phase marks the strongest divergence between temperature elevation and humidity reduction, reflecting the impact of thermal energy on water vapor dynamics.

As the afternoon progresses and the water temperature starts to decline, the evaporation rate decreases, allowing moisture to accumulate in the surrounding air. This shift facilitates the condensation of water vapor, thereby increasing relative humidity levels once again. This cyclical interaction underscores the thermodynamic relationship between heat transfer and moisture balance in the pond ecosystem.

The observed pattern not only reflects natural atmospheric processes but also highlights the critical role of thermal fluctuations in regulating the microclimate of shrimp ponds. Effective understanding of these temperature-humidity interactions is crucial for optimizing aquaculture practices [21]. By managing water temperature and maintaining appropriate humidity levels, aquaculture practitioners can create a stable and conducive environment for shrimp growth, ultimately enhancing both health and productivity. This insight is vital for strategic environmental control in sustainable shrimp farming.

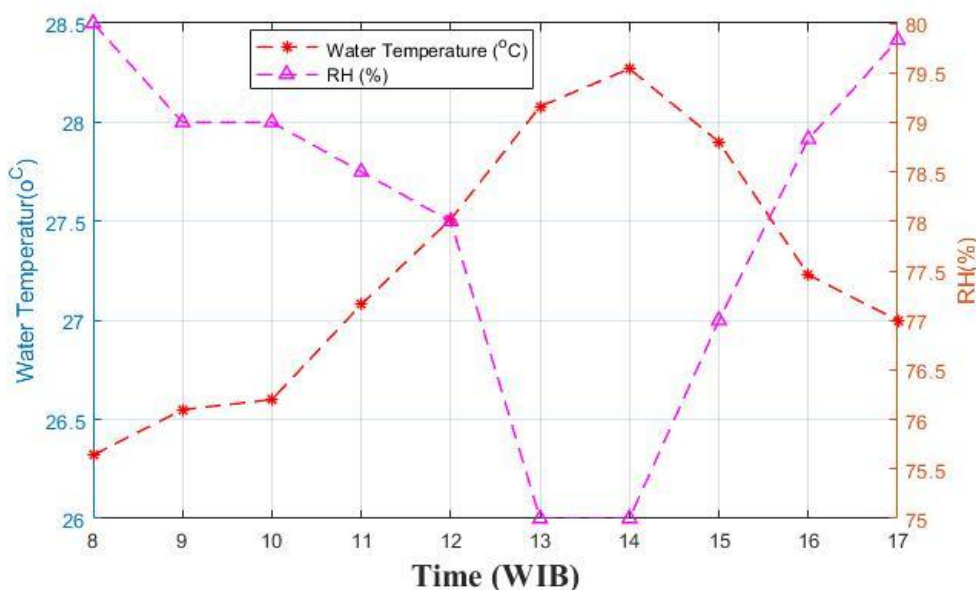


Fig 11. Variation of water temperature and relative humidity (rh) over time in in wib zone on the first day of testing

Fig. 11 to 13 comprehensively illustrate the temporal dynamics of water temperature (°C) and relative humidity (RH%) in shrimp ponds during three distinct testing phases. The graphical representation indicates a consistent trend where water temperature progressively rises from the early morning, reaching its peak around 14:00 to 15:00 WIB. Following this peak, water temperature gradually declines as the afternoon transitions into evening. This diurnal fluctuation is primarily driven by solar radiation, which intensifies during midday and subsequently diminishes as the sun sets, resulting in a decrease in ambient and water temperatures.

