Smart Water Quality Assessment System Using IOT

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***Abstract*: The rapid depletion of clean water resources due to industrial expansion, city development, and drastic climate variations has made water quality monitoring a vital aspect of environmental conservation. Ordinary methods of water quality testing are often labor-intensive, time-taking, and minimal in scope. This paper develops an IoT-based water quality monitoring system made to tackle these challenges by enabling real-time, affordable, and adaptable water pollution assessment. The system utilizes an ESP8266 microcontroller, along with pH, turbidity, TDS, and temperature sensors, to collect and transmit data to a virtual server. The integration of an aquatic boat allows for comprehensive sampling from various locations within a water body, ensuring accurate and reliable data collection. The system was tested in multiple water bodies, demonstrating its effectiveness in monitoring water quality and providing actionable insights for environmental management.**

***Keywords*: Internet Of Things, Water Quality Assessment, ESP8266, ATMEGA328, pH Sensor, Turbidity Sensor, TDS Sensor, Temperature sensor, Environmental Conservation.**

1. Introduction

One of the most essential elements for maintaining life is water, but pollution, climate change, and over-exploitation are deteriorating its quality. Based on the World Health Organization (WHO) report, over 2 billion people drink water polluted with feces, which can result in flare-ups of waterborne diseases like cholera, dysentery, and typhoid. Contaminated water sources are extremely dangerous for human health. Conventional techniques for monitoring water quality, which depend on routine sample collection and laboratory examination, are frequently expensive, prolonging, and insufficient for prompt decision-making. By allowing for the constant testing of vital water quality parameters, the integration of Internet of Things (IoT) technology into water quality monitoring offers a revolutionary remedy [1]. This system measures temperature, turbidity, pH, and total dissolved solids (TDS) using inexpensive sensors.

Data is wirelessly sent to remote servers for constant monitoring and analysis. Sensor data is processed by microcontrollers, and wireless communication technologies guarantee smooth data transfer. This IoT-based strategy is appropriate for a variety of applications in both cities and country sides because it makes affordable, scalable, and simple to implement. This system supports proactive interventions, enables early contamination detection, and improves water management strategies by offering real-time insights water that is safe to drink [2].

2. Literature Survey

Multiple researches have analyzed the application of IoT for water quality monitoring, showing its ability to enhance real-time data collection and optimize water resource management. Kumar et al. (2024) introduced an IoT-enabled system for pond management, addressing key challenges such as sensor accuracy and energy optimization. Their study highlighted the creative possibilities of IoT technologies in automating water quality assessment and improving aquaculture productivity. Similarly, Nisar et al. (2018) created an IoT-based structure for soft-shell crab farming, employing LoRa technology for long-range communication and utilizing a Node-RED dashboard for remote monitoring. Their approach showcased the benefits of low-power, long-range communication in aquaculture applications. Meanwhile, Chowdhury et al. (2019) implemented a photovoltaic-powered system for river water purification testing, points out the importance of constant power supply to ensure uninterrupted data transfer and reliable monitoring in isolated local areas.

Despite the success of these studies, challenges remain in developing a budget-friendly, scalable, and comprehensive smart water quality assessment system. Existing solutions often focus on specific applications, such as aquaculture or river monitoring, without offering a unified approach that integrates multiple sensors, real-time data transmission, and widespread deployment capabilities [3]. This paper aims to close these gaps by introducing a sophisticated IoT-driven framework that merges multiple sensors to monitor key parameters like pH, turbidity, Total Dissolved Solids (TDS), and temperature. Additionally, the structure introduces an innovative feature—

aquatic boat integration—to enhance data collection across larger water bodies. By leveraging wireless communication, cloud-based storage, and energy-efficient designs, this solution aims to provide a more robust, real-time, and cost-effective approach to water purification assessment for various environments. The proposed system is designed to be modular and scalable, allowing for easy adaptation to different water purification needs, from small-scale aquaculture farms to large river systems [4].

