A development of an IoT-based temperature-TDS monitoring system for shrimp cultivation pond

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Abstract

High-quality water resources are important parameters for the sustainability of human civilization, the health of ecosystems, and the advancement of vital sectors. High-quality water is also needed for shrimp cultivation ponds. However, water-quality monitoring in the estuary is limited. In line with this, this study focuses on the design and implementation of an IoT-based TDS and temperature measurement system for estuarine water, aiming to develop an efficient, accurate, and automated prototype to support the fisheries sector in West Lombok regency. This study used a microcontroller, temperature and TDS (total dissolved solids) sensors, a wireless router, and a display. These elements were developed as a water-quality-level monitoring system based on TDS and temperature. The system was calibrated using a standard comparator before being examined under real conditions. The calibration procedure was conducted inside a controlled chamber at a water temperature of 25°C for 60 minutes, with a steady flow rate. All procedures were repeated three times and tested using a Student's *t*-test. The IoT platform was tested using RSSI values with a 2s update interval. The calibration data were interpreted as a linear function between the standard and the developed system. The resulting design shows that the developed system can be installed at a shrimp cultivation pond with good performance. The designed system has a linearity of more than 90%. The system has a reliable accuracy level over 30 consecutive measurement days, resulting in the percentages of 85% to 93% (average = 91%). It can be concluded that IoT data communication via a wireless internet router performs well, with RSSI> -50 dBm for both sending and receiving. The IoT platform using ThingSpeak shows good performance (good stability), with a 2-second interval between data updates.

Keywords: clean water and sanitation; Internet of Things; Lombok Island; temperature; total dissolved solids.

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INTRODUCTION

The availability of high-quality water resources is an absolute prerequisite for the sustainability of human civilization, the health of ecosystems, and the advancement of vital sectors. Unfortunately, the surge in global population and the intensification of human activity have made water pollution a pressing environmental issue. This situation demands an effective water quality monitoring system to maintain resource sustainability and public health.

In Indonesia, water quality challenges have become a major issue. Data from the Ministry of Environment and Forestry (KLHK) frequently indicates a decline in the quality of natural water sources. This phenomenon is exacerbated in coastal and estuarine areas (Touhami, Qoraychy, and Hammani 2025; Wisha, Wijaya, and Hisaki 2025; Zhu et al. 2025). In these locations, high population density and activity have led to a substantial increase in household waste. The disposal of waste and sewage from various activities worsens water quality. Furthermore, as an estuary area, this region faces a dual threat: seawater intrusion, which limits freshwater availability, and pollution from land-based activities. This situation raises significant concerns for clean water supplies and the sustainability of local ecosystems.

Temperature and TDS (Total Dissolved Solids) become fundamental indicators for assessing water quality, including the groundwater and seawater. Temperature measures the physical property of water's thermodynamic behaviour, which is directly related to the energy changes. TDS indicates the total mass of dissolved solids (both mineral and organic) in water. High levels of TDS can describe pollution or excess minerals that can harm health, damage industrial equipment, and inhibit plant growth. A previous study shows that TDS levels often exceed recommended limits in many locations (Mohammadpour et al., 2025). Therefore, understanding and monitoring temperature and TDS (including other parameters such as EC (electrical conductivity), pH, etc.) distribution is crucial for sustainable groundwater management and for distinguishing freshwater from brackish water (Jung, 2026).

Estuaries, as estuarine environments, exhibit highly dynamic water conditions due to the mixing of freshwater from rivers with seawater. Changes in TDS levels in these areas indicate varying seawater intrusion following tidal cycles, seasonal fluctuations, and local pollution. To maintain ecosystem balance and support sustainable water resources for communities, a monitoring system capable of accurately capturing these dynamic changes is required. However, conventional monitoring methods such as manual sampling and laboratory analysis face significant challenges. These processes are time-consuming, costly, and most importantly, do not provide real-time data. These limitations hinder rapid response to sudden changes in water quality, even though changes in TDS and temperature levels in the field are rapid and require reliable, portable measuring devices (Fourie, Lekota, and Bergh 2025; Ndou and Nontongana 2025).

