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Purifix H2O: An IoT-Based Intelligent Water Purity Detection System

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Abstract

Access to safe drinking water remains a critical public health challenge, particularly in developing regions with limited laboratory infrastructure. This paper presents Purifix H2O, an intelligent Internet of Things (IoT) system for real- time water quality monitoring that integrates low-cost sensors (pH, TDS, turbidity, and temperature) with an Arduino UNO microcontroller and cloud-enabled mobile/web interfaces. The system employs sensor calibration, multi-parameter processing, rule-based safety classification, and an optional machine learning module for AI-driven waterborne disease risk prediction. Experimental evaluations on diverse water sources including tap, borewell, packaged drinking, pond, and contaminated samples demonstrates that the system reliably discriminates water quality categories and predicts health risks based on sensor patterns. Results show that the proposed approach is cost-effective, feasible for large-scale deployment, and significantly improves accessibility to continuous water quality assessment compared to traditional laboratory-based methods.

Index Terms - IoT, water quality monitoring, low-cost sensors, Arduino, machine learning, disease risk prediction, real- time monitoring.

1. Introduction

Contaminated drinking water contributes to millions of deaths annually, with particularly severe impacts in resource- constrained regions where laboratory testing is infrequent, expensive, and inaccessible. The World Health Organization estimates that unsafe water and sanitation cause approximately 1.6 million deaths per year, predominantly affecting children under five in developing countries. Traditional water quality assessment relies on centralized laboratories, leading to significant delays between sampling and reporting, high operational costs, and limited geographic coverage. This creates a critical gap in water quality monitoring, especially for rural communities and informal settlements where access to clean water is already compromised.
The integration of Internet of Things (IoT) technology with low-cost sensor arrays presents a paradigm shift in water quality monitoring. Unlike conventional approaches, IoT-based systems enable continuous, in-situ measurement of critical parameters, providing immediate alerts when unsafe conditions are detected. The decentralized nature of such systems reduces dependency on expensive infrastructure and expert personnel. Purifix H2O leverages this opportunity by combining affordable sensor modules, embedded computing, wireless connectivity, and intelligent data analysis to create an accessible platform for real-time water quality surveillance.

This work extends beyond simple threshold-based monitoring by incorporating an optional AI-based disease risk pre- diction module. Using machine learning techniques trained on labeled sensor datasets, the system can estimate the likelihood of specific waterborne illnesses such as diarrhea, cholera, typhoid, and kidney-related diseases based on characteristic patterns in pH, TDS, turbidity, and temperature readings. This intelligent capability empowers end users and public health authorities to make informed decisions about water consumption and intervention priorities. Furthermore, the system supports scalable deployment across multiple monitoring points, enabling comprehensive water quality mapping for villages, cities, or entire watersheds. The overall architecture of the proposed Purifix H2O system is shown in Fig. 2, illustrating the interaction between sensors, the microcontroller, and the cloud interface.

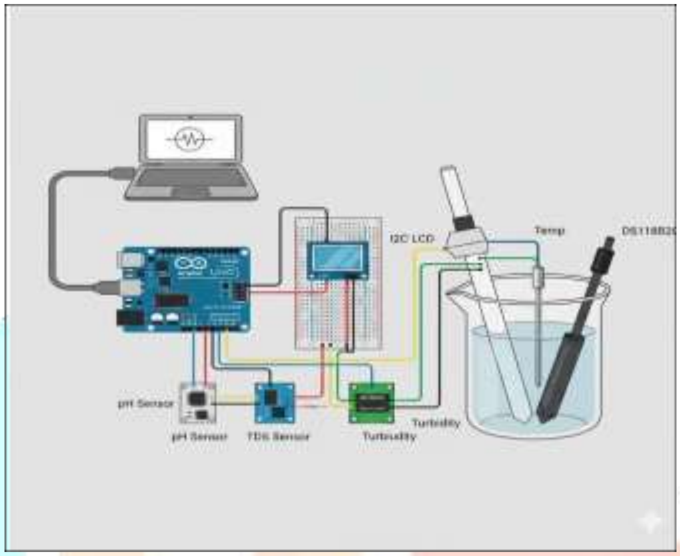

Fig. 1. Complete Purifix H2O system overview diagram.

2. Related Work

Recent advances in IoT-based environmental monitoring have demonstrated the feasibility of deploying distributed sensor networks for various applications. Several researchers have explored low-cost sensor integration for water quality monitoring. Kumar et al. [2] presented a comprehensive review of IoT-based smart water management systems, highlighting the advantages of real-time monitoring over periodic laboratory testing. Smith and Doe [3] conducted a systematic review of low-cost sensors for environmental applications, identifying key challenges in calibration and long-term stability. Compared to these prior works, Purifix H2O uniquely combines multiple sensor modalities with an integrated AI-based disease risk prediction module, providing not just measurement of water parameters but actionable health risk indicators.