3. System Design and Methodology

A. System Architecture

The developed intelligent water analysis system integrates both physical and digital elements, which are integrated to guarantee instant and continuous operation. It utilizes various sensors, including a pH sensor to measure acidity or alkalinity, a turbidity sensor for knowing water transparency, a TDS sensor to measure dissolved substances, and a temperature sensor to detect thermal changes affecting water composition and ecosystems. Data processing is managed by an ATmega328 microcontroller, which performs analog-to-digital conversion (ADC), while the ESP8266 enables wireless transmission of data to cloud storage. To enhance monitoring coverage, a remote-controlled aquatic boat is deployed, carrying these sensors to collect samples from various locations [5]. A Blynk-based mobile application provides real-time visualization and alerts, ensuring prompt intervention when necessary. By leveraging IoT and wireless communication, this system offers a scalable and efficient solution for continuous water quality monitoring, contributing to environmental sustainability and public health protection.

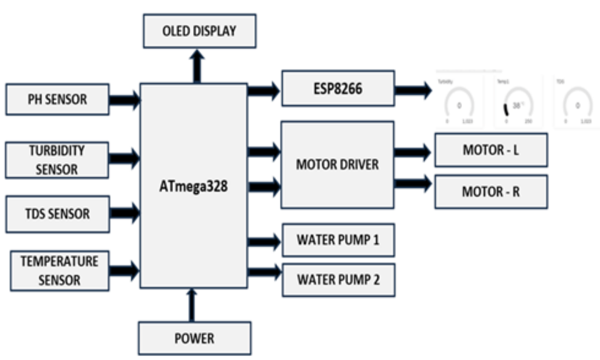

Fig. 1. Block diagram of implemented system

B. System Workflow

The system workflow of the designed IoT-integrated water evaluation model follows an organized approach to ensure efficient and accurate assessment. The primary stage, data collection, involves various sensing devices, such as pH, turbidity, TDS, and temperature sensors, which continuously monitor water quality parameters from the targeted water body. These sensors detect variations in water composition and environmental conditions, forming the foundation for real-time analysis. In the data processing stage, the ATmega328 microcontroller plays a crucial role by receiving raw sensor readings and converting them into a digital format using analog-to-digital conversion (ADC). This conversion ensures that data is processed efficiently for further transmission and analysis. Following processing, the data transmission phase is managed by the ESP8266 microcontroller, which facilitates seamless wireless communication. Using Wi-Fi connectivity, the ESP8266 transmits the processed information is transmitted to a remote server, ensuring local access and storage for continuous monitoring. Finally, in the data visualization stage, the Blynk mobile application serves as an interaction platform, displaying real-time data in an intuitive format. It provides alerts and notifications if water quality parameters exceed pre-defined safety thresholds, enabling timely intervention. This integrated workflow enhances ecological surveillance, promoting community well-being and sustainable water management.

By integrating multiple sensors, microcontrollers and remote storage and processing of data transmission ensures accurate monitoring and timely notifications for any anomalies exceeding safe water quality limits. The use of the Blynk mobile application further enhances accessibility, allowing users to monitor and assess water quality and its purity which leads to take necessary actions when required. This innovative approach contributes to improved environmental sustainability, public health protection, and effective water resource management, serves as an essential and necessary thing for modern water monitoring applications.

