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DESIGN OF WATER QUALITY MONITORING SYSTEM USING EDGE PROCESSING TECHNIQUE

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Abstract *:* The Internet of Things (IoT) provides an effective approach for real-time water quality monitoring by connecting sensors, embedded controllers, and cloud-based monitoring platforms. This paper presents a low-cost IoT-enabled water quality monitoring system based on the ESP8266 NodeMCU microcontroller, integrated with turbidity, pH, and DS18B20 temperature sensors. The system continuously acquires water quality parameters and performs initial data processing at the edge using the ESP8266 before transmitting the measured information to the Blynk cloud platform through a wireless connection. Turbidity measurements are used to assess the clarity of water, while the pH sensor determines whether the water is acidic or alkaline. The DS18B20 sensor provides temperature measurements, which are useful for monitoring variations in water conditions and supporting reliable sensor measurements. By processing sensor data locally, the proposed system reduces unnecessary data transmission and enables faster monitoring. The Blynk platform provides a user-friendly interface for remotely visualizing sensor readings and observing water quality conditions in real time. Experimental testing demonstrates the feasibility of the developed prototype for continuous water quality observation. The proposed system is economical, compact, and suitable for applications such as agricultural water monitoring, aquaculture, and environmental water-quality assessment.

Index Terms - Internet of Things (IoT), Water Quality Monitoring, ESP8266, Edge Processing, Turbidity Sensor, pH Sensor, DS18B20, Blynk, Real-Time Monitoring.

I. INTRODUCTION

Water quality monitoring is essential for protecting environmental health, ensuring safe water usage, and supporting the effective management of water resources [1]. Increasing industrialization, urbanization, and population growth have contributed to the deterioration of water quality, creating a need for continuous and timely monitoring of water conditions [2]. Conventional water quality assessment methods commonly involve manual sampling and laboratory analysis. Although these methods can provide reliable measurements, they are often time-consuming and labor-intensive, making them less suitable for applications that require continuous observation and rapid identification of changes in water conditions [3].

The advancement of Internet of Things (IoT) technology has enabled the development of automated monitoring systems that can collect and communicate environmental data in real time [4]. IoT-based monitoring systems integrate sensors, microcontrollers, wireless communication, and cloud platforms to support continuous data acquisition and remote observation. Cloud-based platforms also provide convenient mechanisms for displaying and accessing sensor information through web and mobile interfaces [5]. However, when data processing depends primarily on remote cloud services, communication delays and network dependency can affect the responsiveness of real-time monitoring systems [6], [7]. Edge processing offers an alternative approach by performing preliminary processing closer to the point where the data is generated, thereby reducing unnecessary data transmission and improving system responsiveness [8].

This paper presents the design and implementation of a real-time water quality monitoring system using the ESP8266 NodeMCU microcontroller [9]. The proposed system incorporates three sensors: a turbidity sensor, a pH sensor, and a DS18B20 digital temperature sensor. The turbidity sensor is used to evaluate the clarity of water based on the presence of suspended particles, while the pH sensor determines the acidic or alkaline condition of the water. The DS18B20 sensor measures water temperature and provides additional information about the monitored water environment. The ESP8266 acts as the central processing unit, acquiring sensor measurements and performing initial data processing locally before transmitting the processed information through Wi-Fi to the Blynk cloud platform.

The primary objective of this work is to develop a low-cost and practical water quality monitoring system while demonstrating the application of edge processing in an IoT-based architecture. Local processing at the ESP8266 enables sensor information to be handled near the source before cloud transmission, helping to reduce unnecessary communication and support faster system response. The Blynk platform is used for remote visualization of the measured parameters, enabling users to observe water quality information through a mobile or web-based interface.

The proposed methodology consists of sensor integration, calibration, real-time data acquisition, local edge processing, wireless communication, and cloud-based visualization [10,11]. The developed prototype was tested under different water conditions to observe variations in the measured parameters. The resulting system provides a compact and economical approach to continuous water quality observation and can support applications such as agricultural water monitoring, aquaculture, and environmental water-quality assessment [12].

II. MATERIALS AND METHODS

The proposed real-time water quality monitoring system was developed by integrating IoT-based sensing, an ESP8266 microcontroller, edge-level data processing, wireless communication, and cloud-based visualization. The system measures three important water quality parameters, namely pH, turbidity, and temperature. Sensor measurements are acquired by the ESP8266, processed locally, and transmitted through Wi-Fi to the Blynk cloud platform for remote monitoring. IoT-based water quality monitoring approaches have been increasingly adopted because they enable continuous data acquisition and remote observation of water conditions [13,14].

II.1. Internet of Things

The Internet of Things (IoT) provides the communication framework for connecting physical sensing devices with digital monitoring platforms. In the proposed system, IoT technology is used to acquire water quality measurements and make the collected information accessible to a remote user. The sensing unit periodically obtains pH, turbidity, and temperature measurements, while the ESP8266 performs processing and wireless communication. The resulting information is transmitted to the Blynk platform, where it can be displayed through a graphical monitoring dashboard. Similar IoT architectures have been investigated for continuous water quality monitoring and remote data acquisition [15,16].

II.2. Embedded System and ESP8266 Microcontroller

The monitoring unit is implemented using the ESP8266 NodeMCU microcontroller. The controller was selected because of its compact size, low implementation cost, processing capability, and integrated Wi-Fi connectivity. It serves as the central unit responsible for acquiring sensor measurements, performing local processing, and transmitting the processed information to the cloud platform.

The ESP8266 receives signals from the connected water quality sensors and converts them into corresponding parameter values. It also performs the required calibration and basic data processing before transmission. The use of microcontroller-based platforms for IoT water quality monitoring has been reported in several previous studies [17,18].