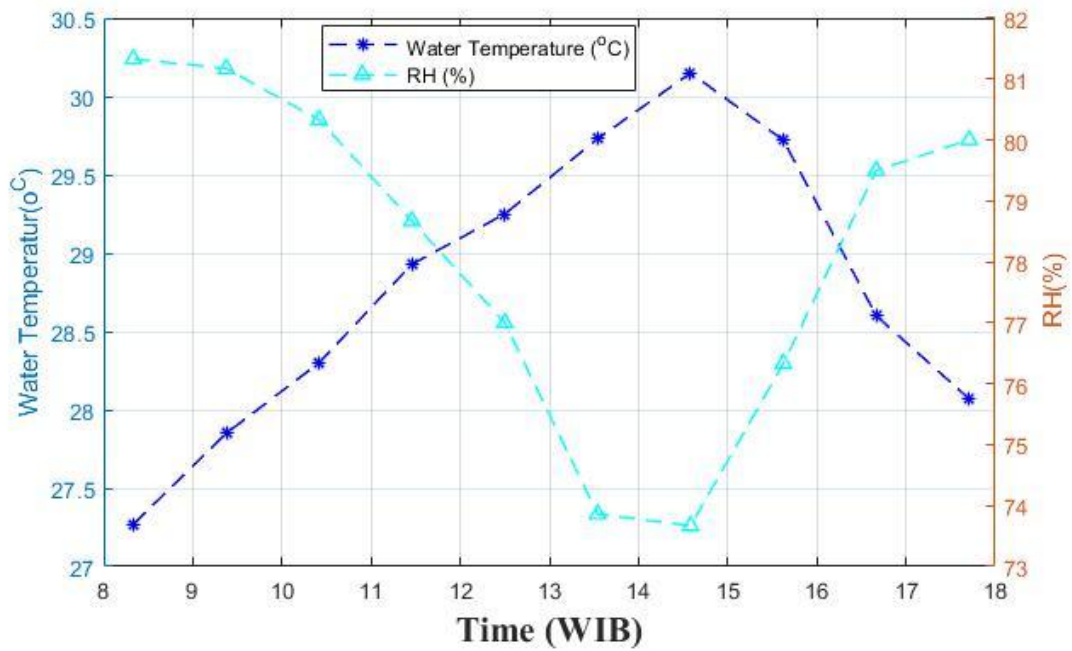


Fig 12. Variation of water temperature and relative humidity (RH) over time in in wib zone on the second day of testing

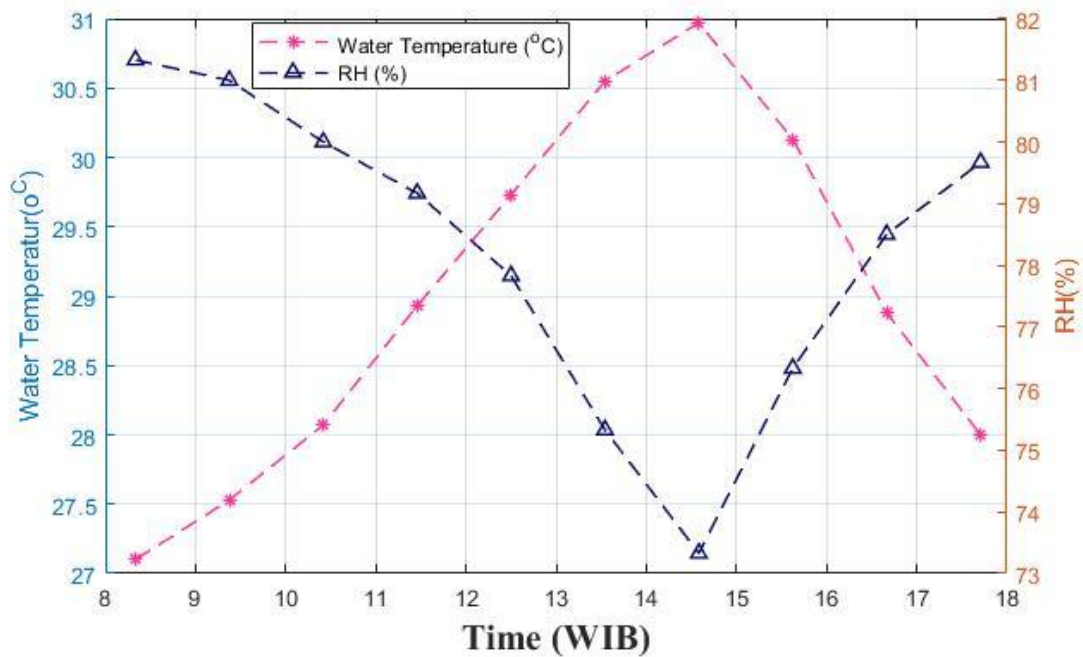


Fig 13. Variation of water temperature and relative humidity (RH) over time in in wib zone on the third day of testing

Conversely, relative humidity (RH%) demonstrates an inverse correlation with water temperature across all testing phases. In the morning, RH% is observed to be at its highest, corresponding with lower water temperatures and reduced evaporation rates. As solar intensity increases, water temperature rises, which subsequently accelerates the evaporation process. This heightened evaporation reduces the moisture content in the surrounding air, thereby lowering

relative humidity levels. This phase typically continues until midday, coinciding with the peak in water temperature.

The afternoon period marks a shift in this dynamic. As the sun's intensity wanes and water temperature declines, atmospheric moisture begins to condense, leading to a gradual recovery in RH%. This process is consistent with thermodynamic principles, where cooler temperatures facilitate moisture accumulation in the air. Such cyclical interactions highlight the natural evaporative cooling mechanisms that regulate the pond's microclimate. This predictable inverse relationship between water temperature and relative humidity is not only indicative of standard atmospheric thermodynamics but also plays a critical role in the ecological stability of shrimp ponds. Effective management of these parameters is crucial for maintaining optimal pond conditions, ensuring shrimp health, and promoting growth [4]. Understanding these interactions enables aquaculture practitioners to make informed decisions on environmental control, enhancing sustainability and productivity in shrimp farming operations.

CONCLUSION

The analysis of Figures 11-13 demonstrates a consistent inverse relationship between water temperature and relative humidity (RH) throughout the testing phases in the shrimp pond. Water temperature steadily increases from morning to midday, reaching its peak around 14:00 to 15:00 WIB, then gradually decreases in the afternoon. Conversely, RH is highest in the morning, decreases as the temperature rises, and increases again in the afternoon. This pattern is driven by thermodynamic interactions where rising temperatures accelerate water evaporation, lowering humidity, while cooling in the afternoon promotes moisture condensation, increasing RH levels. These dynamics are crucial for understanding pond climate stability.

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