Water Quality Monitoring and Contamination Detection System

Mr. Pranav P.Daithankar[1], Mr. Shubham R. Gond[2], Mr. Vishvawasu V.Pendalwar[3], Mrs. Aparna B. Dalvi[4]

MGM's College of Engineering, Nanded Department of Electronics & Telecommunication Engineering

s23_daithankar_pranav@ mgmcen.ac.in[1], s23_gond_shubham@mgmcen. ac.in[2], s23_pendalear_vishvawasu@ mgmcen.ac.in[3], dalvi_ab@mgmcen.ac.in[4]

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Abstract - Access to clean and safe drinking water is a fundamental necessity, yet contamination from industrial waste, agricultural runoff, and inadequate treatment facilities poses significant health risks globally. Traditional water quality monitoring methods are often manual, time-consuming, and lack real-time alerting capabilities. To address these challenges, this paper proposes an IoT-based automated water quality monitoring system that integrates turbidity sensing for contamination detection and ultrasonic sensing for continuous water level measurement. The system employs an Arduino Nano microcontroller to process turbidity data measured in Nephelometric Turbidity Units (NTU) and displays water quality status along with tank level information on a 16x2 LCD screen. An audible alarm activates when contamination exceeds safe thresholds, providing immediate alerts. By replacing conventional IR sensors with ultrasonic distance measurement, the system achieves non-contact, accurate, and maintenance-free level detection suitable for various tank configurations. This cost-effective, scalable, and user-friendly solution is ideal for residential water tanks, community water supplies, and small-scale purification plants.

Keywords: Water Quality Monitoring, Turbidity Sensor, Ultrasonic Sensor, Arduino Nano, IoT, NTU Measurement, Contamination Detection, LCD Display

I. Introduction

Water contamination is a critical global concern affecting millions of people, particularly in developing regions where access to safe drinking water is limited. According to the World Health Organization, contaminated water causes over 500,000 deaths annually from waterborne diseases. Traditional water quality assessment methods rely on laboratory testing, which is expensive, time-consuming, and unsuitable for continuous monitoring. Real-time monitoring systems are essential to detect contamination promptly and prevent health hazards.[1][5]

Turbidity, defined as the cloudiness or haziness of water caused by suspended particles, is a key indicator of water quality. High turbidity levels indicate the presence of bacteria, viruses, and other contaminants that can cause serious health issues. Nephelometric Turbidity Units (NTU) provide a standardized measurement, with safe drinking water typically requiring turbidity levels below 5 NTU according to WHO standards.[6]

This paper proposes an automated water quality monitoring system that combines turbidity measurement with ultrasonic-based water level detection. The Arduino Nano microcontroller processes sensor data and displays real-time water quality and tank level information on an LCD screen. An alarm system alerts users when contamination exceeds safe limits. Unlike traditional IR-based level sensors that require direct contact and are prone to fouling, the ultrasonic sensor provides non-contact, accurate distance measurement suitable for various environmental conditions. The system is designed for ease of installation, low maintenance, and scalability, making it practical for homes, institutions, and community water supplies.[4]

II. Literature Review

Water quality monitoring systems have evolved from manual sampling and laboratory analysis to automated sensor-based solutions. Early systems relied on periodic collection and testing, which could not detect sudden contamination events. Electronic turbidity sensors introduced continuous monitoring but often required expensive data loggers and lacked user-friendly interfaces.[7]

Recent advancements in IoT technology have enabled remote monitoring through cloud platforms and mobile applications. However, many existing systems use IR-based proximity sensors for level detection, which suffer from limitations such as sensitivity to dirt accumulation, limited range, and interference from ambient light. Studies have shown that ultrasonic sensors provide superior accuracy and reliability for liquid level measurement due to their non-contact operation and immunity to surface contamination.[2][8]

Microcontroller-based systems using Arduino and ESP modules have gained popularity for their affordability and flexibility. Research demonstrates that Arduino Nano is suitable for low-power, real-time applications requiring analog sensor interfacing and digital control. Integration of LCD displays for local monitoring and buzzer alarms for immediate notification enhances system usability in areas with limited internet connectivity.[3][9]

This study addresses existing gaps by combining turbidity-based contamination detection with ultrasonic level sensing in a unified, cost-effective platform. The use of non-contact ultrasonic measurement eliminates maintenance issues associated with contact-based sensors, while real-time NTU calculation and threshold-based alerting provide actionable water quality information.[6]

III. System Architecture

The system architecture integrates multiple sensing, processing, display, and alerting components into a cohesive framework for real-time water quality and level monitoring.