II.3. Sensor Configuration

Three sensors are employed in the proposed system to measure the selected water quality parameters: a pH sensor, a turbidity sensor, and a DS18B20 temperature sensor.

pHSensor:

The pH sensor is used to determine the acidic or alkaline condition of the water. The sensing electrode produces an electrical signal related to the hydrogen ion concentration of the water sample. The signal is acquired by the ESP8266 and converted into a pH value after calibration.

TurbiditySensor:

The turbidity sensor is used to estimate the concentration of suspended particles in the water. Its operation is based on the interaction of light with particles suspended in the sample. Variations in the received light intensity produce an electrical output that is processed by the ESP8266. The resulting turbidity value is generally expressed in Nephelometric Turbidity Units (NTU).

DS18B20TemperatureSensor:

A DS18B20 digital temperature sensor is used to measure the temperature of the water sample. The sensor communicates with the ESP8266 through the 1-Wire protocol and provides digital temperature measurements. A pull-up resistor is connected to the data line to support reliable communication.

II.4. Edge Processing

Edge processing is an important component of the proposed monitoring architecture. Instead of transmitting all raw sensor information to a remote server for processing, the ESP8266 performs essential processing operations locally. These operations include sensor data acquisition, signal conversion, calibration, and preparation of measurement values for transmission.

Processing data close to the sensing location can reduce unnecessary communication and improve the responsiveness of the monitoring system. It can also reduce the quantity of information transferred through the network. IoT-based water quality systems have increasingly incorporated local processing and intelligent monitoring approaches to improve system efficiency and response capabilities [19].

II.5. Cloud-Based Monitoring and Visualization

The processed sensor measurements are transmitted to the Blynk cloud platform through the Wi-Fi interface of the ESP8266. Cloud-based monitoring provides an accessible interface for displaying sensor readings and observing changes in water conditions remotely.

The Blynk dashboard is configured to present the measured pH, turbidity, and temperature values. The graphical interface allows the user to observe the current measurements without being physically present at the monitoring location. Cloud-connected IoT architectures have been widely investigated for remote water quality monitoring applications.

II.6. Wireless Communication Using Wi-Fi

Wireless communication is required to transfer the processed sensor information from the monitoring unit to the remote cloud platform. The ESP8266 provides integrated Wi-Fi connectivity, eliminating the requirement for an additional wireless communication module.

After sensor data acquisition and local processing, the ESP8266 establishes an internet connection and transmits the measured values to the Blynk platform. The use of Wi-Fi-based communication provides a relatively simple and flexible approach for IoT-based environmental monitoring systems.

II.7. Data Acquisition and Signal Processing

The data acquisition stage involves obtaining electrical signals from the connected sensors. The pH and turbidity modules generate analog signals, whereas the DS18B20 provides temperature information digitally. The ESP8266 processes the signals according to the corresponding sensor interface.

The raw sensor outputs are converted into meaningful measurement values using appropriate calibration procedures. Calibration is necessary because the electrical output generated by a sensor does not directly represent the final water quality parameter. Therefore, sensor-specific conversion and calibration are applied before the measurements are transmitted to the cloud platform.

For analog measurements, the ESP8266 acquires the corresponding sensor voltage through its analog input. The measured signal is subsequently processed using the relevant calibration relationship. The processed values are then prepared for wireless transmission and visualization.

II.8. Water Quality Parameters

The proposed system focuses on pH, turbidity, and temperature as the primary parameters for assessing the condition of the monitored water.

pH: pH represents the acidic or alkaline nature of water and is expressed on a scale ranging from 0 to 14. A pH value close to 7 represents a neutral condition, while lower values indicate acidic conditions and higher values indicate alkaline conditions.

Turbidity: Turbidity represents the degree of cloudiness caused by suspended particles in water. It is commonly expressed in NTU and provides an indication of particulate contamination.

Temperature: Temperature influences several physical, chemical, and biological processes occurring in water. Monitoring temperature together with pH and turbidity provides additional information for evaluating changes in water conditions. The use of multiple parameters for IoT-based water quality assessment has been discussed in previous monitoring studies.

II.9. Real-Time Monitoring

The proposed system operates as a real-time monitoring unit in which water quality measurements are periodically acquired and processed. After processing, the measured values are transmitted to the Blynk cloud platform and displayed on the monitoring dashboard.

Continuous monitoring provides a faster method of identifying changes in water conditions compared with periodic manual sampling. When variations in the measured parameters occur, the user can observe the changes through the remote dashboard and take appropriate action when necessary. Real-time IoT-based monitoring has been explored for environmental and water management applications.

II.10. Overall System Integration

The proposed system integrates sensing, local processing, wireless communication, and cloud visualization into a single monitoring framework. The pH sensor, turbidity sensor, and DS18B20 temperature sensor are connected to the ESP8266 NodeMCU. The controller acquires the sensor measurements and performs the required local processing and calibration. The resulting values are transmitted through Wi-Fi to the Blynk cloud platform.

The overall operating sequence is as follows:

1. The water sample is monitored using the pH, turbidity, and temperature sensors.
2. The sensor outputs are acquired by the ESP8266 NodeMCU.
3. The ESP8266 performs local conversion, calibration, and data processing.
4. The processed measurements are transmitted through the Wi-Fi network.
5. The measurements are received and displayed on the Blynk cloud dashboard.
6. The user remotely observes the water quality parameters in real time.

The integration of sensing devices, microcontrollers, wireless communication, and cloud-based monitoring provides a practical framework for developing low-cost and remotely accessible water quality monitoring systems[20].

III. SYSTEM BLOCK DIAGRAM

The proposed water quality monitoring system is designed to acquire, process, and remotely display important water quality parameters in real time. The overall system consists of a NodeMCU ESP8266 microcontroller, pH sensor, turbidity sensor, DS18B20 temperature sensor, power supply, and Blynk application. The sensors collect information from the water sample and provide the corresponding electrical signals to the ESP8266 for further processing.