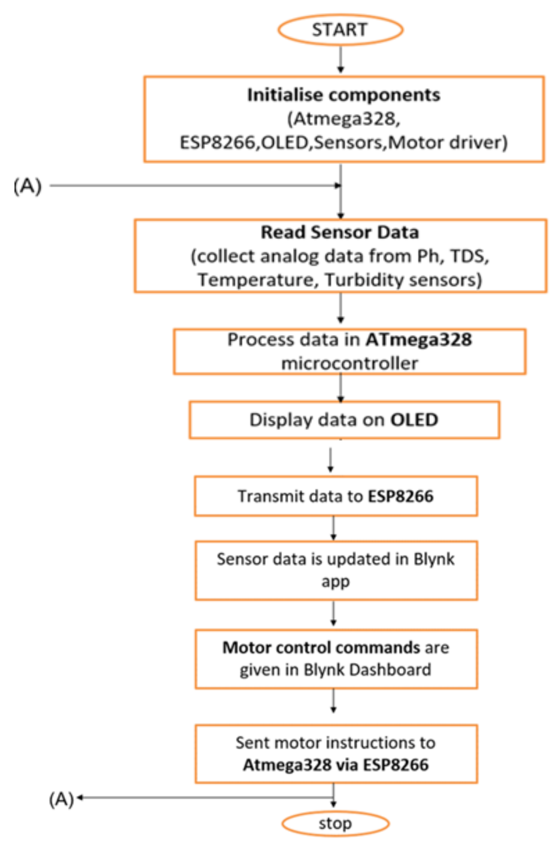

Fig. 2. Algorithm for the system overflow

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4. Circuit Design and Implementation Results

A. Circuit Diagram

The circuit diagram illustrates the integration of multiple sensors, microcontrollers, and actuators to facilitate real-time evaluation of key water characteristics. The system utilizes sensors for pH, turbidity, Total Dissolved Solids (TDS), and temperature to collect vital water quality information. These sensors produce analog signals, which are then processed by the ATmega328 microcontroller through an Analog-to-Digital Conversion (ADC) mechanism. The processed data is transmitted wirelessly to a cloud-based platform via the ESP8266 Wi-Fi module, enabling remote access and continuous monitoring. To enhance functionality, the system includes motor drivers and MOSFETs, which regulate the operation of water pumps and propulsion motors. This feature allows the system to collect data dynamically across different sections of a water body, ensuring comprehensive monitoring. The water pumps facilitate sample collection and filtration, while the propulsion motors enable autonomous movement in aquatic environments, such as lakes, rivers, and reservoirs. These components collectively contribute to efficient data acquisition and environmental monitoring [6].

To validate the system's functionality, a simulation was conducted using Proteus software. The findings showcased the system's ability to precisely monitor and evaluate the parameters instantly. The turbidity sensor, for example, provided readings indicating water clarity, with values below 10 NTU signifying safe drinking water and values exceeding 35 NTU indicating contamination. Similarly, pH measurements below 7 denoted acidic conditions, while values above 7 signified alkalinities. The successful simulation confirms the system's potential for real-world applications, ensuring proactive water quality management and early detection of contamination. This IoT-based solution offers an affordable and expandable approach to maintaining water safety in urban and rural environments.

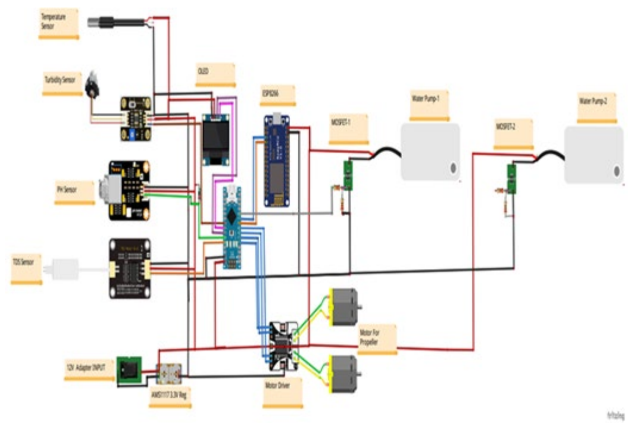

Fig. 3. Circuit diagram for the proposed system

B. Hardware

The hardware implementation of the IoT-based driven system is realized through a custom-designed Printed Circuit Board (PCB), ensuring seamless integration of all components for efficient performance. The PCB incorporates essential modules, including an ESP8266 Wi-Fi module for wireless communication, power regulation circuits for stable voltage supply, and a microcontroller-based signal processing unit for data handling. The ATmega328 microcontroller serves as the system's core, interfacing with sensors such as pH, turbidity, Total Dissolved Solids (TDS), and temperature sensors to collect water quality data [7].