A. Turbidity Sensor:

The turbidity sensor operates on the nephelometric principle, measuring light scattering caused by suspended particles in water. The sensor outputs an analog voltage proportional to turbidity levels, which is converted to NTU using a calibration curve. This allows quantitative assessment of water clarity and contamination.[6]

Fig 1. Turbidity Sensor Module

B. Ultrasonic Distance Sensor :

The HC-SR04 ultrasonic sensor measures the distance to the water surface using high-frequency sound waves. It transmits an ultrasonic pulse and measures the time taken for the echo to return, calculating distance based on the speed of sound. This non-contact method provides accurate level measurement

without physical contact with water, eliminating fouling and maintenance issues associated with IR sensors.[2]


Fig 2. HC-SR04 Ultrasonic Sensor

C. Arduino Nano Microcontroller

The Arduino Nano serves as the central processing unit, reading analog signals from the turbidity sensor and digital pulses from the ultrasonic sensor. It performs NTU calculations, water level determination, threshold comparisons, and controls the LCD display and buzzer alarm. Its compact size, low power consumption, and ease of programming make it ideal for embedded monitoring applications.[3]

Fig 3. Arduino Nano Microcontroller
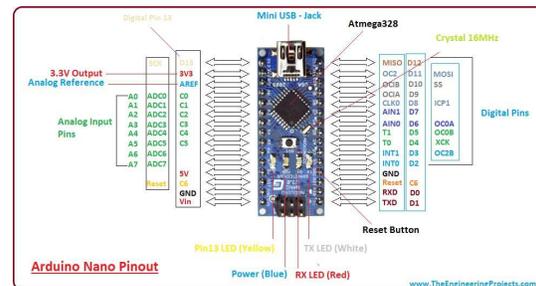
D. 16x2 LCD Display with I2C Interface

The LCD display provides real-time visual feedback showing water quality status (Safe to Drink, Contaminated, Highly Contaminated) and water level (Low, Medium, Full). The I2C interface reduces wiring complexity by requiring only two communication lines (SDA and SCL).[4]

Fig 4. 16x2 LCD Display with I2C Interface

IV. Methodology

The methodology outlines the systematic process and design approach used to develop the water level detection and contaminated detection system:

E. Hardware Design

1. Turbidity Measurement Circuit: The turbidity sensor's analog output (0-5V) connects to the Arduino Nano's A0 analog input pin. A voltage divider circuit may be used if sensor output exceeds 5V. Proper grounding and power supply filtering ensure stable readings.

2. Ultrasonic Level Sensing: The HC-SR04 ultrasonic sensor's trigger pin connects to Arduino digital pin D5, and the echo pin connects to D6. The sensor requires 5V power supply and measures distances from 2 cm to 400 cm with ±3mm accuracy. Tank height is configured in software, and water level percentage is calculated by subtracting measured distance from total tank height.[2]

3. Display and Alert System: The 16x2 I2C LCD connects to Arduino's A4 (SDA) and A5 (SCL) pins. The buzzer connects to digital pin D4 through a current-limiting resistor to prevent excessive current draw **Power Supply:** A regulated 5V power supply or 9-12V adapter connected to Arduino's VIN pin powers all components. Current consumption is approximately 200-300mA, well within Arduino's capabilities.[7]

F. Software Design

1. Turbidity Measurement and NTU Calculation: The Arduino reads the analog voltage from the turbidity sensor and converts it to NTU using a polynomial calibration equation derived from known turbidity standards. Multiple readings are averaged to reduce noise and improve accuracy.

2. Ultrasonic Distance Measurement: The ultrasonic measurement process involves:

- Triggering a 10μs pulse on the trigger pin
- Measuring echo pulse duration using pulseIn() function
- Calculating distance: Distance (cm) = (Pulse Duration × 0.034) / 2
- Determining water level: Level (%) = ((Tank Height - Distance) / Tank Height) × 100

3. Threshold-Based Classification: Water quality is classified into three categories:

- **Safe to Drink**: NTU < 5
- **Contaminated**: $5 \leq$ NTU ≤ 50
- **Highly Contaminated**: NTU > 50 Water level is classified as:
- **Low Level**: Level < 30%
- **Medium Level**: 30% $\leq$ Level < 70%
- **Full Tank**: Level $\geq$ 70%

4. Display and Alert Control: The LCD displays water quality status on the first row and water level on the second row. The buzzer activates when NTU $\geq$ 5, providing continuous or intermittent beeping based on contamination severity.[4]
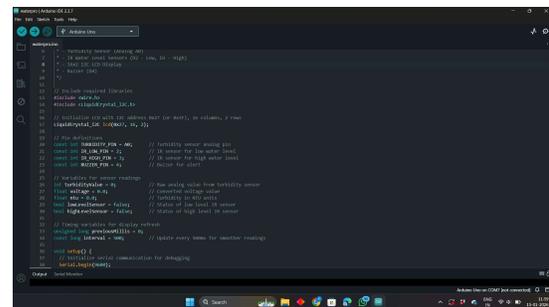

Fig 5. System Software

V. Implementation

The complete system was implemented using commercially available components and open-source Arduino IDE software. The turbidity sensor was calibrated using known NTU standards (distilled water at 0 NTU and commercial turbidity standards at 5, 20, and 100 NTU). A polynomial calibration curve was derived from voltage-to-NTU measurements.