The emergence of IoT (Internet of Things) technology offers innovative solutions to overcome these limitations. By integrating EC and temperature sensors into an IoT-based system, water quality data can be automatically collected, transmitted, and analyzed from any location with a stable connection over an IoT platform (Fakhriyah, Marwoto, Cahyono, & Iswari, 2022). This system enables early anomaly detection and instant alerts, facilitating faster, more accurate decision-making in environmental management. The benefits of IoT have been proven effective across various applications; one study even successfully implemented IoT for real-time water quality assessment, achieving >90% accuracy in TDS measurements.

Lombok Island and shrimp farming are closely linked, as West Nusa Tenggara (NTB) Province, which includes Lombok, is one of Indonesia's leading centers of shrimp farming. Besides tourism, shrimp farming, particularly whiteleg shrimp, is a leading sector in NTB, capable of producing hundreds of tons of shrimp per harvest cycle. NTB is also a hub for large-scale shrimp farming, driving the regional economy.

Challenges facing shrimp farming in Lombok include environmental issues, such as mangrove ecosystem destruction and water pollution, as well as conflicts with local livelihoods, including those of fishermen and farmers. Other challenges include price fluctuations, disease outbreaks, difficulties in obtaining quality seeds and feed, and weak regulations regarding coastal land use. Many systems have been developed for monitoring shrimp cultivation processes. However, the main problem in this area is the measurement method. The most probable method is by using a single measurement point. This method is relatively cheaper than multiple measurements. It is related to the characteristic of seawater or brackish water that is very different from fresh water. Physically, brackish water has high salinity, which makes it hard to be measured non-stop or using multiple direct measurements. That is why a real-time monitoring system is urgently required, especially one that can be customized to specific needs, such as the condition in a real shrimp pond.

Developing an integrated, reliable temperature-TDS monitoring system for estuarine water conditions in Indonesia, particularly in the estuaries surrounding West Lombok Regency (West Nusa Tenggara Province), is challenging. Additionally, West Lombok regency is categorized as a shrimp-farming area. These areas have high cultivation activity, particularly in several coastal areas, such as Kuranji Dalang Village, with a primary focus on whiteleg shrimp. These activities require high-quality water to improve production. Hence, this gap underscores the need for research focused on designing practical, integrated systems — specifically for temperature and TDS measurements — that can operate effectively in estuarine environments. Therefore, this research focuses on the design and implementation of an IoT-based TDS and temperature measurement system for estuarine water, aiming to develop an efficient, accurate, and automated prototype to support the fisheries sector in West Lombok regency. The research novelty is highlighted at the operational level of the measurement system, where the developed system was deployed in a real pond for over 30 days with high accuracy. The system was also connected to the IoT platform, which operated nonstop, 24 hours a day. All of these benefits have a significant impact on the local shrimp cultivation pond, especially for monitoring water quality without relying on any indirect or single measurement method.

METHODS

System Development

This study used a microcontroller (ATMega2560-ESP8266 board), temperature and TDS sensors (DFRobot), a wireless router, and a display (liquid-crystal display 20x4) (Budianto et al., 2023). These elements were developed as a water-quality-level monitoring system based on TDS and temperature. All components were embedded in an acrylic box (3 mm thick) (Amalia, Wardoyo, Dharmawan, Nurhuda, & Budianto, 2021). The sensors were soldered to a PCB (printed circuit board), including the pin connector, jumper cable, and pin headers (Figure 1) (Andreini et al. 2020; Yani et al. 2024). The TDS sensor was connected to analog pin A0, and the water temperature sensor to analog pin A1. The voltage pins of the sensors were connected to the microcontroller's Vcc pin (5 V) after being regulated using a voltage regulator. The output signals from these analog pins were conditioned and converted into TDS and temperature data using an ADC formula:

