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Water Quality Monitoring System – Using IOT Devices

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ABSTRACT

This paper presents the design and implementation of an intelligent, real-time water quality monitoring system using Internet of Things (IoT) technology. The system integrates temperature, turbidity, and total dissolved solids (TDS) sensors with an ESP32 microcontroller to provide both local (LCD) and graphical (via a Python-based desktop application) data visualization. This scalable, low-cost solution is evaluated for various water sources and compared with World Health Organization (WHO) guidelines [1].

Keywords*:* Water quality, IoT, ESP32, TDS, turbidity, WHO Guidelines.

INTRODUCTION

A. Background Information

Water is the most critical resource for sustaining life, yet its quality is increasingly compromised by pollution, industrial discharges, and inadequate waste management practices. Considering growing health concerns over contaminated water, there is a pressing need for reliable and intelligent water monitoring systems [1].

B. Research Issue

Traditional water quality assessment methods depend largely on time-intensive laboratory tests and manual sampling. These approaches delay real-time decision-making. This research aims to develop a real-time water monitoring system using IoT technology to measure temperature, turbidity, and TDS, with data displayed both locally and on a desktop application through a Python-based interface for live visualization of fluctuations.

C. Importance of the Investigation

The proposed system offers a scalable and cost-effective solution for environmental monitoring. It is applicable for residential, agricultural, and industrial water usage. By bridging sensor data acquisition with real-time desktop visualization, the system enhances safe water management practices in both urban and rural settings [1].

II. LITERATURE REVIE

Overview of Relevant Literature

Recent studies have explored water quality monitoring using pH and turbidity sensors [5]. However, many existing solutions remain prohibitively expensive or lack real-time cloud integration. Projects based on WiFi-enabled microcontrollers such as Arduino and Raspberry Pi demonstrate potential for affordable and effective monitoring [5].

Key Theories or Concepts

Key concepts underpinning this work include the Internet of Things, sensor calibration, cloud data streaming, and adherence to WHO water quality guidelines [1]. A central component is the ESP32 microcontroller, known for its dual-core processing and integrated WiFi functionality [2].

Gaps in Literature

Current systems often focus on single parameters without combining a complete suite of measurements or offering both local and remote monitoring [5]. Many academic prototypes also overlook real-time analysis and alert mechanisms, limiting their practical implementation.

III. METHODOLOGY

A. Research Design

An ESP32 microcontroller is integrated qwith a DS18B20 temperature sensor, a TDS sensor, and a turbidity sensor [3]. Local data display is managed by an LCD, while real-time data is transmitted to a Python-based desktop UI for graphical visualization and live monitoring.

B. Data Collection Methods

Sensor data is collected at regular intervals and transmitted via serial communication to a Python application. The application plots the live data using graphical tools such as Matplotlib. Each sensor is calibrated to provide readings in appropriate units (°C for temperature, NTU for turbidity, and ppm for TDS) [2].

C. Sample Selection

Water samples were taken from a variety of sources—including tap water, filtered water, and stagnant water—to verify that the sensor system is capable of distinguishing between clean and contaminated water [4].

D. Data Analysis Techniques

Sensor outputs are translated into meaningful values by applying mathematical algorithms. For instance, voltage readings are converted into TDS values using a cubic polynomial regression [4], and turbidity is calculated via a quadratic function. These readings are then compared with WHO guidelines for water quality [1].

E. Formulas Used

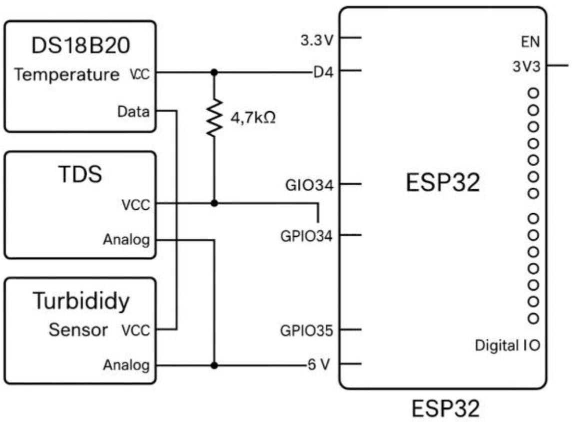
TDS Conversion Formula:
$TDS\ (ppm) = 133.42 * V^3 - 255.86 * V^2 + 857.39 * V$