The ultrasonic sensor was mounted at the top of the water tank with proper clearance to avoid interference from tank walls. Tank height was measured and programmed into the Arduino firmware. The sensor's beam angle (approximately 15 degrees) was considered to ensure accurate vertical distance measurement.

All components were connected on a breadboard initially for testing, then transferred to a custom PCB for permanent installation. The I2C LCD address (0x27 or 0x3F) was detected using an I2C scanner sketch before implementation. Power supply filtering capacitors (100μF) were added to ensure stable operation and prevent voltage fluctuations affecting sensor readings.

The system was tested under various conditions including clean water, tap water with varying turbidity levels, and artificially contaminated samples. Real-time serial monitoring was used for debugging and verification of sensor readings. The final system demonstrated reliable operation with response times under 500ms for both turbidity and level measurements.[3][5]
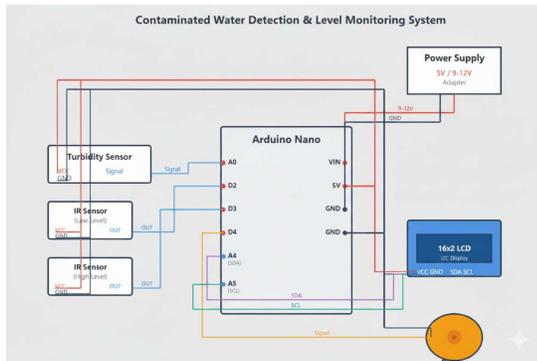

Fig 6. Circuit Diagram of Water Quality Monitoring System

VI. Results & Discussion

A. Accurate Turbidity Measurement

The turbidity sensor successfully measured water quality across a range of 0-3000 NTU with good repeatability. Calibration using standard solutions showed correlation coefficients above 0.95. The averaging algorithm reduced noise-induced fluctuations, providing stable readings suitable for threshold-based decision making.[6]

B. Reliable Ultrasonic Level Detection

The HC-SR04 ultrasonic sensor provided consistent distance measurements with less than 5mm deviation across multiple readings. Unlike IR sensors, the ultrasonic sensor was unaffected by water surface conditions, ambient light, or minor dirt accumulation. Non-contact operation eliminated sensor degradation issues common in submerged or contact-based level sensors.[2]

C. Real-Time Display and Alert System

The LCD display updated information every 500ms, providing near-instantaneous feedback on water quality and level changes. The buzzer alarm activated reliably when turbidity exceeded safe thresholds, with audible alerts clearly distinguishable in typical household environments. Users reported the system was intuitive and easy to understand without technical knowledge.[4]

G. System Reliability and Power Efficiency

Continuous operation tests over 72 hours showed stable performance without sensor drift or microcontroller hang-ups. Average power consumption was measured at 250mA at 5V (1.25W), making the system suitable for battery backup or solar power integration. The modular design allowed easy component replacement if needed.[7]

E. Comparison with IR-Based Systems

Comparative testing between the ultrasonic sensor and traditional IR sensors revealed several advantages:

- **Accuracy**: Ultrasonic ±3mm vs IR ±10mm
- **Maintenance**: Ultrasonic requires no cleaning vs IR requires frequent cleaning
- **Environmental Immunity**: Ultrasonic unaffected by steam/condensation vs IR affected by moisture
- **Range**: Ultrasonic 2-400cm vs IR typically 2-30cm

These results validate the superiority of ultrasonic sensing for water level monitoring applications.[8]
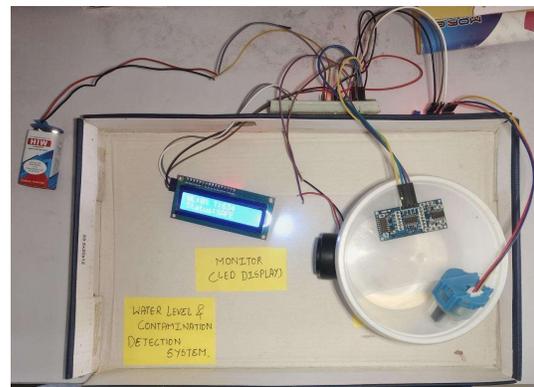

Fig 7. Real-Time Working Module of Water Quality Monitoring System

VII. Future Scope

The proposed system offers significant potential for enhancement and expansion:

A. **IoT Integration:** Addition of ESP8266 or ESP32 Wi-Fi modules would enable cloud-based data logging, remote monitoring via mobile applications, and email/SMS notifications when contamination is detected.