$$y = a\,(5 \cdot output / 1023) + b \tag{1}$$

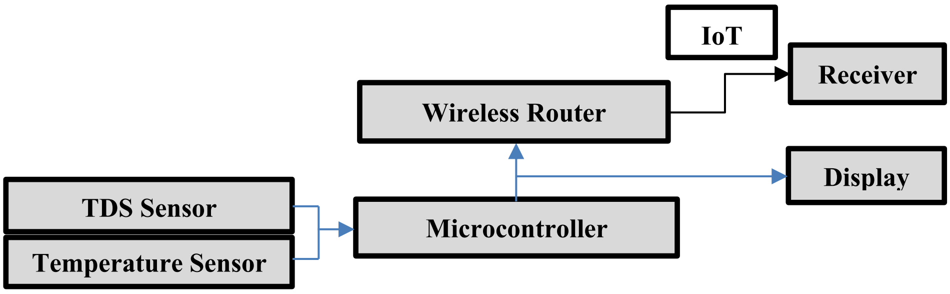

Figure 1. Schematic of the Designed System

The developed system was installed at a big pond in the estuary area surrounding the Kuranji Dalang Village, West Lombok regency, West Nusa Tenggara. The system was installed at that pond for 30 consecutive days. This pond was used for shrimp cultivation with a continuously flowing water system (operating 24 hours nonstop). A wireless router was used to communicate data between the system and the receiver station via the Internet Protocol (ThingSpeak.com, an IoT database). The RSSI (Received Signal Strength Indicator) parameter was used to measure data latency in IoT communication. The ThingSpeak platform was set to update the data every second (sampling time and update interval time *t* = 2s; the signal delay was not included in this parameter).

Calibration

The developed system was calibrated using a standard device (a TDS meter) to measure TDS levels accurately. This procedure was conducted in a closed chamber (temperature = 25°C). The system was considered calibrated when the linearity level was up to 98%. This calibration process was conducted by placing the developed system and the standard system in the chamber. Then, the verified water samples were poured into this chamber while the TDS and temperature values were recorded every second for one hour (60s). This treatment was repeated three times to improve the accuracy of the system examination inside a controlled water temperature (25 ^{o}C) and steady water flow rate.

System Examination

Equation (2) was used to calculate the linearity levels using a linear function. Equation (3) was used to predict the accuracy level of the TDS and temperature data (CSV-formatted data from the system). The data from the standard device (*c*) and the developed system (*d*) were used to calculate the accuracy level (*A*). The notations a and b represent the gradient and the constant of a linear function. The IoT connection was also tested, and the RSSI (Received Signal Strength Indicator) value was recorded (Budianto, 2022).

$$d = a.c + b \tag{2}$$

$$A = 100 - (\frac{|c-d|}{c} x100\%) \tag{3}$$

Statistical Analysis

All recorded data (from 30 days of the sampling periods) were interpreted as the mean and the standard deviation. The mean values from all data groups were compared using a Student's *t*-test. All data calculations and interpretations were conducted using Microsoft Excel (Data Analysis: Analysis ToolPak plug-in).

RESULTS AND DISCUSSION

System Calibration

Table 1 shows the calibration data obtained with a standard comparator device. This procedure was conducted inside a closed chamber. According to the results, the system is calibrated, with a linearity of 98.25. This value was obtained with a response time of 2 s (average) for the temperature sensor. Besides, the TDS sensor has a faster response time, showing a delay time of < 2s. These results indicate that the developed system can be examined in the real environment. These results are consistent for a measurement condition with a controlled temperature of ~25 °C. As shown in the sensor's datasheet, the sensor's accuracy is about 90% when tested in water at 25 °C. Besides, the TDS level's range is about 0-1000 ppm. The calibration data indeed show that the developed system can measure the verified water sample with the concentrations of 224-1000 ppm. Compared to the standard device, the value is very close (221-1000 ppm). In other words, the calibration data represents the performance of an accurate system (with a controlled water temperature of 25 °C and no water flow rate). No significant differences were obtained in the system calibration result ($p < 0.05$).