Turbidity Estimation Formula:
$Turbidity\ (NTU) = -1120.4 * V^2 + 5742.3 * V - 4352.9$

G. Integration of Databases and Extended Data Storage

The system incorporates a database that regularly saves timestamped sensor readings to enable long-term analysis. Along with the relevant date and time, each data entry contains the temperature (°C), turbidity (NTU), and TDS (ppm) values. The database is made to effectively manage constant data flow while preserving data accessibility and integrity for additional analysis.

Circuit Diagram



Analysis and Visualization of Monthly Data

A month of data collection is followed by the retrieval of the stored information to create thorough graphical representations. Tools like Matplotlib are used to construct line charts and scatter plots that show trends, identify anomalies, and evaluate how the overall quality of the water has changed over time. Based on observational data collected over a month, these visualizations help assess environmental conditions, spot pollution trends, and suggest appropriate solutions.

Hardware used

i. Turbidity Sensor

The turbidity sensor uses light dispersed by suspended particles to determine how cloudy the water is. By highlighting the existence of contaminants, it aids in water quality monitoring.

ii. Temperature sensor

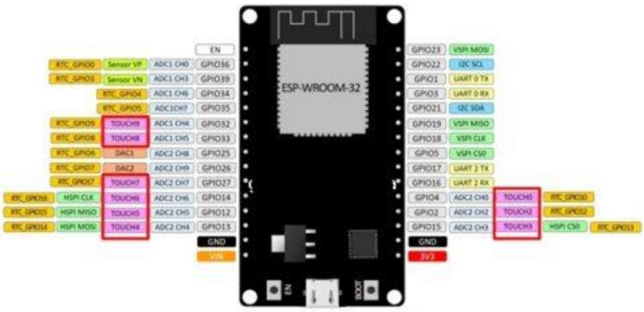
The temperature sensor measures the water's temperature, which affects chemical and biological properties like dissolved oxygen and reaction rates. Real-time monitoring helps detect unusual variations indicating pollution or environmental issues.

iii. TDS Sensor

The TDS sensor offers real-time TDS results in parts per million (ppm) and monitors the amount of dissolved solids in water. TDS level monitoring aids in determining if water is suitable for industrial, agricultural, and drinking uses.

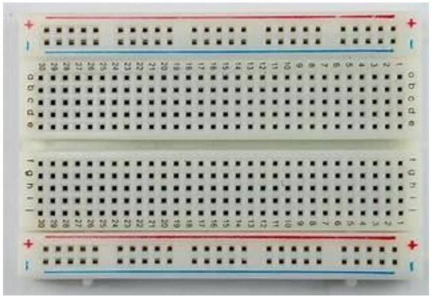
iv. ESP32

Our system's primary processor is the ESP32, a low-cost, low-power microcontroller with integrated Bluetooth and Wi-Fi. It facilitates wireless connectivity for Internet of Things-based water quality monitoring and gathers and analyzes real-time sensor data.



v. Breadboard

Our water quality monitoring sensors are easily connected and prototyped using a breadboard, which eliminates the need for soldering and enables flexible testing and adjustments during system development.



vi. Jumper Wire

Short electrical cords called jumpers are used to connect sensors and modules to the ESP32 without the need for soldering. While our Smart Water Quality Monitoring System is being tested and prototyped, they guarantee flexible, effective, and dependable wiring.

vii. LCD Display

Real-time sensor readings, such as temperature, TDS, and turbidity levels, are shown on an LCD (Liquid Crystal Display), allowing for instantaneous local monitoring of water quality parameters.

