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Real-Time IoT for Water Quality Monitoring System in Seaweed Aquaculture Ponds

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ABSTRACT
Approximately 8.6% of the total marine biota consists of seaweed, which is an abundant biological resource in Indonesian waters. Various types of food, cosmetic ingredients, and other products are made from seaweed. The water quality in ponds greatly affects the growth of Gracillaria sp. seaweed. Poor water quality, such as high levels of pollutants or toxins, can damage seaweed growth. Drastic temperature changes also disrupt the physiological processes and growth of seaweed. The aim of this research is to develop a system that can monitor water quality and display this information in real-time using the Internet of Things. The method used involves measuring temperature, current strength, light intensity, and water pH. These sensors are connected to a microcontroller as the control center, and the data is sent to a website for monitoring purposes so that steps can be taken more quickly to adjust water quality needs. The integration of sensors and IoT is working well, but the reliability of the sensors still needs to be tested and calibrated. Additionally, adjustments to the environmental conditions around the sensors are necessary for them to function properly.
Keywords:Internet, IOT,Seaweed,Sensor,Microcontroller

INTRODUCTION

The Internet of Things (IoT) is a system aimed at extending the benefits of sustainable internet connectivity. This system includes the exchange of information, remote control, and extensive use of sensors[1], [2], [3]. IoT can also be used in the livestock and agricultural sectors, where all components are connected to local and global networks through sensors that are always active and internally integrated[4], [5], [6].

The findings of this research will provide insights into the relationship between water quality and the growth of Gracilaria sp. seaweed[7], [8]. The goal is to utilize internet assistance to facilitate economic activities in general and indirectly impact economic growth and development in line with the goals of the Digital Economy[9]. Based on the description, the research problems in this study are: (1) How to connect and integrate sensor data with IoT devices and the water quality monitoring system website for Gracellia sp. seaweed cultivation ponds? (2) How to maintain the reliability of the sensor measurement data in the water quality monitoring system for Gracellia sp. seaweed cultivation ponds?

Evidence of the benefits of IoT can be seen in research conducted by Aryotejo et al. in 2024, which demonstrated the use of IoT in monitoring water quality in shrimp farming[10]. Another study by Yulieth et al. in 2022 concluded that most IoT applications are used in water quality monitoring[5]. Furthermore, research by Iniyan et al. in 2024 resulted in an IoT is used for monitoring water quality utilizing automatic sensors. There are many other applications of IoT in various fields.

Seaweed is a potential resource that has long been utilized by the community as food and medicine. The market opportunity for seaweed is growing. This is supported by the fact that many researchers have begun studying the materials and benefits of seaweed, and the seaweed market is likely to expand in the future[11]. Current developments have significantly advanced the utilization of seaweed, especially its processing into agar. Seaweed is an irreplaceable commodity because there are no synthetic products for it. Seaweed cultivation is labor-intensive, meaning it can absorb a lot of labor[12]. Indonesia has great potential in seaweed production and processing. According to data, Indonesia is the largest seaweed producer in the world, being the second-largest producer of seaweed. Indonesia will produce 9.6 million tons of seaweed in 2022, accounting for 65% of aquaculture production, with 65,000 households involved in seaweed farming[13], [14]. In this study, IoT is applied to monitor water quality at seaweed cultivation sites.The urgency in seaweed cultivation research is that failures are often caused by various factors. One of them is the slow growth of seaweed due to unfavorable environmental conditions at certain times or seasons[11], [15]. Generally, these conditions are influenced by pests and diseases. Gracilaria Sp. seaweed often responds differently when planted in different ponds[16]. The seeds used are the same good seeds, but when planted in different pond locations, the seaweed is damaged, and crop failure occurs. This is concerning because seaweed farmers have not been able to overcome these problems[17]. It can be concluded that these factors are caused by the planting location or environment. Ponds have different specifications depending on their location, including the strength of the water flow irrigating the pond, the intensity of sunlight received, and even the pH of the pond water.

METHOD

This research will use software such as Windows, XAMPP, Visual Studio Code, and Arduino IDE. The hardware to be used includes WeMos D1 R1 WiFi ESP 8266, sensor shield, temperature sensor, current sensor, light sensor, pH sensor, power supply, WiFi module, solar panel, access point, and jumper cables. Arduino will be used as the controller to process and manage the processes with the system embedded in the microcontroller[18], [19]. The monitoring equipment circuit can be seen in Figure 1.

