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Water Monitoring System Using Remote-Control Boat

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Abstract

Water is an indispensable resource in the food industry, fundamental to various processes such as ingredient mixing, cleaning, and cooling. Ensuring the quality of this water is paramount for upholding food safety standards and adhering to regulatory requirements. Conventional methods of water quality monitoring, which typically involve manual sampling and laboratory analysis, are often laborious, time-consuming, and only offer a static snapshot of water conditions. These limitations become particularly challenging when monitoring large water bodies like reservoirs and treatment tanks, where comprehensive coverage is difficult to achieve. The lack of automation and real-time feedback in existing systems can lead to delayed detection of contaminants, resulting in costly recalls, regulatory penalties, and damage to a company's reputation, especially in an industry where minor contamination can have severe consequences, such as foodborne illnesses. This project addresses these critical challenges by proposing a remote-controlled (RC) boat-based water quality monitoring system integrated with Internet of Things (IoT) technology. The system utilizes a combination of turbidity, Total Dissolved Solids (TDS), and temperature sensors to measure key water quality parameters, transmitting real-time data to a mobile application for remote oversight. The RC boat facilitates data collection from multiple points within a water body, significantly improving monitoring coverage and accuracy compared to static sensors. This innovative solution seeks to enhance water monitoring efficiency in the food industry, mitigate contamination risks, and ensure compliance with food safety regulations.

1. Introduction

Water is an essential resource in the food industry, integral to numerous processes like ingredient mixing, cleaning, and cooling [1]. Maintaining the quality of this water is crucial for food safety and for meeting regulatory requirements. However, conventional methods of monitoring water quality are typically manual, labor-intensive, and do not provide real-time data [2]. Manual sampling is usually conducted periodically, which may overlook critical changes in water quality, increasing the risk of health hazards and compromising product integrity [3]. Additionally, the large size of industrial water bodies, including reservoirs and treatment tanks, poses a challenge for comprehensive monitoring across all areas. The lack of automation and real-time feedback in existing monitoring systems increases the risk of delayed detection of contaminants, which can lead to costly recalls, regulatory fines, and damage to the company’s reputation.

This challenge is especially significant in the food industry, where even minor contamination can have severe consequences, including the spread of foodborne illnesses. Thus, there is a need for a more efficient and automated solution to monitor water quality continuously and accurately, providing immediate alerts when deviations from safe parameters are detected. To address these challenges, this project proposes a remote-controlled (RC) boat-based water quality monitoring system integrated with Internet of Things (IoT) technology [4]. The system utilizes a turbidity sensor, a TDS sensor and a temperature sensor to measure key water quality parameters, with real-time data transmission to a mobile application for remote monitoring. The use of an RC boat allows for the collection of data from multiple points within the water body, improving coverage and accuracy compared to fixed-location sensors. This innovative approach aims to enhance water monitoring efficiency in the food industry, reduce the risks of contamination, and support compliance with food safety regulations.

2. Literature Review

The pervasive issue of water pollution, exacerbated by urbanization and industrialization, necessitates innovative approaches to water quality monitoring [5]. Traditional manual sampling methods are inefficient and costly, providing limited real-time insights. The advent of Wireless Sensor Networks (WSN) and Internet of Things technologies has revolutionized water quality monitoring by enabling continuous sensing, automated control, and wireless data collection [6].

This project leverages the integration of IoT with RC boats for environmental monitoring and data collection. By equipping RC boats with IoT-enabled sensors and communication technologies, these systems can collect and transmit crucial water quality data such as pH, temperature, and Total Dissolved Solids in real-time. This capability is especially pertinent for industries like food production, where stringent water quality is vital for safety and regulatory adherence. IoT integration allows these RC boats to autonomously navigate challenging or inaccessible water bodies, reducing human effort and operational costs compared to conventional methods [7]. Collected data from IoT sensors is transmitted wirelessly through communication technologies such as Wi-Fi, LoRa, or cellular networks to cloud platforms, where it can be analyzed and visualized using advanced software tools [8]. This real-time data availability enables proactive decision-making, such as identifying sources of contamination or implementing corrective measures promptly. Moreover, recent advancements in IoT technologies, including edge computing and artificial intelligence (AI), have further enhanced the capabilities of these systems [9]. Edge computing processes data locally on the device, reducing latency and improving efficiency, while AI-powered analytics enable pattern recognition, anomaly detection, and predictive insights, making water monitoring more precise and actionable.