IV. RESULTS

A. Outlining the Results

The Python-based graphical user interface and a local LCD display both successfully received real-time water quality data from the system. The highest levels of contamination were found in stagnant water, tap water had moderate readings, and filtered water samples had the lowest amounts of TDS and turbidity. There was a strong correlation between the measured temperature and the room temperature [3]. Sensor data was also entered into a database for future reference. Insights into patterns and variations in water quality were provided by the creation of graphical representations of the data collected over a month.

B. Interpretation and Analysis of Data

The technology accurately identified water quality problems in real-time by comparing sensor outputs with predetermined safety benchmarks [1]. Matplotlib was used to depict the month-long data, which was retrieved and analyzed efficiently thanks to the integration of database storage. This made it possible to compare various water sources across time and identify patterns and anomalies in water quality. The desktop dashboard worked well for both historical data analysis and continuous visualization.

C. Suggestions for Upcoming Studies

The promising performance of this low-cost prototype suggests that future work could focus on integrating additional sensors (e.g., pH sensors), exploring alternative data storage solutions such as blockchain for enhanced security [5], and employing artificial intelligence for automated water quality classification and alert generation.

D. Generated Graph

Temperature Over a Month
Day of the month (X-axis: 1 to 30)
Y-axis: Celsius temperature
Over the course of 30 days, temperatures range from roughly 20 to 30 degrees Celsius. A number of mid-month peaks can be observed, such as the temperature approaching its maximum (~29–30 °C) on days 9 and 16, and troughs around the beginning and end of the month (around days 3 and 27, when it dips to ~20–21 °C). Environmental variables or variations in the room's temperature could be the cause of this variability.

TDS During a Month
Day of the month (X-axis: 1 to 30)
TDS in ppm on the Y-axis
The approximate range of TDS values is 50 ppm to 500 ppm. On days 9, 14–15, 19, and particularly on day 27, when levels go close to the top bound (~480–500 ppm), there are noticeable surges. Cleaner samples are indicated by lower findings (~80–120 ppm) on days 5 and 22. These variations demonstrate the daily variations in TDS and emphasize the significance of ongoing monitoring

Turbidity During a Month
Day of the month (X-axis: 1 to 30)
Y-axis: NTU Turbidity
Turbidity levels range from almost 0 NTU (extremely clear) to 100 NTU (very murky). Days 4, 5, 13, and 20–21 will have sharp peaks, signifying times when the suspended solids are higher. On the other hand, turbidity is very low (less than 10 NTU) on days 1, 6, and 14. Finding contamination episodes or sediment disturbances can be aided by such patterns.