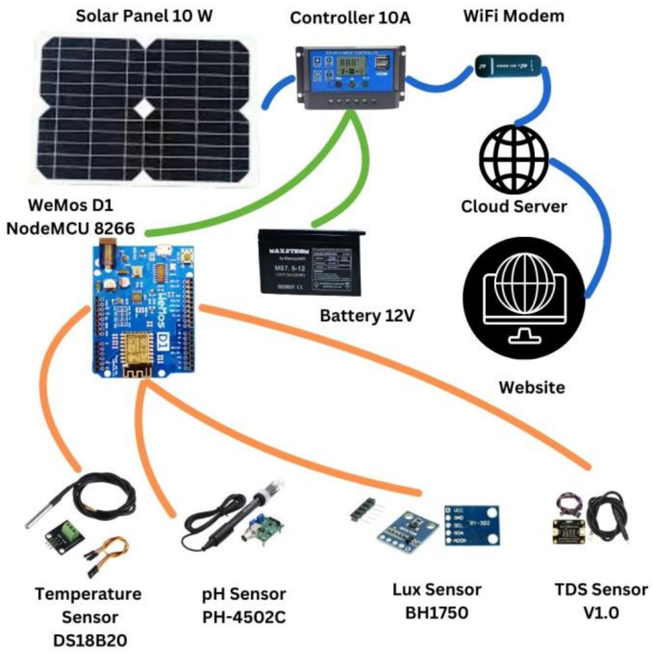


Figure 1. Detailed block diagram of the proposed system

System Architecture

This IoT-based water quality monitoring system architecture is designed to monitor various water quality parameters in real-time in seaweed aquaculture ponds[20], [21]. The main components used in this system include WeMos D1, temperature sensor, pH sensor, lux sensor, and TDS sensor. In Table 1, the sensors and WeMos are connected using the C programming language with the Arduino IDE. There are 3 sensors connected to pin A0, which will be activated alternately by setting pins 2, 3, and 4 to HIGH alternately according to the measurement time. Table 2 is for the WiFi internet connection with WeMos, a USB plug-in modem and Internet from mobile broadband are used. The system is connected to the internet via a WiFi modem and powered by a 12V battery recharged using a 10W solar panel and a 10A controller.

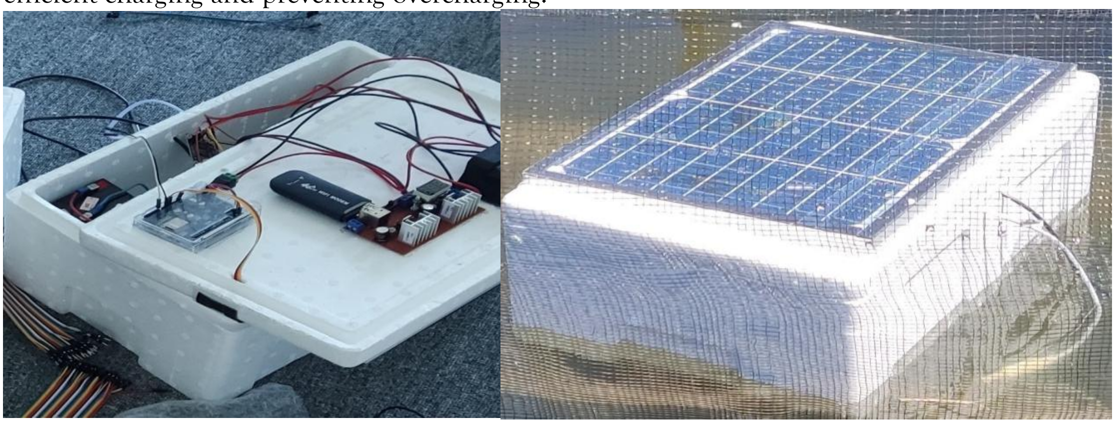
Table 1. Sensor and WeMos Connections

Sensor	Include	Const	Pin
PH Meter	Wire.h	Float PH_CALIBRATION Float PH_LOW Float PH_HIGH A0, INPUT	4, OUTPUT
BH1750	BH1750.h		SCL SDA
DS18B20	Wire.h	A0, INPUT	3, OUTPUT
TDS Sensor Meter V1.0	Wire.h	A0, INPUT	2, OUTPUT

Table 2. WeMos Connection with WiFi Internet

Include	Const
ESP8266WiFi.h	SSID="Marana"
WiFiClient.h	PWD ="*********"
ESP8266HTTPClient.h	url=http://syamtech.my.id/Marana/receivedata.php"