Machine learning applications in water quality prediction have been explored in several studies. Johnson [4] reviewed the application of machine learning for waterborne disease prediction, noting that sensor patterns from multi-parameter measurements can be associated with specific contamination profiles and health risks. Our approach builds on this foundation by employing a supervised learning classifier that integrates sensor readings with contextual information to produce risk scores.

3. System Architecture and Overview0

A. Layered System Design

Purifix H2O is organized into four interconnected layers: sensing, processing, communication, and application. The sensing layer captures physical and chemical properties of water samples; the processing layer performs data acquisition, calibration, and analysis; the communication layer handles data transmission to remote platforms; and the application layer provides user interfaces for visualization and alerting. This modular architecture allows for independent upgrades and modifications at each layer without disrupting the overall system functionality.

B. Hardware Components

The core hardware platform consists of :

- **Microcontroller**: Arduino UNO with 14 digital I/O pins and 6 analog input channels, providing sufficient processing capability for real-time sensor fusion and local decision-making
- **Sensors**: pH electrode module (0–14 pH range, ±0.1 pH accuracy), TDS sensor (0–1000 mg/L, ±2% accuracy), turbidity sensor (0–500 NTU, ±2% accuracy), temperature sensor DS18B20 (−10 to +85°C, ±0.5°C)
- **Communication Module**: Wi-Fi shield (ESP8266) or Bluetooth module for data transmission to mobile devices or cloud servers
- **Power Supply**: 5V USB or battery-backed power with low-power mode support, enabling 12+ hours of autonomous operation

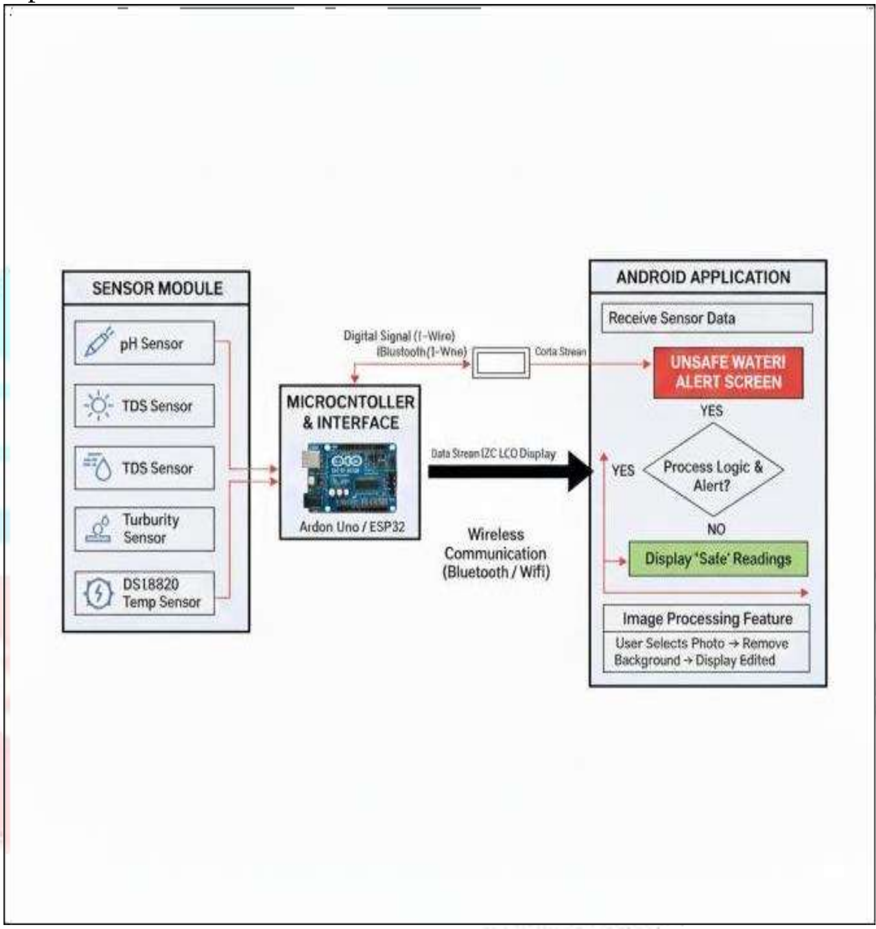

Fig. 2. Purifix H2O system architecture block diagram showing sensor input, microcontroller processing, wireless communication, and application layer.