The PCB layout is meticulously designed to optimize signal integrity, reduce electromagnetic interference, and ensure efficient power distribution across all components. High-current components, such as MOSFETs for controlling water pumps and propulsion motors, are strategically placed to prevent overheating and enhance thermal management.

Additionally, noise-isolation techniques are applied to minimize signal disruptions, ensuring accurate sensor readings.

The compact and professionally fabricated PCB enhances the system's reliability, durability, and ease of deployment. Its modular design allows for scalability, making it suitable for diverse applications in urban and rural water monitoring. This robust hardware platform ensures long-term stability, supporting real-time water quality assessment for improved environmental and public health management.

The PCB layout for an IoT-based water quality monitoring system, modelled in Fusion 360. It can be also be designed in a similar PCB design software. The layout features a dual-layer PCB, with traces in blue (bottom layer) and green (top layer), ensuring compact and efficient routing. The design includes multiple through-hole and surface-mounted components with well-organized traces for power, signal, and ground connections. Mounting holes are positioned for secure enclosure integration. This optimized PCB layout enhances signal integrity, power distribution, and reliability which ensures its effectiveness for immediate and continuous water quality assessment tasks.

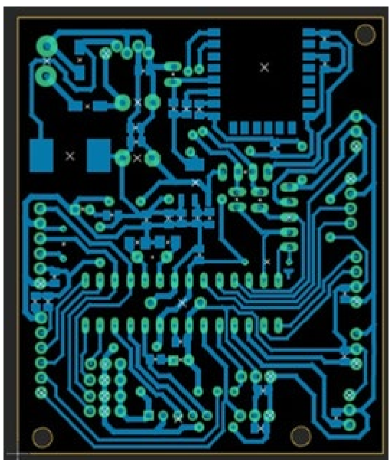

Fig. 4. PCB layout on fusion 360

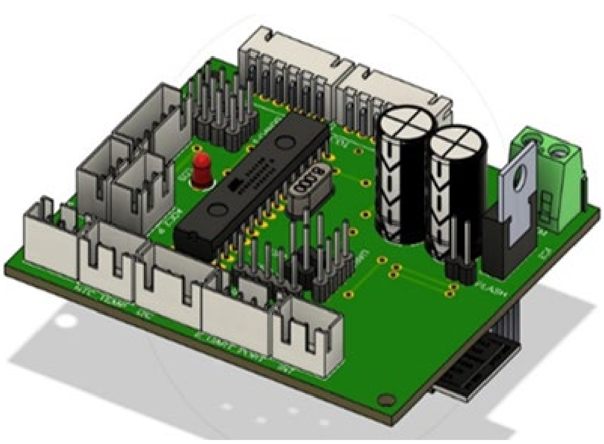

Fig. 5. PCB 3D design on fusion 360

C. Hardware Fabrication

The PCB fabrication is a crucial step in developing a dependable and high-performance digital system for instant water quality assessment. This circuit board incorporates sensing devices, a central processing unit, and a wireless transmission module to monitor essential factors, while relaying data to a distant server or mobile interface. Designed for durability and efficiency, the fabricated PCB ensures stable power distribution, minimal interference, and seamless IoT connectivity, making it ideal for environmental and industrial applications.

Fig. 6. shows the top layer of the PCB, featuring a microcontroller, an LED indicator a voltage regulator, and pin headers for sensor connections.

The bottom layer, visible in the Fig 7. highlights the circuit traces, surface-mounted components, and a wireless interface (Wi-Fi or Bluetooth) utilized for instant data transfer. The PCB is designed using double-layer fabrication, ensuring compact routing of electrical connections while maintaining signal integrity. The microcontroller processes sensor data, and the IoT module enables wireless connectivity, allowing users to monitor water quality remotely. The presence of voltage regulators and power management.