WeMos D1 is A microcomputer responsible for collecting data from various sensors and transmitting it to the server via a WiFi connection, temperature sensor for measures the water temperature to ensure an optimal environment for seaweed growth, pH Sensor for measures the acidity or alkalinity of the water, which is crucial for seaweed health, lux sensor for measures the light intensity around the pond, which affects seaweed photosynthesis and TDS Sensor for measures the total dissolved solids in the water, which is an indicator of water quality. Figure 2(a) shows the module used, which includes WeMos D1, Sensor, solar Panel, controller, battery, and modem. WiFi Modem to connects the system to the internet to ensure that monitoring data can be accessed in real-time remotely. The WeMos D1 transmits the data collected from the sensors to the server via this connection. 12V Battery is provides power for the entire system. This battery is designed to support continuous system operation, 10W Solar Panel for recharges the 12V battery. In Figure 2(b), this solar panel converts solar energy into electrical energy used to charge the battery and 10A Controller for regulates the flow of electricity from the solar panel to the battery, ensuring efficient charging and preventing overcharging.



(a) (b)

Figure 2. Modul Implementation of; (a) The module used includes WeMos, modem, controller, sensor, and battery. (b) solar panel module and the shape of the device createdWith this architecture, the water quality monitoring system can operate independently, collecting and transmitting essential data about the water conditions in the seaweed aquaculture pond in real-time. This allows for more effective monitoring

and quick response to environmental changes, which is vital for maintaining the health and growth of seaweed.

Comparative data

In this study, the comparative data used consists of two types. First, measurement data obtained directly from the laboratory, where various water quality parameters such as temperature, lux, TDS, and pH are measured using precision instruments. This data provides an accurate picture of water quality conditions at specific points in time and is used as the primary reference in the analysis. Second, the standard data that indicates the range of temperature, lux, TDS, and pH considered optimal for seaweed growth. These standards are obtained from scientific literature and industry guidelines, established based on research and best practices in seaweed aquaculture. This data helps determine whether the water conditions in the pond meet the optimal criteria to support healthy seaweed growth.

These two types of comparative data are continually compared to evaluate the effectiveness of the IoT-based water quality monitoring system used in this study. Table 3 illustrates the water quality standards that are beneficial for seaweed growth, which serve as a reference in data analysis and determining the success of the implemented monitoring system. By using these two types of comparative data, the study aims to ensure that the monitoring system is not only capable of accurately measuring water quality parameters but also provides relevant information for decision-making in seaweed pond management.

Table 3. Seaweed Pond Water Quality Standards[16], [16], [18], [22]

Parameter	Standar
pH	7 – 8.5
Temperature	20°C - 28°C
Light Intensity	1500 – 3000 Lux
TDS	450 – 700 ppm

Data reading and conversion

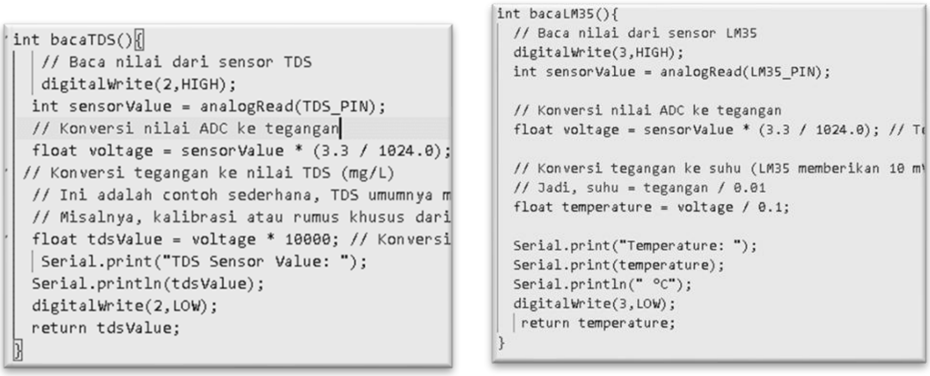
C is a popular choice for embedded system development due to its efficiency in resource management and its close relationship with hardware. The IoT-based water quality monitoring system that uses WeMos D1 and four sensors (temperature, pH, lux, and TDS) utilizes C language to write program code responsible for reading sensor values, processing data, and sending the results to the server[23]. In Figure 3(a), the code for reading the sensor value is displayed, which will directly provide a value in Lux units. This value is stored and then sent to the server. Figure 3(b) shows how to read the pH on the pH sensor, where the received value is in the form of electrical voltage and then converted using equations (1) and (2). Figure 3(c) shows a snippet of the program code for reading the TDS value. The resulting value is in the form of voltage, which is then converted using equation (1) and (3). Figure 3(d) displays the program code for reading the temperature value. The resulting value is also in the form of voltage, which is then converted using equation (1) and (4).

```
int cahaya(){
  float lux = lightmeter.readLightLevel();
  Serial.print("Lux: ");
  Serial.println(lux);
  return lux;
}
```