The water quality parameters monitored in this project include turbidity, temperature, and Total Dissolved Solids (TDS). The World Health Organization (WHO) has established safe ranges for each of the water quality parameters [10]. Turbidity measures water clarity by detecting light scattered by suspended particles, while temperature impacts microbial growth and indicates abnormal thermal discharges. TDS measures the concentration of dissolved inorganic salts, minerals, and metals, with high levels affecting water taste and potentially indicating contamination. The choice of microcontrollers and communication protocols is also critical for system performance. The project utilizes the ESP32 microcontroller and relies on wireless data transmission, with options like Wi-Fi suitable for short-distance communication between sensors, controller, and application [11]. Cloud platforms such as ThingSpeak are essential for real-time data visualization, storage, and analysis, offering capabilities for generating charts, tables, and alerts when readings fall outside acceptable thresholds [12]. Previous works have demonstrated the effectiveness of similar systems in addressing global water pollution challenges and ensuring safe drinking water through continuous monitoring.

3. Methodology

The methodology section provides a detailed description of the project's execution, including a system block diagram, circuit design schematic and prototype design. These techniques enhance accountability and ensure the project's reproducibility, ensuring the project's success.

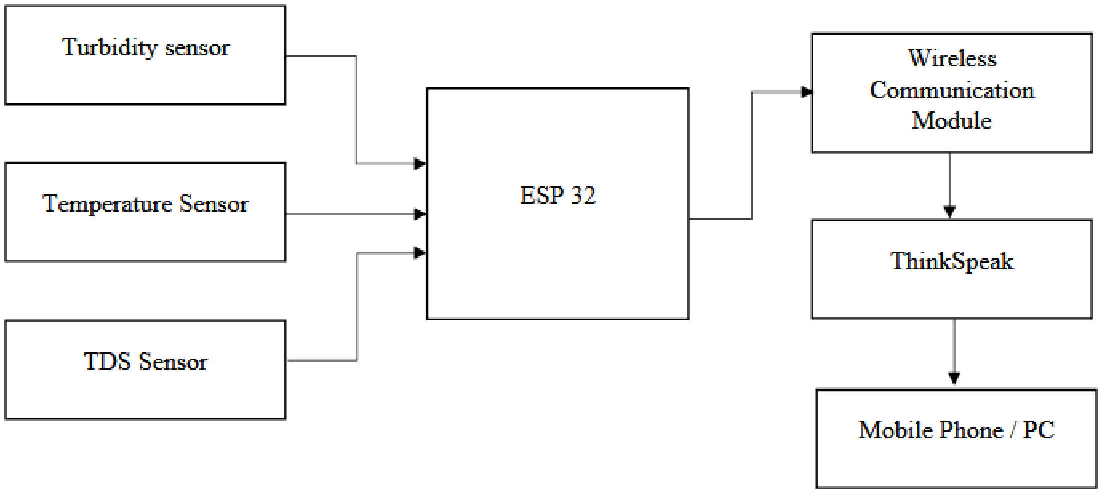


Fig.1: *Block Diagram*

Figure 1 visually represents the architectural framework of the IoT-based water quality monitoring system, meticulously designed to assess and track critical water parameters. At the core of this system is the ESP32 microcontroller, functioning as the central control unit. It's tasked with efficiently managing data acquisition from various integrated sensors, processing this raw data, and subsequently transmitting it wirelessly. The system incorporates three crucial sensors for comprehensive water quality assessment: a turbidity sensor, which measures the water's clarity by detecting suspended particles; a temperature sensor (DS18B20), vital for monitoring thermal variations that can impact aquatic life and water chemistry; and a TDS (Total Dissolved Solids) sensor, used to determine the concentration of dissolved inorganic substances, indicating water purity or contamination levels. The wireless communication module, a key feature integrated directly within the ESP32, facilitates seamless data transmission to a designated cloud platform, such as ThingSpeak. This IoT integration is fundamental, enabling real-time remote monitoring of water quality parameters from anywhere via connected mobile phones or personal computers.