The pH sensor determines the acidic or alkaline condition of the water, while the turbidity sensor detects suspended particles that affect water clarity. The DS18B20 sensor measures the temperature of the water. The sensor outputs are received by the ESP8266, which acts as the central processing unit of the proposed system.

An important feature of the system is the use of local or edge-level processing. Instead of transmitting all raw sensor information directly to the cloud, the ESP8266 performs the required processing of the acquired measurements before transmitting the resulting values. This reduces unnecessary communication and supports faster monitoring of the measured parameters.

The ESP8266 has an integrated Wi-Fi interface, which is used to communicate with the Blynk cloud platform. After processing, the water quality measurements are transmitted through Wi-Fi and displayed on the Blynk application. The user can remotely observe the measured pH, turbidity, and temperature values through the monitoring interface. Thus, the proposed architecture provides a simple and low-cost approach for continuous water quality observation.

The complete system is powered by an appropriate power source capable of supplying the required voltage to the NodeMCU and connected sensors. Figure 1 illustrates the overall block-level operation of the proposed water quality monitoring system.

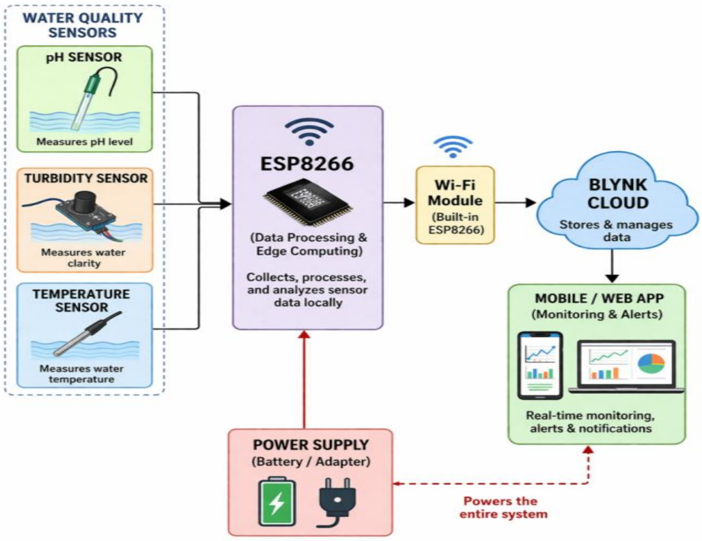


Figure 1. Block diagram of the proposed water quality monitoring system

The major components represented in the block diagram are:

- NodeMCU ESP8266 Microcontroller
- pH Sensor
- Turbidity Sensor
- DS18B20 Temperature Sensor
- Power Supply
- Built-in Wi-Fi Connectivity
- Blynk Cloud/Application

III.1. ESP8266 NodeMCU Microcontroller

The NodeMCU ESP8266 is used as the main controller of the proposed monitoring system. It is a compact development board based on the ESP8266 system-on-chip and provides convenient interfaces for connecting external sensors. Its low cost, small size, processing capability, and integrated Wi-Fi connectivity make it suitable for IoT-based sensing applications.

In the proposed system, the ESP8266 receives measurements from the pH, turbidity, and temperature sensors and performs the required local processing. The processed information is then transmitted to the Blynk platform using the built-in Wi-Fi interface. This arrangement allows sensing, local processing, and wireless communication to be performed using a single controller.

The ESP8266 also supports commonly used communication protocols and can be programmed using the Arduino IDE. Its combination of processing capability and wireless connectivity makes it suitable for developing a compact real-time water quality monitoring prototype.

III.2. Turbidity Sensor

The turbidity sensor is used to determine the clarity of the water by detecting suspended particles present in the sample. Suspended materials such as soil particles, organic matter, algae, and other impurities can increase the turbidity of water. Therefore, turbidity is an important parameter for evaluating changes in water quality.

The sensor works on an optical sensing principle. A light source is directed toward the water sample, and the variation in received or scattered light is detected by the sensing element. When the concentration of suspended particles increases, the interaction of the particles with the transmitted light changes the sensor output. The resulting electrical signal can therefore be used to estimate the turbidity level.

In the proposed system, the turbidity sensor provides an analog output that is acquired by the ESP8266. The sensor requires suitable power and signal interfacing because the electrical characteristics of the sensor output must be compatible with the controller's analog input. Calibration is performed to establish the relationship between the sensor output and the corresponding turbidity value.

III.3. DS18B20 Temperature Sensor

The DS18B20 is a digital temperature sensor used to measure the temperature of the water sample. It is suitable for the proposed system because the sensor is available in a waterproof form, making it convenient for direct measurement in liquid environments.

The sensor communicates with the microcontroller using the 1-Wire communication protocol. This protocol allows temperature data to be transferred digitally through a single data line in addition to the required power and ground connections. The DS18B20 provides a temperature measurement accuracy of approximately ±0.5°C within its specified operating range under appropriate operating conditions.

A pull-up resistor, typically 4.7 kΩ, is connected between the data line and the supply voltage to maintain proper communication on the 1-Wire bus. In the proposed system, the temperature measurement obtained from the DS18B20 is processed by the ESP8266 and subsequently transmitted to the Blynk application for remote observation.

III.4. pH Sensor

The pH sensor is used to determine whether the water sample is acidic, neutral, or alkaline. The pH scale generally ranges from 0 to 14, where a value close to 7 represents neutral conditions. Values below 7 indicate acidic conditions, whereas values above 7 indicate alkaline conditions.

The sensing mechanism is based on the electrochemical response of a pH electrode to the hydrogen-ion concentration of the water sample. The electrode generates a small electrical potential corresponding to the pH of the solution. A signal-conditioning circuit is used to make this signal suitable for acquisition by the microcontroller.