(a)

```
int bacapH(){
  // Baca nilai dari sensor pH
  digitalWrite(4, HIGH);
  int sensorValue = analogRead(pH_PIN);
  // Konversi nilai ADC ke tegangan
  float voltage = sensorValue * (V_REF / 1024.0);
  // Konversi tegangan menjadi pH
  float pH = 7 + ((voltage - 2.5) * 3.5) + 3.5; //
  Serial.print("pH Value: ");
  Serial.println(pH);
  digitalWrite(4,LOW);
  return pH;
}
```

(b)



(c) (d)

Figure 3. Program code for; (a) Lux Sensor, (b) pH Sensor, (c) TDS Sensor, (d) Temperature Sensor

Equation for pH conversion :

$$v = sensorValue \times \left(\frac{v\_ref}{1024}\right) \quad (1)$$

$$pH = pH_{Low} + \left(3.5(v - 2.5)\right) + 3.5 \quad (2)$$

Equation for TDS conversion :

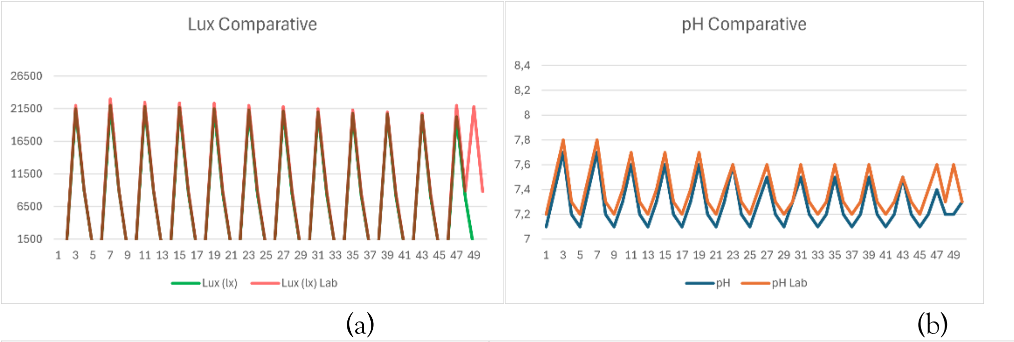
$$tdsValue = v \times 10000 \quad (3)$$

Equation for Temperature conversion :

$$temperature = v/0.1 \quad (4)$$

RESULTS AND DISCUSSION

In this trial phase, we used two different sets of measurement data: 50 measurement data from the IoT-based monitoring device and 50 measurement data from laboratory tests. The primary objective of this trial was to evaluate the accuracy of the IoT-based water quality monitoring system compared to more conventional laboratory measurement methods. Figure 4(a) showing the IoT monitoring system showed an accuracy of 89% in measuring light intensity (lux). Although there were some differences, this result indicates that the system is capable of providing a reasonably good estimate of lighting conditions in the seaweed pond. The pH measurement using the IoT device achieved an accuracy of 98%. This result is very close to the laboratory data, indicating that the pH sensor in this system is very reliable in measuring the acidity or alkalinity of the pond water as shown in Figure 4(b).The IoT system recorded an accuracy of 99% in measuring water temperature as shown in Figure 4(c). This signifies that the system can consistently and accurately measure temperature, which is an important parameter in the management of seaweed ponds. Figure 4(d), the TDS measurement using the IoT system showed an accuracy of 98%. This demonstrates that the IoT device is quite reliable in measuring the total dissolved solids in the water, which is a key indicator of water quality.Overall, the IoT-based water quality monitoring system tested showed excellent performance with high accuracy for all measured parameters. The use of this device can be an efficient and effective alternative for measuring water quality in seaweed ponds, especially given the system's capability to perform real-time monitoring and wirelessly transmit data to the server. This trial's results highlight the great potential of implementing IoT technology in aquaculture, allowing for more responsive and sustainable water quality oversight. With high accuracy levels, this system can help seaweed farmers maintain optimal pond conditions, thereby supporting healthy and productive seaweed growth.