3.1 System Flowchart

Figure 2 system flowchart for the water monitoring system using RC boat

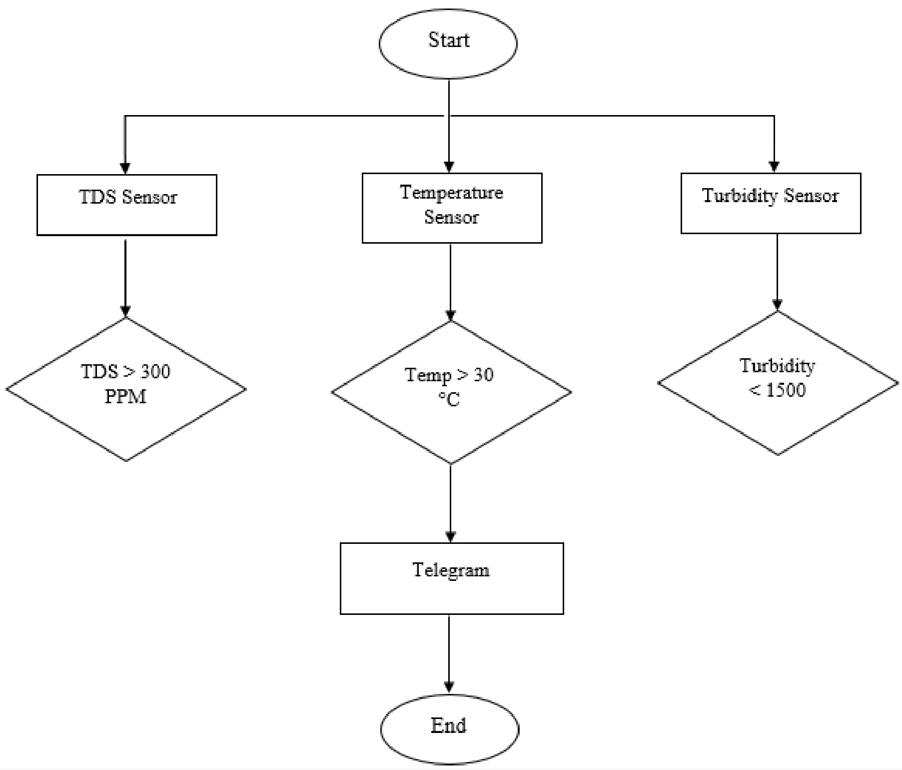


Fig.2 *System Flowchart*

Figure 2 outlines the sequential operation of the water quality monitoring system. The process commences with the ESP32 microcontroller initiating and establishing a network connection. Following this, all integrated sensors (turbidity, temperature, and TDS) are initialized to prepare for data collection. The system then enters its primary operational loop, where it continuously reads and processes data from these sensors. This processed data is subsequently transmitted wirelessly to the ThingSpeak cloud platform for storage and real-time visualization. A critical step involves comparing the collected data against predefined safe operating thresholds. Should any parameter deviate from these limits, the system is configured to trigger an immediate alert. The entire cycle then repeats, ensuring continuous and responsive water quality monitoring.

3.2 Circuit Design

The Circuit design for water monitoring system using RC boat illustrate in Figure 3.

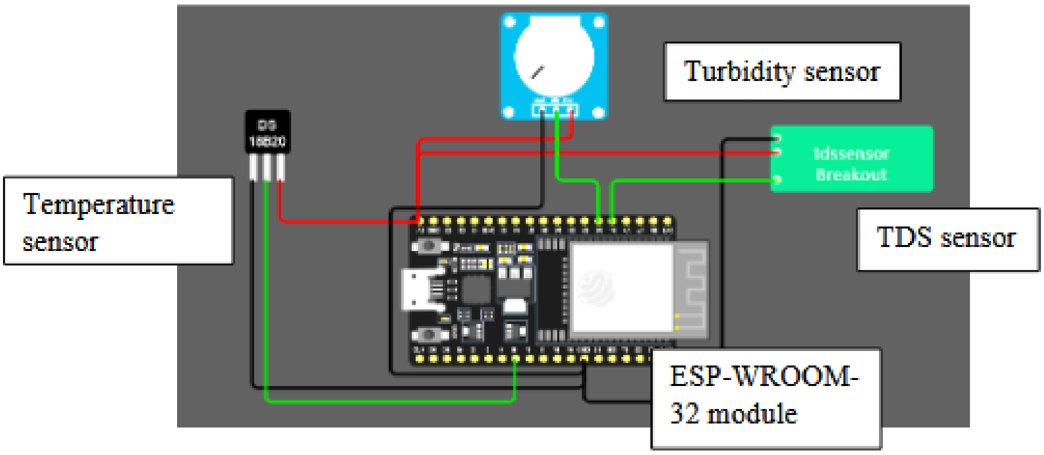
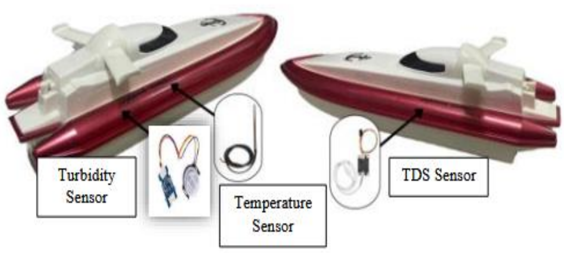