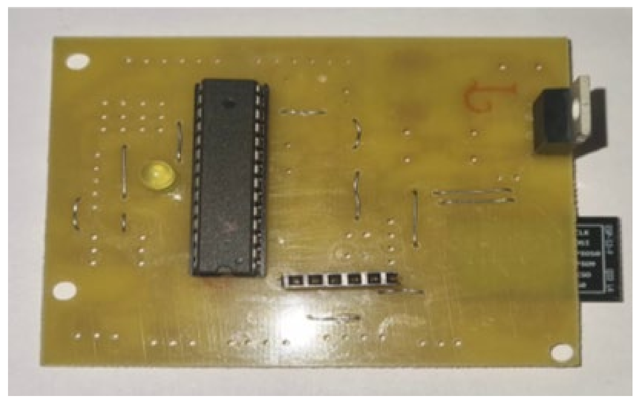

Fig. 6. PCB fabrication of top layer

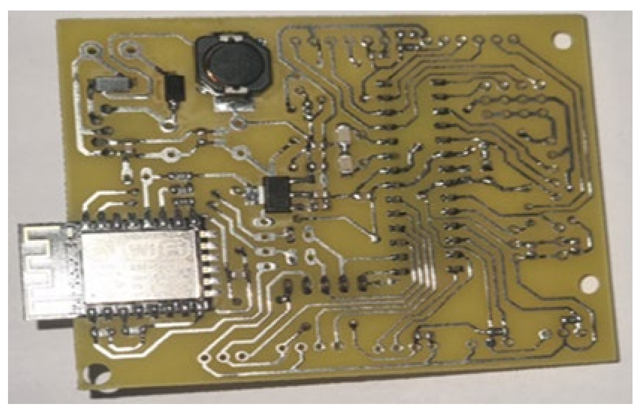

Fig. 7. PCB fabrication of bottom layer

Additionally, the PCB layout follows design best practices, with well-organized traces, minimal noise interference, and strategic component placement for optimal performance. The drilled mounting holes facilitate secure enclosure integration, enhancing durability in real-world applications. This fabricated PCB serves as the backbone of the IoT-based water quality monitoring system, enabling efficient data acquisition, processing, and remote monitoring.

5. Hardware Results – Testing of Water

Water quality is assessed using essential factors such as pH, clarity, dissolved solid concentration, and temperature, which are analyzed to verify its suitability for consumption. The potential level of hydrogen in drinking water should ideally range between 6.5 and 8.5, as recommended by the World Health Organization (WHO). A pH lower than 6.5 indicates acidity, which can lead to corrosion in pipes and potential leaching of toxic metals, while a pH above 8.5 may cause a bitter taste and reduce the effectiveness of disinfectants like chlorine. Turbidity, which measures water clarity, should be less than 1 NTU (Nephelometric Turbidity Unit) for safe drinking water, though the maximum allowable limit is 5 NTU. High turbidity can indicate suspended particles, microbial contamination, or pollutants, making water unsafe for consumption.

The optimal concentration of Total Dissolved Solids (TDS) should be under 300 mg/L, while the highest acceptable threshold for safe drinking water is 500 mg/L. Elevated TDS levels can influence flavor, increase water hardness, and introduce toxic elements like arsenic, lead, or fluoride. Water temperature is also essential in preserving its flavor and overall quality and microbial stability, with an ideal range between 10°C and 25°C. Higher temperatures can cause the aquatic organisms to have a severe effect on their health, because the more warmer the water is, much lesser will be the oxygen dissolved in the water. Solubility of oxygen in the water will be less at high temperature. Maintaining these parameters within recommended limits ensures that drinking water is safe, clear, and free from harmful contaminants.