For reliable measurements, the pH sensor requires calibration using standard buffer solutions. In the proposed system, calibration is carried out before measurement so that the sensor output can be related to the corresponding pH value. The calibrated measurement is then processed by the ESP8266 and made available through the Blynk monitoring interface.

III.5. Power Supply

A reliable power source is essential for continuous operation of the proposed monitoring system. The power supply provides the required operating voltage to the NodeMCU ESP8266 and the connected sensors. Since different components may require different voltage levels, appropriate regulated power connections are used to ensure safe and stable operation.

For the developed prototype, the power arrangement is selected according to the requirements of the ESP8266, pH sensor, turbidity sensor, and DS18B20 sensor. A common ground is maintained between the controller and sensors to provide a stable reference for signal measurements.

III.6. Communication and Wi-Fi Connectivity

Wireless communication is provided by the built-in Wi-Fi capability of the ESP8266. Unlike systems that require a separate Wi-Fi module, the ESP8266 integrates wireless networking functionality within the microcontroller platform. This reduces the number of external components required in the proposed system.

After acquiring and processing the sensor measurements, the ESP8266 establishes communication with the Blynk platform through a Wi-Fi network. The measured parameters can then be transferred to the cloud interface for remote monitoring. This enables the user to observe the water quality information without being physically present near the sensing unit.

III.7. Edge Processing

Edge processing is an important part of the proposed system because the ESP8266 performs processing close to the point where the sensor data is generated. In conventional cloud-dependent monitoring systems, sensor measurements may be transmitted to a remote server before processing. In the proposed approach, the ESP8266 performs the necessary local processing of the acquired sensor readings before transmitting the required information to the cloud platform.

Local processing can reduce unnecessary data transmission and support faster access to processed measurements. It also reduces dependence on continuous cloud-side processing for basic sensor-data handling. The processed values are subsequently transmitted to Blynk for visualization and remote monitoring.

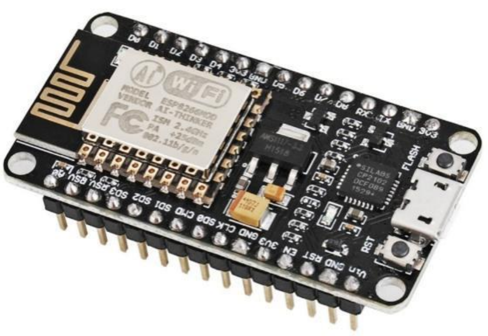
The edge-processing approach is particularly useful for IoT applications where sensor data is generated continuously. By performing suitable processing at the device level, the system can improve communication efficiency while retaining cloud connectivity for remote visualization.

III.8. Blynk Application

Blynk is used as the cloud-based monitoring interface for the proposed water quality monitoring system. It provides a convenient platform through which the sensor measurements received from the ESP8266 can be displayed and monitored remotely.

The ESP8266 communicates with the Blynk platform through Wi-Fi and transfers the processed values of temperature, turbidity, and pH. The Blynk interface can display these parameters using suitable monitoring widgets and graphical representations. This allows the user to observe changes in water quality in real time from a connected device.

The use of Blynk eliminates the need to develop a separate monitoring application for the prototype. It provides a simple interface for presenting sensor readings and supports remote observation of the implemented system. Therefore, the combination of ESP8266, edge-level processing, Wi-Fi communication, and Blynk provides an integrated solution for real-time water quality monitoring.



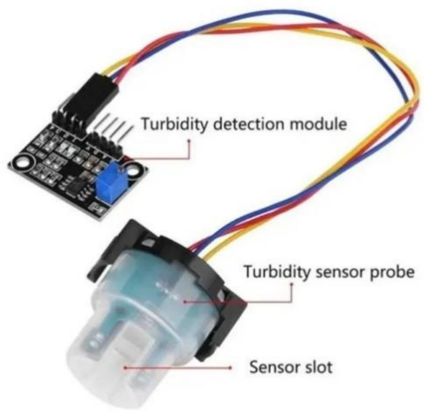


Figure 2. NodeMCU ESP8266 Development Board
Figure 3. Turbidity Sensor

Figure 4. Temperature sensor

Figure 5. pH sensor

IV. PROPOSED WORK

The proposed work presents a real-time water quality monitoring system based on the NodeMCU ESP8266 and IoT technology. The system is developed to measure three important water quality parameters, namely pH, turbidity, and temperature. These parameters are acquired from the respective sensors and processed by the ESP8266 before being transmitted through Wi-Fi to the Blynk platform. The proposed system combines local data processing with cloud-based visualization to provide convenient and continuous monitoring of water quality.

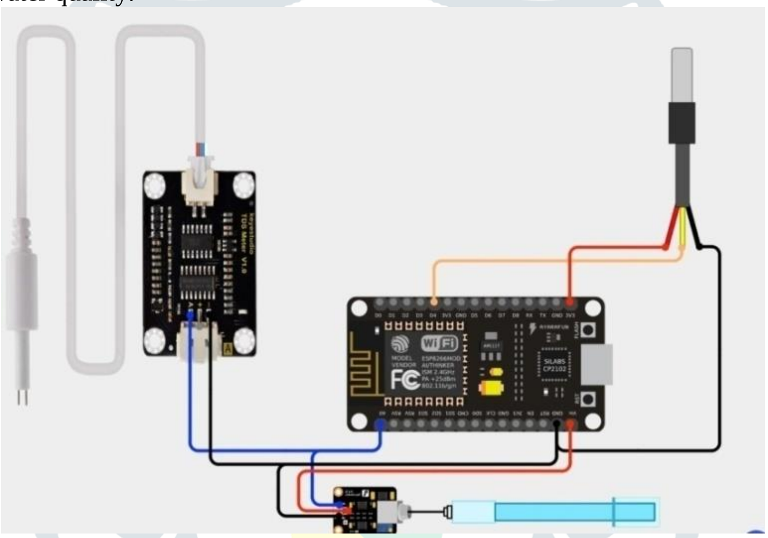


Figure 6. Connection diagram of the proposed water quality monitoring system.