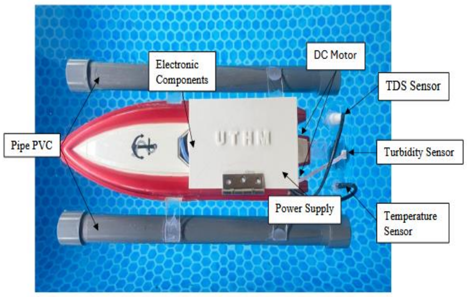
Fig.3 *Circuit Design*

The Figure 3 illustrates the simulated electrical circuit for the Water Monitoring System, developed using Wokwi. At its core, the ESP32 microcontroller acts as the central hub, responsible for gathering and transmitting real-time water quality data. The circuit integrates three primary sensors: a DS18B20 temperature sensor (digital connection to ESP32), which is crucial for temperature readings and for calibrating other sensors; a turbidity sensor (analog connection), measuring water clarity; and a TDS sensor (analog connection via breakout board), indicating the concentration of dissolved solids. The ESP32's wireless capabilities (Wi-Fi/Bluetooth) enable remote data transmission, allowing for real-time monitoring and analysis. This compact and integrated circuit design, when deployed on an RC boat, facilitates versatile water quality assessment across diverse aquatic environments.

3.3 Prototype Design

This section details the development of the physical prototype for the Water Monitoring System using an RC Boat, showcasing the integration of various components onto a pre-existing remote-controlled platform. As illustrated in Figures 4(a) and 4(b), the project began with a commercially available RC boat, serving as the base for our system. The core of this development involved strategically integrating the water quality sensors – specifically the turbidity, temperature (DS18B20), and TDS sensors – onto the RC boat's structure to ensure optimal water contact during operation. A key modification was also undertaken to reconfigure the boat's control system, moving away from its original dedicated controller. This was achieved by integrating an ESP32 microcontroller and developing a custom interface using the Blynk mobile application, thereby enabling remote and intuitive control of the boat's movements through a smartphone. This hands-on integration and modification process transformed the off-the-shelf RC boat into a functional, IoT-enabled water quality monitoring platform.





(a) **(b)**

Fig4:*Prototype Design*

4. Result and Discussion

The section details the outcomes derived from the development and comprehensive testing of the Water Monitoring System using an RC Boat. It focuses on evaluating the system's performance based on its key functional parameters, including the accuracy of sensor data collection (turbidity, temperature, and TDS), the reliability of real-time data transmission to the cloud platform (ThingSpeak), and the effectiveness of the modified RC boat's remote control via the Blynk application. The analysis of these results is crucial for determining whether the developed system successfully meets the established objectives of the project.

4.1 Checkpoint A,B,C

Figure 5(a) shows checkpoint A, initial water quality testing was conducted at a lake to evaluate the baseline performance of the system. The system successfully captured 10 sets of sensor readings, including temperature, TDS, and turbidity. The temperature values ranged between 26.7°C and 28.2°C, while TDS levels varied from 16 ppm to 41 ppm. Turbidity values, measured in analog units, were generally above 2100. Based on the turbidity data, the system correctly identified the water status as either Clean or Cloudy, depending on the range. Overall, the sensor readings closely aligned with the estimated actual values, with most percentage errors remaining low. The average error for Checkpoint A was approximately 2.40%, indicating a reliable level of accuracy. The ThingSpeak platform displayed the sensor trends effectively, confirming the system's reliability in monitoring water quality conditions in the lake environment.