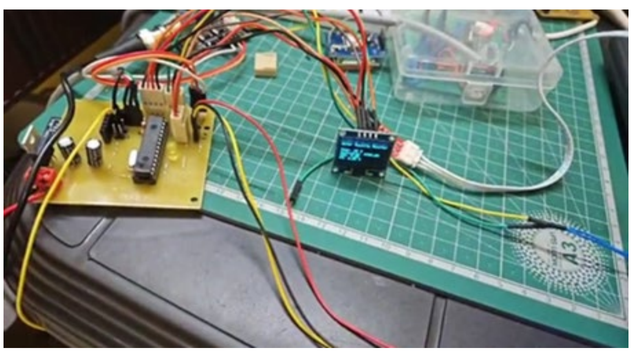

Fig. 8. Hardware implementation of the whole system

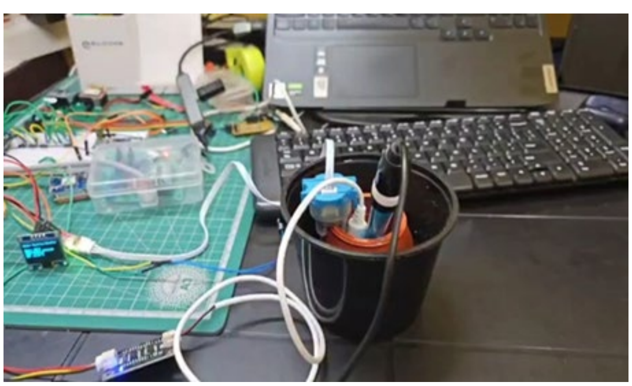

Fig. 9. Testing of water

Fig. 10 illustrates an OLED display module connected to the whole system, presenting instantaneous monitoring of essential factors, such as temperature, turbidity, Total Dissolved Solids (TDS), and pH. The recorded temperature of 40°C is considerably higher than the ideal range of 10°C to 25°C, which is commonly recommended for drinking water. Elevated temperatures can accelerate microbial growth, potentially leading to the proliferation of harmful bacteria, while also affecting the taste.

The turbidity reading of 2814.27 NTU is alarmingly high, significantly exceeding the recommended limit surpassing the advised threshold of below 1 NTU for potable water safety. Such excessive turbidity indicates severe contamination with suspended particles, which could include organic matter, sediments, and potentially harmful pathogens. High turbidity not only affects the clarity of the water but also increases the potential for microbial pollution rise as particles may protect bacteria and viruses from sanitation processes.

Fig. 10. Water is unfit for drinking

In contrast, the TDS value of 24.42 mg/L fits well in the acceptable threshold of below 500 mg/L, indicating a low concentration of dissolved solids. While a low TDS level generally signifies better water quality, other factors, such as pH and turbidity, must be considered to assess overall safety. The recorded pH level of 12.08 is extremely high, making the water highly alkaline. Such a pH level can lead to a bitter taste, potential skin irritation, and adverse health effects if consumed regularly. Overall, the recorded parameters indicate that the water is unsafe for drinking. Proper filtration, turbidity reduction, and pH adjustment are essential to make it suitable for consumption.

6. Results Obtained Through Blynk App

The Blynk dashboard effectively monitors water quality determining factors such as temperature, TDS, and pH in real time, providing valuable insights for applications like water filtration, aquaponics, and industrial monitoring. The fluctuating readings indicate active data transmission, though the pH sensor may require troubleshooting due to consistent zero readings. The graphing feature helps track trends, enabling users to detect anomalies and make informed decisions. Ensuring proper sensor calibration and stable connections will improve accuracy and reliability.

The Fig. 11 shows a Blynk dashboard monitoring water quality determining factors such as temperature, TDS (Total Dissolved Solids), turbidity and pH levels. The interface includes gauge widgets for real-time values and a live graph for tracking trends over time. The readings fluctuate slightly, indicating active data transmission from sensors connected to a microcontroller.

Among these, turbidity is shown in an analog gauge format without conversion to NTU (Nephelometric Turbidity Units). This means the sensor provides a raw analog value that fluctuates based on water clarity but is not digitally processed into NTU. As seen in Figure 11, the turbidity value is at a higher analog level, which later decreases in Figure 12, indicating an improvement in water clarity.