V. DISCUSSION

A. Interpretation of Results

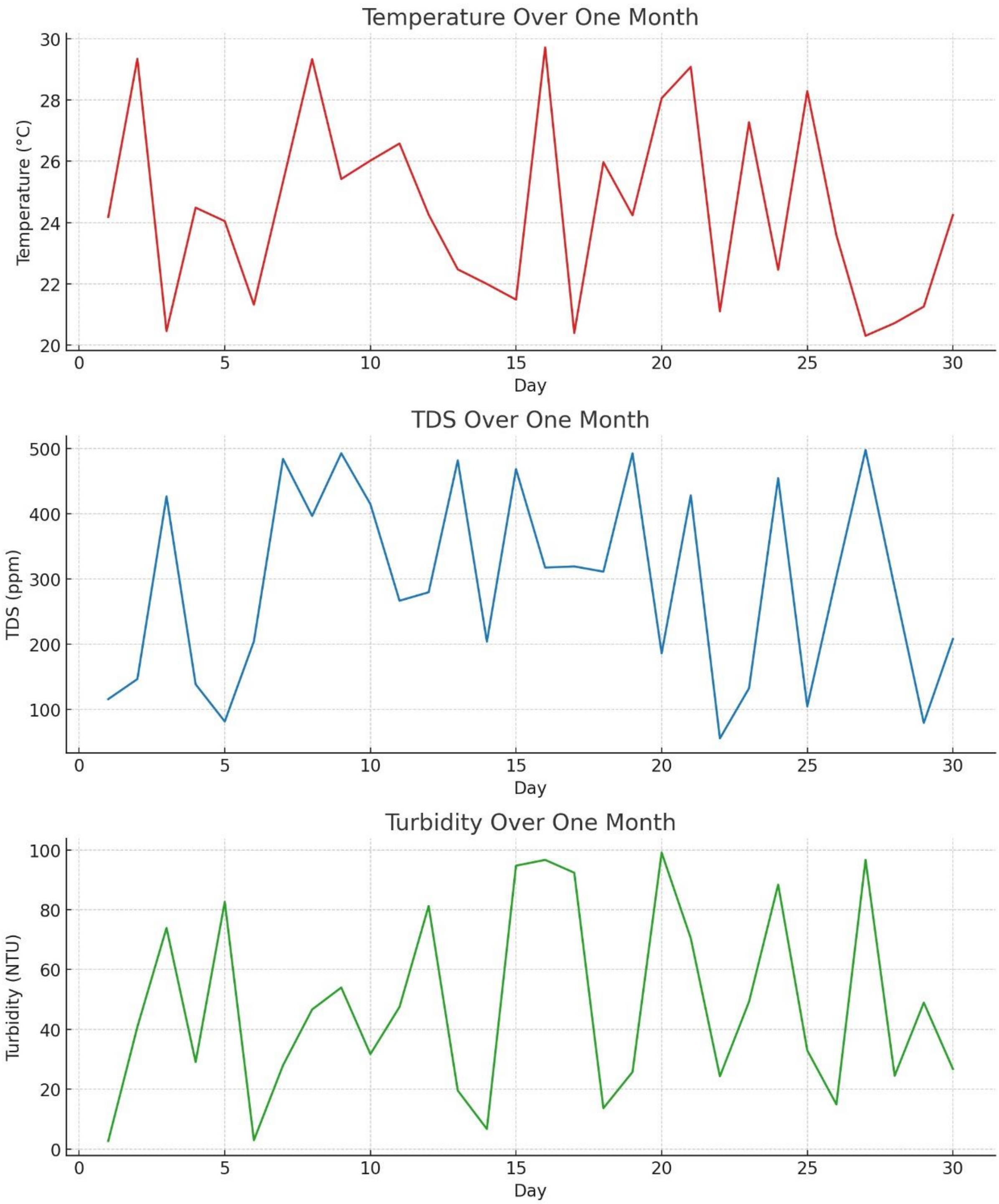
The findings confirm that IoT-based water quality monitoring can effectively automate the collection and evaluation of environmental data. The system’s real-time analysis and desktop visualization enable prompt interventions, making it suitable for small-scale water applications [2].

B. Comparison with Existing Literature

Unlike many existing solutions that either are cost-prohibitive or limited in function [5], this system offers dual display modes (local and cloud-based) and customizable alert features. Its open-source nature and affordability set it apart from expensive commercial alternatives [4].

C. Implications and Limitations

The study shows how real-time data visualization and inexpensive, modular gear may support proactive water management. However, full-spectrum water quality testing is limited in the absence of a pH sensor. Furthermore, even though cloud integration is optional, there is always room for improvement in terms of expanding safe data storage for long-term analysis (for example, by utilizing blockchain).



VI. CONCLUSION

A. Summary of Key Findings

The Smart Water Quality Monitoring System effectively demonstrates the capability to integrate sensor data with IoT technology for real-time monitoring. Temperature, turbidity, and TDS data are accurately measured and communicated via an intuitive Python-based graph dashboard [2].

B. Contributions to the Field

This work adds to the growing body of research on practical IoT applications in environmental monitoring [5]. It provides a cost-effective solution for enhancing public health safety and water resource management in regions lacking extensive laboratory resources [1].

C. Recommendations for Future Research

Future enhancements might include the incorporation of additional sensors (e.g., pH monitoring), exploration of renewable energy sources like solar power, and the use of AI to automatically classify water quality and generate alerts, as well as secure data logging with blockchain technology [5].

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