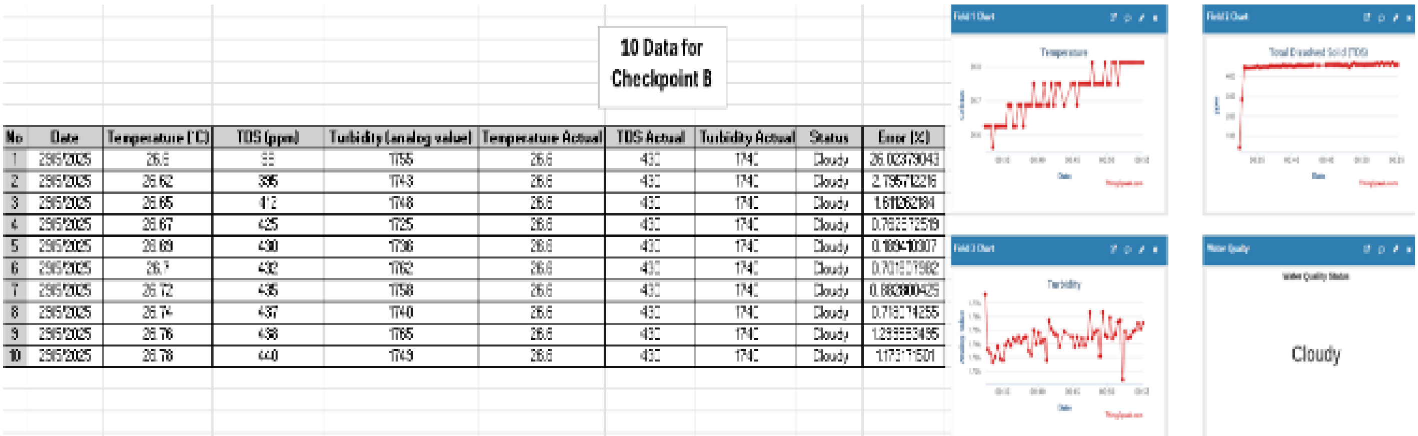
10 Data for Checkpoint A

No	Date	Temperature (°C)	TDS (ppm)	Turbidity (analog value)	Temperature Actual	TDS Actual	Turbidity Actual	Status	Error (%)
1	29/5/2025	28.25	36.38554	2455	27	30	2400	Clean	9.4
2	29/5/2025	27.4375	27.12365	2459	27.1	27	2420	Clean	1.06
3	29/5/2025	27.125	31.4381	2150	26.9	30	2100	Cloudy	2.67
4	29/5/2025	26.875	28.79802	2159	26.9	29	2120	Cloudy	0.91
5	29/5/2025	26.875	27.12365	2143	26.8	27	2100	Cloudy	0.939
6	29/5/2025	26.8125	16.35493	2160	26.8	16	2120	Cloudy	3.61
7	29/5/2025	26.75	27.12365	2174	26.8	27	2150	Cloudy	0.59
8	29/5/2025	26.75	31.76395	2155	26.9	30	2100	Cloudy	3.02
9	29/5/2025	26.6875	26.79073	2149	26.8	27	2100	Cloudy	1.17
10	29/5/2025	26.75	27.12365	2160	26.8	27	2120	Cloudy	0.85

(a)

Fig.5 *Checkpoint A*

Figure 6(a) shows checkpoint B, data was collected from a lake environment to assess water quality under natural conditions. The system successfully recorded 10 sets of readings, showing stable temperature values and significantly higher TDS levels, reaching up to 440 ppm. Turbidity values averaged around 1740 (analog units), and the system consistently classified the water as Cloudy. The percentage error for each sensor remained low, with the average error recorded at approximately 3.18% across all measurements. ThingSpeak visualizations clearly reflected elevated TDS and consistent turbidity readings, confirming the system's effectiveness in monitoring real environmental water conditions with good precision.