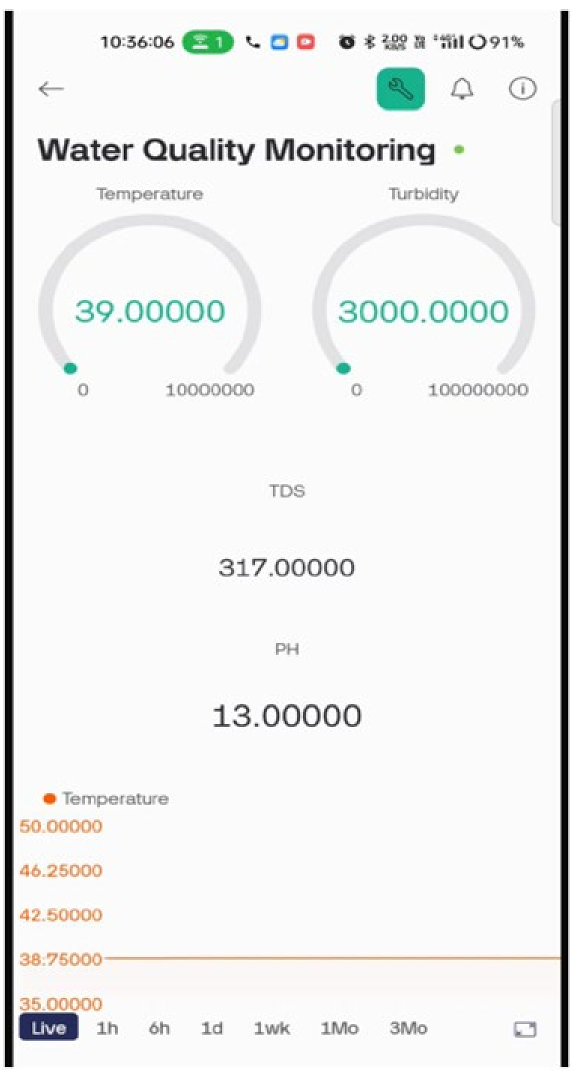

Fig. 11. Blynk result 1

Higher turbidity means more suspended particles in the water, making it unsuitable for consumption or industrial use, whereas a lower turbidity value signifies cleaner water. The temperature readings increase slightly from 39.00°C (Figure 11) to 40.00°C (Figure 12), while TDS levels rise from 317.000 ppm to 344.000 ppm, indicating a higher concentration dissolved substance. The pH values of 13.00 and 14.00 indicate extremely alkaline water conditions.

Since turbidity remains in analog format, the exact NTU values are not available A standardization and transformation approach is required to precisely measure turbidity in NTU, enhancing the system's capability to track and evaluate water quality efficiently. Graphical feature helps track trends, enabling users to detect anomalies and make informed decisions. Ensuring proper sensor calibration and stable connections will improve accuracy and reliability. In the Fig. 11 and Fig. 12 the temperature is around 39°C to 40°C. The graphs display real-time temperature variations with a spike in one of the readings. This feature helps in analyzing water quality trends over different time frames (1 hour, 6hours, 1 day, etc.). The live data update ensures continuous monitoring, making it useful for applications like aquaponics, water filtration, and industrial monitoring.