Table 1. System Calibration Results ($p < 0.05$)

Object	Temperature (°C)	TDS (ppm)	Linearity (%)	R^2 Constant
System	25.26	224-1000	98.25	0.9825
Standard	25.11	221-1000		

System Examination

The developed system was further examined in a real-world environment (a pond) for 30 consecutive days. The results show that it worked continuously for 30 days (non-stop). As seen in Figure 2, the accuracy is consistently >91% (average), indicating high accuracy. On the first day, the accuracy was 93%. On the fifth day, the accuracy increased to 100%. However, the accuracy decreased to 85% on the 11th day. Similar values are found at the 16th, 18th, and 26th. The fluctuation in accuracy was likely strongly influenced by the river's water quality (salt composition, gas content, calcium, etc.) (Ho et al., 2023; Khan et al., 2023), as it differed markedly from groundwater or freshwater conditions. Another strong influencing parameter is the pump performance and the tubes.

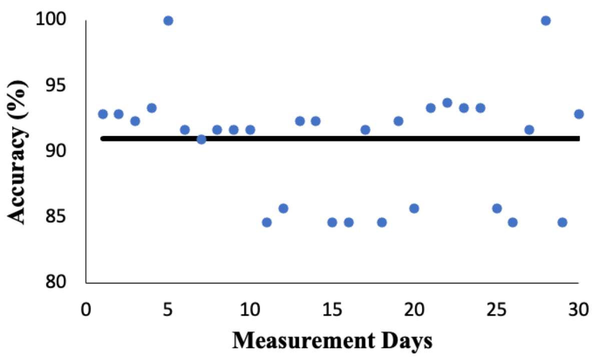

Figure 2. The Accuracy Levels of the System for 30 Consecutive Days

The RSSI parameter represents the IoT data connection over the past 30 days. As seen in Figure 3, the signal strength was powerful. The indicator shows the value between -47 dBm to -40 dBm. The highest value indicates a strong internet connection signal. A higher RSSI value indicates a stronger signal, while a lower RSSI value indicates a weaker signal.

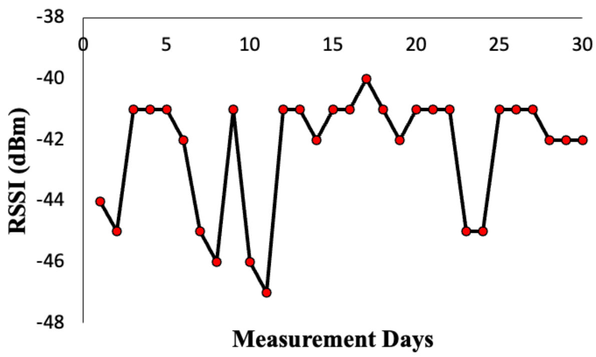

Figure 3. The RSSI Levels of the System for 30 Consecutive Days

The results indicate that IoT technology can transmit signals effectively. Several studies have successfully applied IoT to water quality monitoring. A system was developed to assess water quality in real time, monitoring pH, TDS, temperature, and turbidity with high accuracy, achieving 98.10% accuracy for TDS measurements (Sugiharto, Susanto, & Prasetijo, 2023). Another study also developed an IoT-based water quality monitoring tool with temperature, pH, and TDS sensors, which tests water samples from various sources to measure key parameters (Chuzaini & Dzulkiflih, 2022). Integrated IoT systems have also continuously monitored key parameters, including pH, dissolved oxygen (DO), TDS, and temperature, with stable data delivery (Fakhriyah et al., 2022). All previous studies show that IoT can function properly when the signal strength is high.

CONCLUSION

The developed system can be installed at a shrimp cultivation pond with good performance. The designed system has a linearity of more than 90%. The system has a reliable accuracy level over 30 consecutive measurement days, resulting in the percentages of 85% to 93% (average = 91%). It can be concluded that the IoT data communication using a wireless internet router performs well in sending and receiving data with the RSSI value of >-50 dBm.

Declarations

Author Contribution : Author 1: Conceptualization, Writing - Original Draft, Editing and Visualization
Author 2: Formal analysis; System Development; Methodology
Author 3: Data collection
Author 4: Data collection
Author 5: Writing - Review & Editing; Validation
Author 6: Writing - Review & Editing; Supervision

		Author 7: IoT Development
		Author 8: IoT Development
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