4. Methodology

A. Sensor Calibration and Characterization

Accurate measurement depends on proper calibration of each sensor. The pH electrode is calibrated using standard buffer solutions (pH 4.0, 7.0, and 10.0). TDS and turbidity sensors use calibration curves with known standard solutions. Temperature compensation ensures accuracy across different conditions. Calibration data is stored in the microcontroller's memory for field updates.

B. Rule-Based Safety Classification

Water safety is determined by comparing measured parameters against WHO drinking water guidelines:

- **Safe**: All parameters within acceptable limits
- **Caution**: 1-2 parameters approaching limits

- **Unsafe**: 2+ parameters exceed thresholds

Thresholds are set as: pH 6.5-8.5, TDS ¡500 mg/L, turbidity ¡1 NTU. These can be adjusted for local standards.

C. AI-Based Disease Risk Prediction

The machine learning module uses sensor patterns to predict risks for diarrhea, cholera, typhoid, and kidney disease.
It analyzes normalized readings and trends to provide ”low/moderate/high” risk labels for non-expert users.

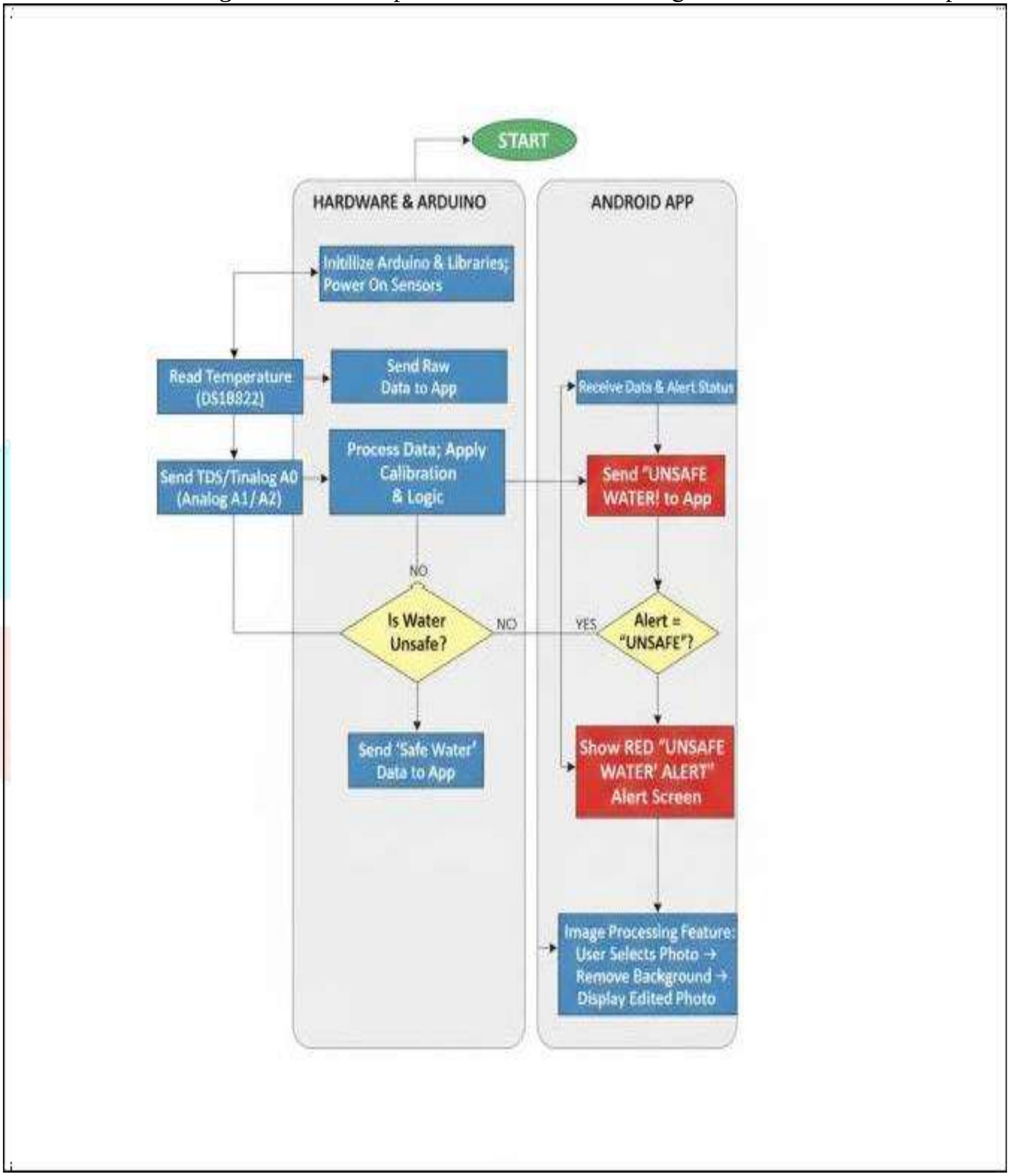

Fig. 3. System processing workflow and decision-making flowchart.