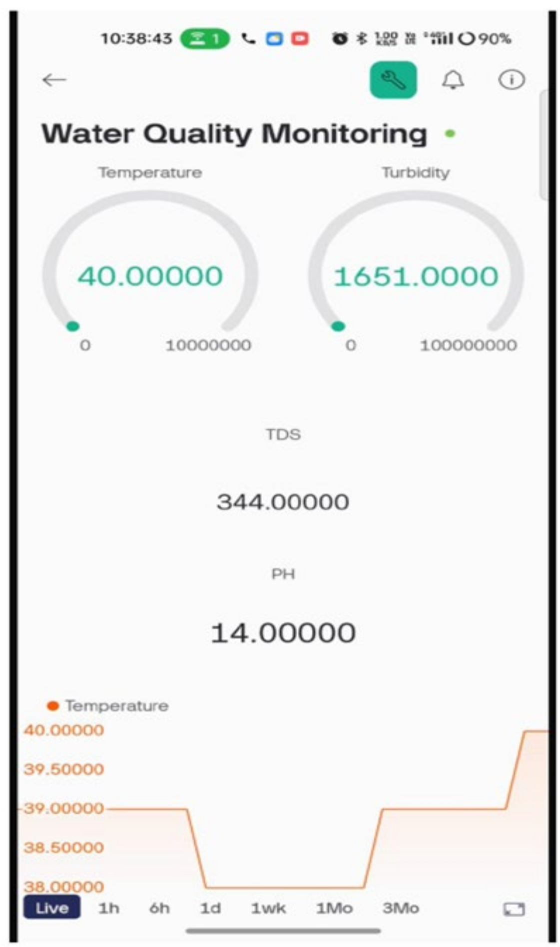

Fig. 12. Blynk result 2

7. Future Scope

In future research, the boat section should be developed according to the circuit diagram and integrated with an IoT dashboard for automated control. This system will enable precise adjustments to the boat's movement, speed, and positioning, ensuring accurate operation during the deposition process. By executing this smart system, users can locally control the boat section, track its performance in real time, and make necessary modifications through a user-friendly interface. This approach will enhance automation, reduce manual errors, and improve the efficiency of the overall deposition system.

8. Conclusion

The proposed IoT-based water quality monitoring system presents an efficient, cost-effective approach for instant water quality evaluation. By integrating several sensors, microcontrollers, and a remote-controlled aquatic boat, the system ensures comprehensive data collection and analysis. The deployment of this system in different water bodies has demonstrated its effectiveness in detecting variations in water quality parameters, enabling proactive environmental management. The wireless data transmission via ESP8266 and real-time visualization through the Blynk mobile application enhance usability and accessibility. Future enhancements could include the incorporation of advanced sensors, such as dissolved oxygen and nitrate sensors, along with machine learning algorithms for predictive analysis. With its potential to support sustainable water resource management, this system acts as an essential instrument for safeguarding the environment, public health, and regulatory compliance in water quality monitoring

References

[1] L. Beck, T. Bernauer, and A. Kalbhenn, "Environmental, political, and economic determinants of water quality monitoring in Europe," *Water Resources Research*, vol. 46, no. 11, Nov. 2010, doi: https://doi.org/10.1029/2009wr009065.

[2] A. M. Gonçalves and T. Alpuim, "Water quality monitoring using cluster analysis and linear models," *Environmetrics*, vol. 22, no. 8, pp. 933–945, Apr. 2011, doi: https://doi.org/10.1002/env.1112.

[3] "Smart Aquaculture Fish Feeding and Water Quality Monitoring," *International Journal of Recent Trends in Engineering and Research*, pp. 210–213, Apr. 2018, doi: https://doi.org/10.23883/ijrter.conf.02180328.035.higz5.

[4] P. Purcell, M. Bruen, J. O'Sullivan, L. Cocchiglia, and M. Kelly-Quinn, "Water quality monitoring during the construction of the M3 motorway in Ireland," *Water and Environment Journal*, vol. 26, no. 2, pp. 175–183, Jul. 2011, doi: https://doi.org/10.1111/j.1747-6593.2011.00274.x.

[5] M. Zessner, "Monitoring, Modeling and Management of Water Quality," *Water*, vol. 13, no. 11, p. 1523, May 2021, doi: https://doi.org/10.3390/w13111523.

[6] N. Brauer, A. T. O'Geen, and R. A. Dahlgren, "Temporal variability in water quality of agricultural tailwaters: Implications for water quality monitoring," *Agricultural Water Management*, vol. 96, no. 6, pp. 1001–1009, Jun. 2009, doi: https://doi.org/10.1016/j.agwat.2009.01.011.

[7] "National Water Quality Monitoring Strategy Update," *Groundwater Monitoring & Remediation*, vol. 14, no. 3, pp. 99–100, Aug. 1994, doi: https://doi.org/10.1111/j.1745-6592.1994.tb00467.x.