The NodeMCU ESP8266 acts as the main controller of the system. It receives the sensor measurements, performs the required processing, and communicates the processed information to the Blynk platform through its built-in Wi-Fi capability. The turbidity sensor is used to determine the presence of suspended particles in the water, the pH sensor measures the acidic or alkaline nature of the water, and the DS18B20 sensor measures the water temperature.

Figure 6 illustrates the electrical connections between the ESP8266 and the different components of the proposed system. The sensors and controller share a common ground to provide a common electrical reference. The turbidity sensor and pH sensor provide analog signals that are acquired through the analog input of the ESP8266, while the DS18B20 communicates digitally with the controller using the 1-Wire protocol. Because the ESP8266 NodeMCU provides a single analog input, the analog sensor measurements are acquired appropriately during system operation rather than assuming simultaneous analog acquisition.

The sensor readings obtained by the ESP8266 are processed locally before transmission. This local processing represents the edge-processing component of the proposed system. After processing, the measured values are transmitted through Wi-Fi to Blynk, where they can be displayed to the user through a monitoring dashboard. This arrangement enables the system to provide real-time access to water quality measurements while reducing unnecessary transmission of raw sensor information.

- *Flowchart of the Proposed Water Quality Monitoring System*

The operating sequence of the proposed water quality monitoring system is presented in **Figure 7**. The flowchart describes the major stages involved in system initialization, sensor measurement, local processing, wireless communication, and remote monitoring. The system repeatedly executes these operations to provide continuous updates of the measured water quality parameters.

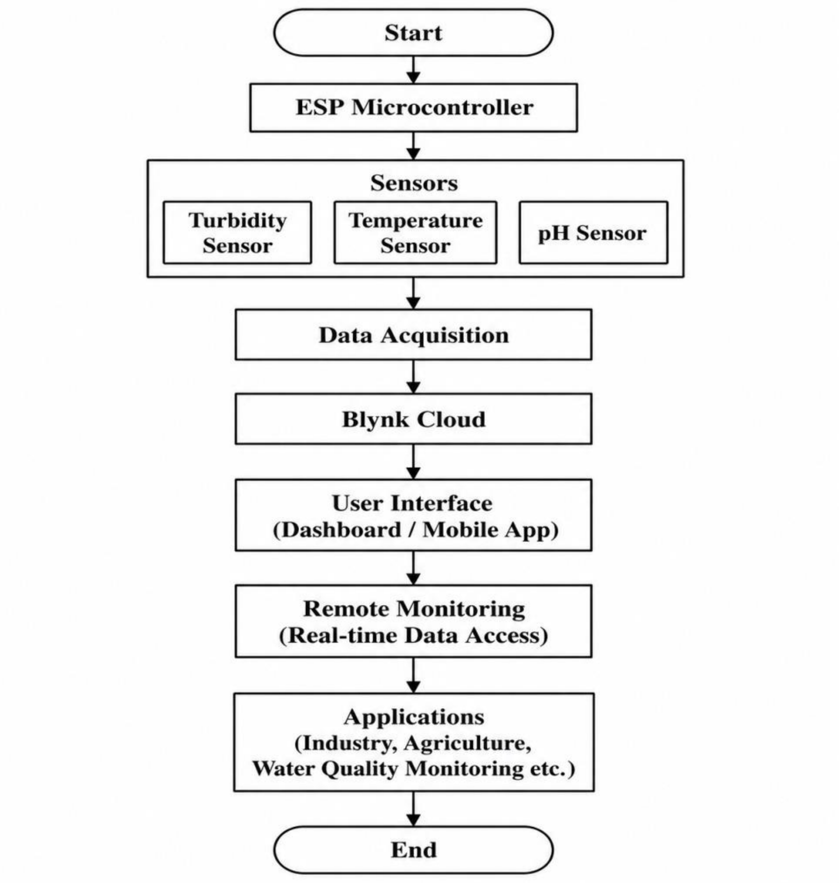


Figure 7. Flowchart of the proposed water quality monitoring system

A. System Initialization

The monitoring process begins with the initialization of the NodeMCU ESP8266. During this stage, the microcontroller initializes the connected sensors and configures the required communication interfaces. The Wi-Fi connection and Blynk communication are also established so that the measured data can subsequently be transmitted to the monitoring platform.

B. Sensor Data Acquisition

After successful initialization, the ESP8266 acquires measurements from the connected sensors. The proposed system uses three sensors:

- **pH sensor:** Determines the acidic or alkaline condition of the water.
- **Turbidity sensor:** Detects suspended particles and provides an indication of water clarity.
- **DS18B20 temperature sensor:** Measures the temperature of the water sample using digital 1-Wire communication.

The sensor measurements are periodically obtained by the ESP8266 and passed to the processing stage.

C. Local Data Processing

The acquired measurements are processed locally by the ESP8266 before they are transmitted to the cloud platform. The processing stage includes reading the sensor outputs, converting the acquired signals into meaningful measurement values, and preparing the data for transmission.

Local processing is an important feature of the proposed system because the initial handling of sensor data is performed close to the sensing point. This edge-processing approach can reduce unnecessary communication and support faster availability of processed measurements.

D. Wireless Data Transmission

Following local processing, the ESP8266 uses its integrated Wi-Fi capability to transmit the processed water quality measurements to the Blynk platform. The wireless connection eliminates the requirement for a physical communication link between the monitoring unit and the user interface.