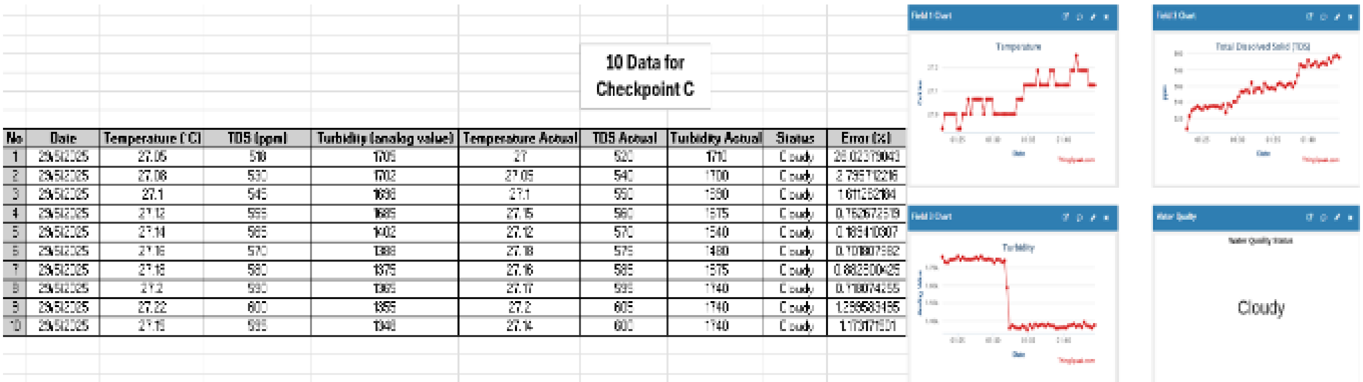


No	Date	Temperature (°C)	TDS (ppm)	Turbidity (analog value)	Temperature Actual	TDS Actual	Turbidity Actual	Status	Error (%)
1	29/5/2025	26.6	[illegible]	1755	26.6	430	1740	Cloudy	26.02379043
2	29/5/2025	26.62	395	1743	26.6	430	1740	Cloudy	2.795712216
3	29/5/2025	26.65	412	1748	26.6	430	1740	Cloudy	1.611262184
4	29/5/2025	26.67	425	1725	26.6	430	1740	Cloudy	0.762372519
5	29/5/2025	26.69	430	1736	26.6	430	1740	Cloudy	0.189410307
6	29/5/2025	26.7	432	1762	26.6	430	1740	Cloudy	0.701807982
7	29/5/2025	26.72	435	1758	26.6	430	1740	Cloudy	0.882800425
8	29/5/2025	26.74	437	1740	26.6	430	1740	Cloudy	0.718074255
9	29/5/2025	26.76	438	1765	26.6	430	1740	Cloudy	1.239583495
10	29/5/2025	26.78	440	1749	26.6	430	1740	Cloudy	1.173171501

(a)

Fig.6 *Checkpoint B*

Figure 7(a) shows checkpoint C involved further testing at a different point in the lake, where water quality showed higher dissolved solid content and lower turbidity levels compared to previous checkpoints. The system recorded TDS values increasing up to 600 ppm, while turbidity values decreased to around 1350 analog units. Despite the wider range of values, the system accurately categorized the water status as Cloudy throughout all 10 data points. Slight variations between sensor and actual values were expected and helped evaluate the accuracy under varying lake conditions. The average error for Checkpoint C was approximately 1.60%, demonstrating high consistency and accuracy. The ThingSpeak charts supported these observations, displaying trends in temperature, rising TDS, and a noticeable turbidity drop, confirming consistent performance of the system in dynamic lake environments.



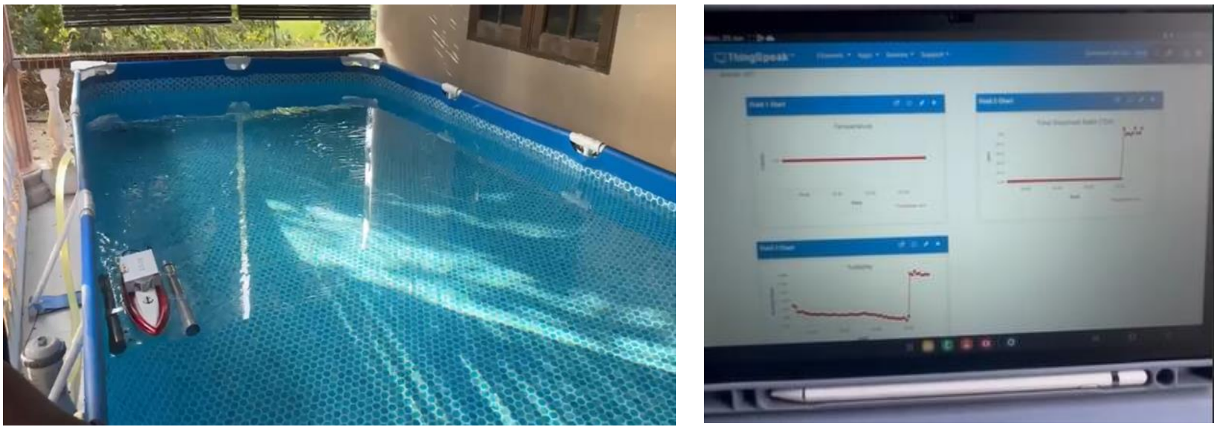
No	Date	Temperature (°C)	TDS (ppm)	Turbidity (analog value)	Temperature Actual	TDS Actual	Turbidity Actual	Status	Error (%)
1	29/5/2025	27.05	510	1705	27	520	1710	Cloudy	26.02379043
2	29/5/2025	27.08	530	1702	27.05	540	1700	Cloudy	2.795712216
3	29/5/2025	27.1	545	1698	27.1	550	1590	Cloudy	1.611262184
4	29/5/2025	27.12	555	1685	27.15	560	1575	Cloudy	0.762672519
5	29/5/2025	27.14	565	1402	27.12	570	1540	Cloudy	0.189410307
6	29/5/2025	27.16	570	1388	27.18	575	1480	Cloudy	0.701807982
7	29/5/2025	27.18	580	1375	27.16	585	1575	Cloudy	0.882500425
8	29/5/2025	27.2	590	1365	27.17	595	1740	Cloudy	0.718074255
9	29/5/2025	27.22	600	1355	27.2	605	1740	Cloudy	1.239583495
10	29/5/2025	27.19	595	1340	27.14	600	1740	Cloudy	1.173171501