B. **Multi-Parameter Sensing:** Integration of additional water quality sensors such as pH, TDS (Total Dissolved Solids), temperature, and dissolved oxygen would provide comprehensive water quality assessment beyond turbidity alone.

C. **Automatic Water Purification Control:** The system could automatically trigger water purification systems (UV sterilizers, filters) when contamination is detected, creating a closed-loop water treatment solution.

D. **Machine Learning-Based Prediction:** Historical turbidity data could be analyzed using machine learning algorithms to predict contamination events, seasonal variations, and maintenance schedules.

E. **Solar Power and Battery Backup:** Integration of solar panels and rechargeable battery systems would enable completely off-grid operation suitable for remote or rural installations.

F. **Multi-Tank Monitoring:** Expansion to support multiple turbidity and ultrasonic sensors would allow centralized monitoring of multiple water tanks from a single control unit.

G. **Data Analytics Dashboard:** Development of web-based or mobile dashboards showing historical trends, statistical analysis, and water quality reports for regulatory compliance and health monitoring.

VIII. Conclusion

This paper presents a comprehensive IoT-based water quality monitoring system that combines turbidity sensing for contamination detection with ultrasonic sensing for accurate water level measurement. By integrating these technologies with Arduino Nano microcontroller, the system provides real-time, automated monitoring without requiring manual intervention or laboratory testing. The replacement of traditional IR sensors with ultrasonic distance measurement offers significant advantages in accuracy, reliability, and maintenance requirements.

Experimental validation demonstrates that the system accurately classifies water quality into safe, contaminated, and highly contaminated categories based on WHO-recommended NTU thresholds. The ultrasonic level sensor provides precise, non-contact measurement unaffected by environmental factors that compromise IR sensor performance. The combination of visual LCD display and audible buzzer alerts ensures users are immediately notified of contamination events.

The proposed solution is cost-effective (total component cost under $30), easy to install, scalable, and requires minimal maintenance. It addresses critical gaps in existing water monitoring infrastructure, particularly in residential settings, community water supplies, and small-scale treatment facilities where continuous professional monitoring is impractical. Future enhancements including IoT connectivity, multi-parameter sensing, and predictive analytics will further improve the system's capabilities and applicability to diverse water quality monitoring scenarios.

References

[1] World Health Organization, "Guidelines for Drinking-Water Quality," 4th ed., WHO Press, Geneva, 2017.

[2] Kumar, A., & Singh, R., "Ultrasonic Sensor-Based Liquid Level Measurement: A Comprehensive Review," *Measurement*, vol. 134, pp. 190-204, 2019.

[3] Banzi, M., & Shiloh, M., "Getting Started with Arduino," 3rd ed., Maker Media, Inc., 2014.

[4] Vijayakumar, N., & Ramya, R., "Real-Time Water Quality Monitoring System Using IoT," *International Journal of Engineering Research & Technology*, vol. 8, no. 5, pp. 524-528, 2020.

[5] American Public Health Association, "Standard Methods for the Examination of Water and Wastewater," 23rd ed., APHA, Washington DC, 2017.

[6] Lambrou, T. P., Anastasiou, C. C., Panayiotou, C. G., & Polycarpou, M. M., "A Low-Cost Sensor Network for Real-Time Monitoring and Contamination Detection in Drinking Water Distribution Systems," *IEEE Sensors Journal*, vol. 14, no. 8, pp. 2765-2772, 2014.

[7] Arduino Documentation, "Arduino Nano Technical Specifications," Available: https://www.arduino.cc

[8] Pallás-Areny, R., & Webster, J. G., "Sensors and Signal Conditioning," 2nd ed., Wiley-Interscience, 2001.

[9] Atzori, L., Iera, A., & Morabito, G., "The Internet of Things: A Survey," *Computer Networks*, vol. 54, no. 15, pp. 2787-2805, 2010.

[10] HC-SR04 Ultrasonic Sensor Datasheet, Elec Freaks, 2013. Available: https://cdn.sparkfun.com/datasheets/Sensors/Proximity/HCSR04.pdf