The processed values of pH, turbidity, and temperature are transferred periodically so that the monitoring interface can be updated with the latest measurements.

E. Blynk-Based Remote Monitoring

The Blynk platform provides the user interface for observing the measured water quality parameters. The received values are presented using suitable widgets and graphical displays. This enables users to monitor the current pH, turbidity, and temperature values remotely through a connected device.

The remote monitoring capability makes the proposed system more convenient than conventional measurement methods that require the user to be physically present at the measurement location.

F. Continuous Monitoring

After the sensor values are transmitted and displayed, the system returns to the measurement stage and starts another monitoring cycle. The ESP8266 continuously repeats the sequence of data acquisition, local processing, wireless transmission, and visualization as long as the system remains powered and connected to the network.

Therefore, the complete workflow provides continuous monitoring of the selected water quality parameters. The integration of sensor-based measurement, ESP8266 edge processing, Wi-Fi communication, and Blynk visualization forms the basis of the proposed real-time water quality monitoring system.

V. RESULTS AND DISCUSSION

A. Prototype Implementation of the Water Quality Monitoring System

The developed prototype was implemented to evaluate the practical operation of the proposed real-time water quality monitoring system. The system integrates a NodeMCU ESP8266 with a pH sensor, turbidity sensor, and DS18B20 temperature sensor. The sensors acquire water quality measurements, which are processed by the ESP8266 before being transmitted through Wi-Fi to the Blynk monitoring platform.

The prototype successfully demonstrated the integration of sensing, local data processing, wireless communication, and remote visualization. The ESP8266 continuously receives measurements from the connected sensors and prepares the corresponding parameter values for transmission. The Blynk interface provides a convenient means of observing the measured values remotely.

The experimental implementation confirms that the proposed system can be used to monitor changes in water quality under different water conditions. The developed prototype also demonstrates the feasibility of combining IoT communication with edge-level processing in a compact and low-cost monitoring unit.

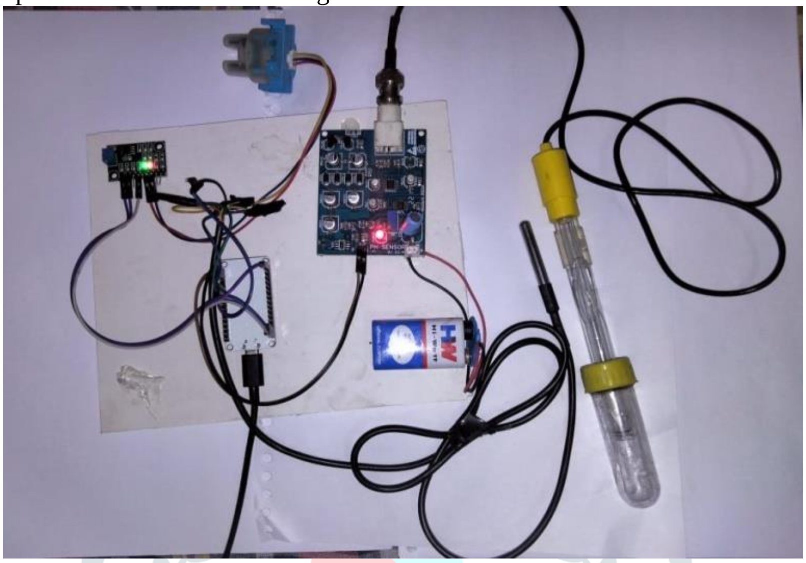


Figure 8. Prototype of the proposed water quality monitoring system

B. Experimental Analysis of Normal Water

An experiment was conducted using a normal water sample to establish the baseline response of the proposed monitoring system. The measured temperature was approximately **25°C**, the turbidity reading was approximately **36**, and the pH value was approximately **7**.

The pH value close to 7 indicates that the tested sample was approximately neutral. The measured temperature represents the condition of the sample during the experiment, while the turbidity measurement provides an indication of the suspended matter detected by the turbidity sensor.

The obtained measurements were successfully acquired by the ESP8266 and displayed through the Blynk monitoring interface. The experiment demonstrates that the system can simultaneously monitor the selected water quality parameters and provide the measured information through a remote dashboard. The normal-water experiment was also used as a reference condition for comparison with the acidic-water sample.

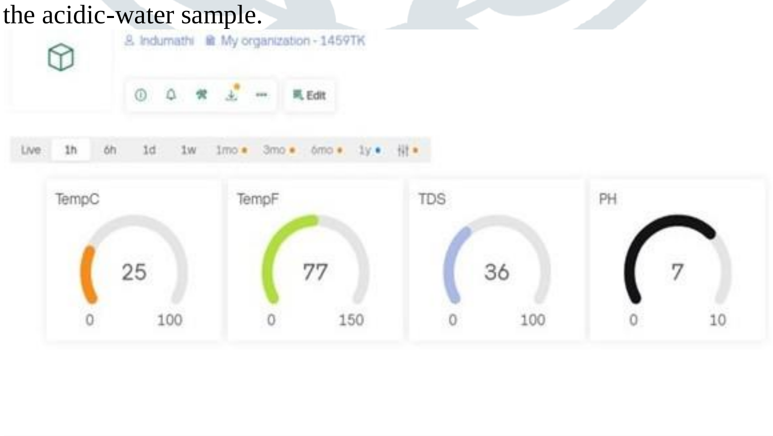


Figure 9. Blynk monitoring dashboard for normal water

C. Experimental Analysis of Acidic Water

A second experiment was performed using an acidic water sample to evaluate the response of the system under a different water condition. The recorded measurements were approximately **26°C** for temperature, **18** for turbidity, and **5** for pH.

The pH value of approximately 5 indicates an acidic condition compared with the near-neutral value obtained from the normal water sample. The change in pH demonstrates that the sensing system can identify variations in the chemical condition of the tested water. The temperature also showed a small variation from the normal-water experiment.