Fig.7 *Checkpoint C*

4.2 Analysis of Water Quality Parameter Measurement Efficiency

The performance of the Water Monitoring System using an RC Boat was rigorously evaluated based on its efficiency and accuracy in collecting data for the specified water quality parameters. This analysis focused on how effectively the system measured turbidity, temperature, and Total Dissolved Solids (TDS) under various conditions representative of real-world monitoring scenarios, particularly relevant for environmental assessment in industries such as food production and water treatment. The evaluation aimed to determine the precision and reliability of the sensor readings, the consistency of data transmission, and the overall capability of the RC boat to facilitate comprehensive water quality assessment across different monitoring points. This thorough evaluation ensures the system's suitability for its intended purpose of providing accurate and reliable water quality insights.

A recent experiment was conducted in a pool, as illustrated in Figures 8(a) and 8(b), to thoroughly evaluate the operational effectiveness of the Water Monitoring System. The findings confirmed the successful performance of two critical aspects of the project. Firstly, the RC boat demonstrated reliable and effective movement across the pool's surface, validating its navigational capabilities for reaching various monitoring points. Secondly, and most importantly, the integrated water monitoring system functioned flawlessly, successfully collecting real-time data for turbidity, temperature, and TDS. This highlights the system's capability to accurately measure and transmit critical water quality parameters in a controlled environment. The success of these pool-based trials provides strong evidence of the system's readiness for practical field applications.



(a) **(b)**

Fig.7 *Water Monitoring Result*

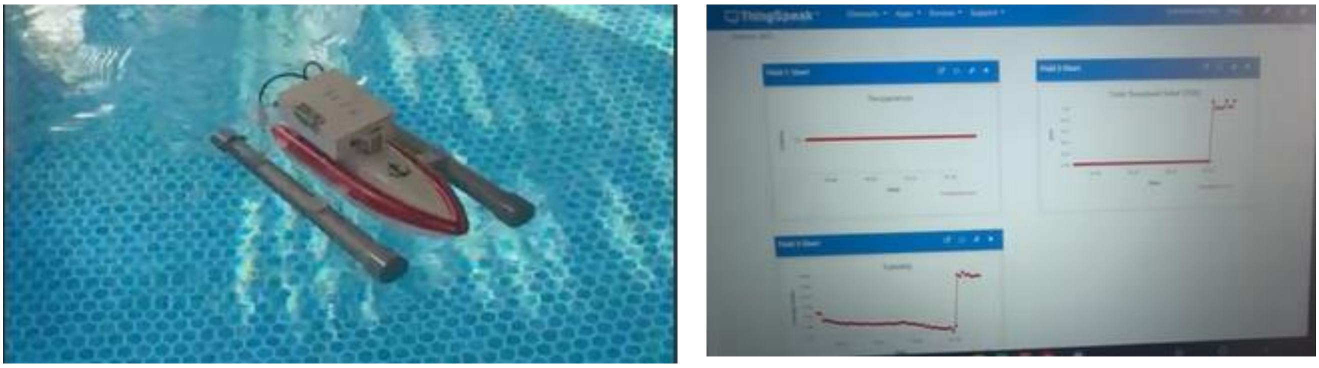
4.3 Project hardware

This section explains the operational functionality of the Water Monitoring System prototype. Figure 9(a) shows the actual prototype of the RC boat when powered on, ready for deployment. The primary operation of this project revolves around its mechanism to effectively collect real-time water quality data and wirelessly transmit it. The innovative design integrates critical sensors directly onto the modified RC boat platform. When powered, the system initiates the ESP32 microcontroller, which then manages the activation and reading of the integrated water quality sensors, showcasing the project's design and efficiency in environmental monitoring.