(c) (d)

Figure 4. Comparative Graph for;(a) Lux, (b) pH, (c) temperature, (d) TDS

3.1. Comparative with Seaweed Pond Water Quality Standards

Data obtained from the IoT-based water quality monitoring system is compared with the standard water quality measurements for seaweed ponds. The results indicate that the accuracy percentages for lux measurement is 26%, pH is 100%, temperature is 26%, and TDS is 100%. The accuracy of pH and TDS measurements is very high, reaching 100%, which demonstrates that the pH and TDS sensors in the IoT-based monitoring system work very well and are consistent with laboratory standards. This data indicates that the system can be relied upon to measure these parameters, providing accurate and trustworthy results.However, the accuracy for lux and temperature measurements is only 26%. Several factors contribute to this low accuracy. For lux measurement, one primary reason is the high variability in lighting conditions within the pond environment, which cannot be perfectly captured by the IoT sensors. Rapid changes in light intensity due to cloud movement, shadows from surrounding structures, and variations between day and night can affect the measurement results and cause discrepancies with laboratory standards.As for temperature measurement, the low accuracy is likely due to suboptimal sensor calibration. The temperature sensor may not respond quickly to changes in the surrounding environment and pond water, resulting in inconsistent data. Other factors that might influence this include differences in the surrounding environmental conditions that can affect the overall temperature measurements.IoT-based monitoring system shows high reliability in pH and TDS measurements, there is a need for improvements in lux and temperature measurements. These improvements could involve more precise sensor calibration and enhancements to the quality of sensors used, enabling the system to provide results that are more accurate and consistent with the standard water quality measurements for seaweed ponds. Thus, the system could become a more effective and efficient tool for real-time monitoring of pond water quality.

IMPLICATIONS FOR THE RESEARCH FIELD AND COMMUNITY

The results obtained from the IoT-based water quality monitoring system for seaweed ponds have several important implications that can affect various aspects, including cultivation techniques, resource management, and environmental sustainability. The IoT system allows real-time monitoring of water quality parameters such as pH, TDS, temperature, and lux[24]. With accurate and up-to-date data, seaweed farmers can make quicker and more precise decisions to maintain optimal pond conditions, thereby improving operational efficiency and potential yield. Although the system showed high accuracy in measuring pH and TDS, there are challenges in measuring lux and temperature[25]. These results indicate the need for further improvements in sensor calibration and the quality of the technology used, which in turn can drive the development of more reliable and advanced IoT technology. By continuously and real-time monitoring water quality, the IoT system helps detect and prevent conditions that could harm the environment, such as pollution or drastic changes in water quality. This contributes to more sustainable and environmentally friendly cultivation practices. Implementing IoT technology in seaweed cultivation can be accessible to small farmers, enabling them to leverage advanced technology that was previously available only to large industries[26], [27]. This can help bridge the technology gap between small and large-scale farmers. The data generated from this IoT monitoring system can serve as valuable data for further research and development of more efficient cultivation methods. Researchers can analyze this data to identify patterns and trends that can help develop more effective cultivation techniques. Overall, the use of IoT-based monitoring systems in measuring seaweed pond water quality offers numerous benefits and opportunities for improvements in various fields. However, continuous efforts are needed to address existing challenges, especially in the measurement of lux and temperature, to ensure the system provides the most accurate and reliable results.

CONCLUSION

Based on the data provided, several important conclusions can be drawn from the research on the IoT-based water quality monitoring system for seaweed farming ponds. The IoT-based monitoring system demonstrates high reliability in measuring pH and TDS, with accuracy levels of 100% for each. This indicates that the pH and TDS sensors in this system are highly accurate and dependable for continuously measuring these critical water quality parameters.However, the accuracy of lux and temperature measurements is lower, with 26% accuracy for each. This suggests challenges with the IoT sensors' ability to accurately measure these parameters. Environmental factors, such as high variability in lighting conditions and suboptimal sensor response to temperature changes, can affect the measurement results. The low accuracy in lux and temperature measurements highlights the need for improved sensor calibration and advancements in the technology used. This is essential to ensure that all water quality parameters can be accurately measured by the IoT system. Despite these challenges, the research findings indicate that the IoT-based monitoring system has significant potential for application in seaweed farming. The key advantage of this system is its ability to perform real-time water quality monitoring, enabling farmers to quickly and accurately respond to changing pond conditions. Implementing IoT technology in water quality monitoring contributes to the sustainability and efficiency of seaweed farming. Continuous monitoring helps detect and prevent conditions that could harm the environment, while also improving operational efficiency.

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