The measured values were processed by the ESP8266 and transmitted to the Blynk platform for remote visualization. The experiment demonstrates the ability of the proposed system to detect changes in water parameters and present the measurements to the user in real time.

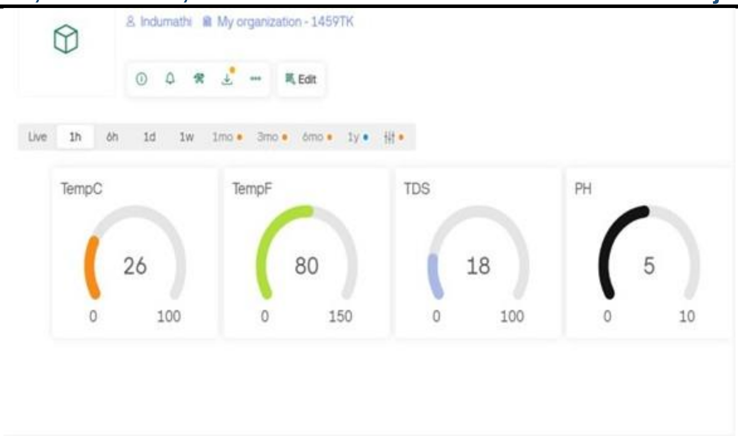


Figure 10. Blynk monitoring dashboard for acidic water

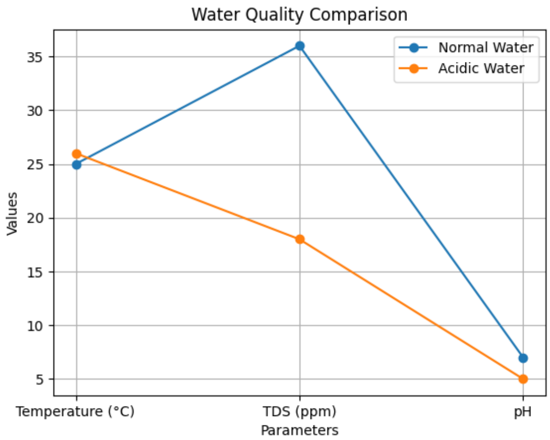
D. Comparative and Temporal Analysis of Water Quality Parameters

A comparison was performed between the measurements obtained from the normal and acidic water samples. The experimental results show that the temperature changed only slightly, from approximately **25°C** for normal water to **26°C** for acidic water. In contrast, a noticeable change was observed in the pH value, which decreased from approximately **7** to **5**.

The turbidity measurements also differed between the two tested samples, with an observed value of approximately **36** for normal water and **18** for acidic water. These experimental observations demonstrate that the proposed system is capable of identifying variations in the measured water parameters under different sample conditions.

The temporal analysis of pH further demonstrates the change in the measured pH value during the experiment. The recorded trend shows a reduction from approximately **7.0** toward **5.0**, indicating a transition from a near-neutral condition toward an acidic condition. This variation demonstrates the usefulness of continuous pH monitoring for identifying changes in water characteristics.

The comparative and temporal results therefore validate the basic functionality of the developed prototype. By continuously acquiring sensor measurements, processing them at the ESP8266, and presenting the resulting values through Blynk, the proposed system provides a practical approach for real-time observation of water quality.



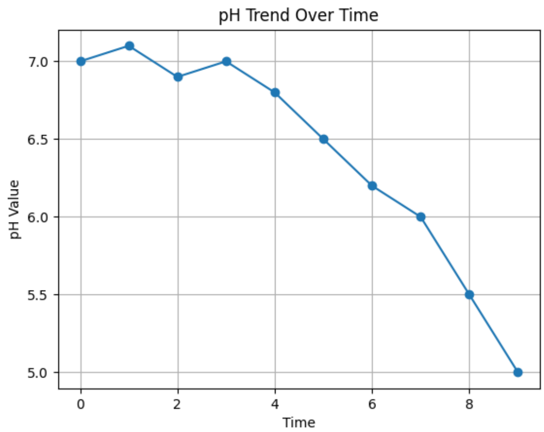


Figure 11. Comparison of Normal and Acidic Water Parameters

Figure 12. pH Variation Over Time

VI. CONCLUSIONS

This paper presented the design and implementation of an IoT-based real-time water quality monitoring system incorporating edge processing. The developed system uses a NodeMCU ESP8266 microcontroller integrated with pH, turbidity, and temperature sensors to monitor key water quality parameters. The sensor readings are acquired and processed locally by the ESP8266 before being transmitted through Wi-Fi to the Blynk platform for remote visualization. This combination of local processing and cloud-based monitoring provides a practical approach for continuous water quality observation.

The experimental evaluation demonstrated that the developed system was able to identify variations between normal and acidic water conditions. The pH sensor detected changes in acidity, while the turbidity sensor responded to changes in water clarity. The DS18B20 temperature sensor provided temperature measurements during the experiments. The obtained observations confirm that the developed prototype can acquire and transmit water quality data in real time and provide useful information for monitoring changes in the tested water samples.

The integration of the Blynk platform enabled remote visualization of the measured parameters through a user-accessible monitoring interface. Sensor values could be observed continuously, allowing the user to monitor changes without being physically present near the prototype. This feature improves the convenience of the monitoring system and demonstrates the usefulness of IoT connectivity for water quality applications.

The use of edge processing allows initial sensor data handling to be performed at the NodeMCU rather than relying entirely on remote cloud processing. Local processing can help reduce the amount of unnecessary data transmitted to the cloud and can support faster handling of sensor information. Thus, the proposed approach combines the benefits of local processing with the accessibility of cloud-based monitoring.