(a) **(b)**

Fig.8 *First Project hardware Operation*

As depicted in Figure 9(b), the system's operation proceeds as the RC boat navigates the water body. The key functional components, including the turbidity, temperature (DS18B20), and TDS sensors, are strategically positioned to ensure continuous immersion and accurate data acquisition. Upon the boat's movement and the sensors being in contact with the water, the ESP32 continuously reads the analog or digital signals from these sensors. Figure 10(a) would then illustrate how these raw sensor readings are processed by the ESP32. As seen in Figure 10(b), once processed, this data is prepared for wireless transmission to the cloud platform (e.g., ThingSpeak) for remote monitoring and analysis, completing the data acquisition cycle and preparing the system for its next set of readings.



(a) **(b)**

Fig.9 *Second Project Operation*

4.4 Project Movement

In its movement mode, the project operates by establishing a connection between the ESP32 microcontroller onboard the RC boat and the Blynk mobile application on a smartphone. The RC boat's movement is entirely dictated by commands issued through this Blynk application, allowing for intuitive and remote navigation. This setup provides precise control over the boat's direction and speed, enabling it to reach desired monitoring locations within a water body. A detailed command specification for each directional function, as configured within the Blynk interface, would typically be outlined in a subsequent table (e.g., Table 4.1), ensuring clear understanding of the control functionalities.

Table 1 *Command Specification*

Command	Description	Motor States	PWM Values
'Virtual 1'	Move Forward	In 1 = HIGH In 2 = HIGH	ENA = 200
'Virtual 2'	Move Backward	In 1 = HIGH In 2 = HIGH	ENA = 200
'Virtual 3'	Turn Left	In 1 = LOW In 2 = HIGH	ENA = 200
'Virtual 4'	Turn Right	In 1 = HIGH In 2 = LOW	ENA = 200
'Virtual 0'	Stop All Motion	In 1 = LOW In 2 = LOW	None

This data details the control logic for the RC boat's movement, managed through the Blynk mobile application. As presented in Table 1, specific commands within the app dictate the boat's navigation. The ' Virtual 1' command initiates forward movement, while 'Virtual 2' causes the RC boat to move backward. For directional changes, 'Virtual 3' and 'Virtual 4' commands are used to maneuver the boat to the respective sides. The 'Virtual 0'command immediately halts all motor activity, providing an essential control feature. This system allows for precise and intuitive control over the RC boat's movement, crucial for effective navigation during water quality monitoring operations.

5. Conclusion

The Water Monitoring System using an RC Boat has successfully achieved its primary objectives of providing efficient, real-time water quality assessment with remote operational capabilities. The system effectively integrates specialized sensors for accurate measurement of key water parameters, namely turbidity, temperature, and Total Dissolved Solids (TDS). The ESP32 microcontroller serves as the central processing unit, managing data acquisition from these sensors and facilitating wireless transmission to a cloud platform like ThingSpeak for real-time visualization and analysis. A core achievement of this project is the successful modification and integration of components onto a pre-existing RC boat platform, transforming it into a mobile monitoring unit. The control logic, managed through the user-friendly Blynk mobile application, provides intuitive and precise navigation of the RC boat, allowing it to access and monitor various locations within a water body. All hardware components, including the RC boat, sensors, and the ESP32 microcontroller, have undergone rigorous integration and testing, confirming the system's reliability and consistent performance in collecting water quality data. The user-friendly interfaces provided by both Blynk and ThingSpeak significantly enhance the system's functionality for remote monitoring and control of environmental parameters. Ultimately, this project represents a significant step in advancing water quality management by leveraging Internet of Things (IoT) principles and mobile robotics. The successful development, comprehensive testing, and demonstrated operational functionality of the Water Monitoring System using an RC Boat confirm its practical applicability and highlight its valuable contribution to the development of automated and efficient solutions for environmental monitoring.

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