Overall, the developed system provides a low-cost and practical solution for real-time monitoring of selected water quality parameters. Its compact design, wireless connectivity, and remote monitoring capability make it suitable for applications such as environmental observation, agricultural water monitoring, aquaculture, and other small-scale water management activities. Future improvements can focus on incorporating additional water quality parameters, improving sensor calibration, expanding the monitoring range, and developing more advanced data analysis and alert mechanisms.

VII. REFERENCES

[1] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash, "Internet of Things: A survey on enabling technologies, protocols, and applications," *IEEE Communications Surveys & Tutorials*, vol. 17, no. 4, pp. 2347–2376, 2015, doi: 10.1109/COMST.2015.2444095.

[2] W. Chen, C. Lin, C. Tsai, and C. Wu, "Wireless sensor network-based water quality monitoring system for aquaculture ponds," *Sensors*, vol. 18, no. 10, p. 3363, 2018, doi: 10.3390/s18103363.

[3] J. Liu, Y. Liu, X. Wang, and Y. Liu, "Development of a portable river and lake water quality monitoring system based on the ESP8266 microcontroller," *Journal of Sensors*, vol. 2021, 2021, doi: 10.1155/2021/6635935.

[4] S. Sahoo, S. Panda, S. Swain, and R. Jena, "IoT based water quality monitoring system using Arduino microcontroller and cloud computing," *International Journal of Scientific & Technology Research*, vol. 9, no. 9, pp. 6926–6930, 2020.

[5] D. Zhang, Q. Yang, H. Ma, and L. Zhang, "Design of a portable water quality monitoring system based on IoT technology," *IOP Conference Series: Earth and Environmental Science*, vol. 273, no. 4, p. 042098, 2019, doi: 10.1088/1755-1315/273/4/042098.

[6] C. Hou, Y. Chen, J. Chen, and F. Tang, "A review of IoT-based water quality monitoring system," *Water*, vol. 11, no. 4, p. 798, 2019, doi: 10.3390/w11040798.

[7] J. Yang and Z. Yu, "Design and implementation of water quality monitoring system based on IoT," in *Proc. 2nd Int. Conf. Data Science and Information Technology (DSIT)*, 2019, pp. 44–48, doi: 10.1145/3352411.3352419.

[8] S. Javed, N. Arshad, N. Javaid, and A. Ahmad, "IoT-based water quality monitoring system using machine learning," *IEEE Access*, vol. 8, pp. 115741–115749, 2020, doi: 10.1109/ACCESS.2020.3004181.

[9] H. Lu, G. Zheng, F. Fang, and Y. Xu, "Research on water quality monitoring system based on Internet of Things," in *Proc. Int. Conf. Water Resources and Environment Engineering (ICWREE)*, 2019, pp. 1–6.

[10] C. Su, X. Li, Q. Xu, and H. Zhang, "Design and implementation of an IoT-based water quality monitoring system," *Journal of Physics: Conference Series*, vol. 1171, no. 1, p. 012130, 2019, doi: 10.1088/1742-6596/1171/1/012130.

[11] T. V. Ho, T. D. Nguyen, T. P. Le, T. D. Vo, and D. L. Nguyen, "A low-cost IoT-based water quality monitoring system for agricultural applications," *Computers and Electronics in Agriculture*, vol. 181, p. 105956, 2021, doi: 10.1016/j.compag.2020.105956.

[12] M. H. A. Rahim, R. M. Sidek, A. R. M. Saad, A. H. Nordin, and T. Sabapathy, "Real-time water quality monitoring system using IoT: A review," *IOP Conference Series: Materials Science and Engineering*, vol. 736, no. 1, p. 012028, 2020, doi: 10.1088/1757-899X/736/1/012028.

[13] M. M. Islam, M. S. Alam, M. M. Rahman, and M. S. Alam, "An IoT-based real-time water quality monitoring system using Arduino for aquaculture pond," *Journal of King Saud University - Computer and Information Sciences*, 2021, doi: 10.1016/j.jksuci.2021.05.013.

[14] L. Chen, S. Zhang, J. Zhao, and C. Liu, "Research on water quality monitoring system based on IoT technology," *Journal of Physics: Conference Series*, vol. 1748, no. 1, p. 012037, 2021, doi: 10.1088/1742-6596/1748/1/012037.

[15] C. Zhu, H. Chen, W. Xu, B. Hu, and X. Luo, "The design of water quality monitoring system based on Internet of Things technology," *IOP Conference Series: Earth and Environmental Science*, vol. 469, no. 1, p. 012057, 2020, doi: 10.1088/1755-1315/469/1/012057.

[16] A. Bansal, V. Chauhan, and A. K. Sharma, "IoT based water quality monitoring system," *IOP Conference Series: Materials Science and Engineering*, vol. 995, no. 1, p. 012108, 2020, doi: 10.1088/1757-899X/995/1/012108.

[17] A. Ahmad, N. Javaid, S. Javed, and N. Arshad, "IoT-based smart water quality monitoring and controlling system using machine learning," *IEEE Access*, vol. 8, pp. 129002–129010, 2020, doi: 10.1109/ACCESS.2020.3006811.

[18] J. Yu, D. Zhu, S. Li, H. Xu, and T. Guo, "Design of water quality monitoring system based on IoT," *Journal of Physics: Conference Series*, vol. 1519, no. 1, p. 012090, 2020, doi: 10.1088/1742-6596/1519/1/012090.

[19] S. Shukla and M. Khari, "Water quality monitoring using IoT: A review," *Materials Today: Proceedings*, vol. 28, pp. 2455–2460, 2020, doi: 10.1016/j.matpr.2020.04.735.

[20] D. Chaudhary and K. K. Lathiya, "IoT based real-time water quality monitoring system using Arduino and cloud computing," *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, vol. 9, no. 1, pp. 2555–2559, 2020, doi: 10.35940/ijitee.A4868.119120.