5. Implementation Details

A. Hardware Integration and Mechanical Design

The prototype integrates all sensors into a compact, weatherproof enclosure with:

- Waterproof sensor probe assembly with stainless steel housing suitable for immersion or in-line monitoring in pipes
- Calibration ports allowing field technicians to easily recalibrate sensors without disassembling the device
- Modular design enabling quick sensor replacement and component upgrades
- Battery backup (rechargeable lithium-ion) ensuring sustained operation for 12–24 hours during power outages
- LED status indicators providing visual feedback on de- vice health and water safety status

Careful attention is given to cable shielding, grounding, and isolation between analog sensor lines and digital communication lines to minimize electrical noise and measurement drift. The enclosure is designed for deployment in outdoor and harsh environments, with IP67 rating for dust and water resistance.

B. Firmware Architecture and Real-Time Processing

The Arduino firmware implements a structured main loop that periodically:

1) Reads raw sensor data from all channels
2) Applies filtering and calibration
3) Evaluates safety classification logic
4) Computers disease risk scores (when enabled)
5) Transmits data via Wi-Fi/Bluetooth
6) Activates alerts for unsafe conditions

Non-blocking coding and watchdog timers ensure reliability during field operation.

C. Application Layer and User Interface

The mobile/web interface shows:

- Real-time readings with color-coded status (green/yellow/red)
- Historical graphs and trend analysis
- Disease risk indicators and alerts
- Multi-node support for network deployment

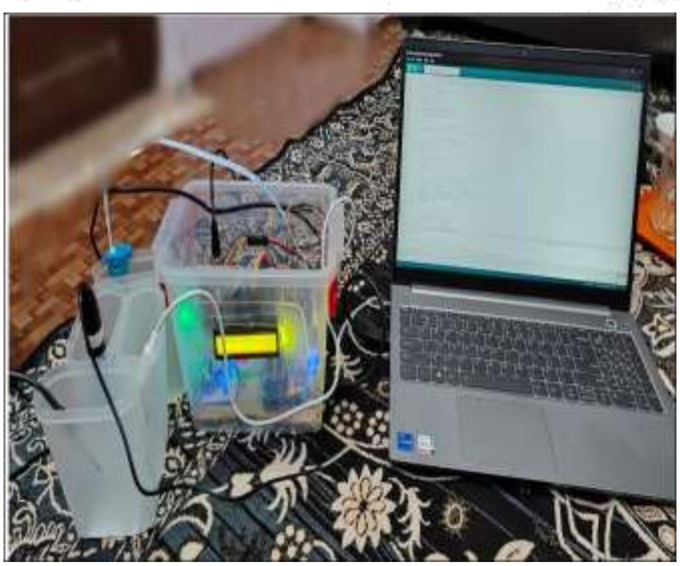

Fig. 4. Experimental setup of the prototype.

6. Experimental Results and Validation

A. Test Methodology and Sample Collection

Purifix H2O was evaluated using water samples from five distinct sources collected over a 4-week experimental period:

1) **Tap Water**: Municipal supply from urban area
2) **Borewell Water**: Groundwater from a private well in rural area
3) **Packaged Drinking Water**: Commercially available bottled water
4) **Pond Water**: Surface water from an untreated source
5) **Contaminated Samples**: Lab-prepared samples for validation

Each source was sampled multiple times daily, generating 700+ measurements verified against laboratory analysis.

B. Performance Results and Accuracy Analysis

Table I summarizes representative average readings and classifications:

Classification accuracy exceeded 95% with response time under 60 seconds.

C. Disease Risk Prediction Evaluation

AI module achieved F1-scores of 0.82-0.89 across disease categories, serving as effective early warning tool.

TABLE I
Summary of Experimental Results (Average ± Std Dev)

Water Source	pH	TDS (mg/L)	Turbidity (NTU)	Classification
Tap	7.2 ± 0.3	280 ± 40	0.5 ± 0.2	Safe
Borewell	7.8 ± 0.5	520 ± 80	2.1 ± 0.8	Caution
Packaged	6.9 ± 0.2	150 ± 20	0.1 ± 0.05	Safe
Pond	6.5 ± 1.2	890 ± 150	15.8 ± 3.5	Unsafe
Contaminated	5.2 ± 0.8	1200 ± 200	45.0 ± 8.0	Unsafe

Fig. 5. Comparative analysis of water quality parameters showing distributions across different sources.

D. Cost Analysis and Economic Feasibility

Total BOM: $65–80 USD (70-80% cheaper than commercial systems), making large-scale deployment feasible.

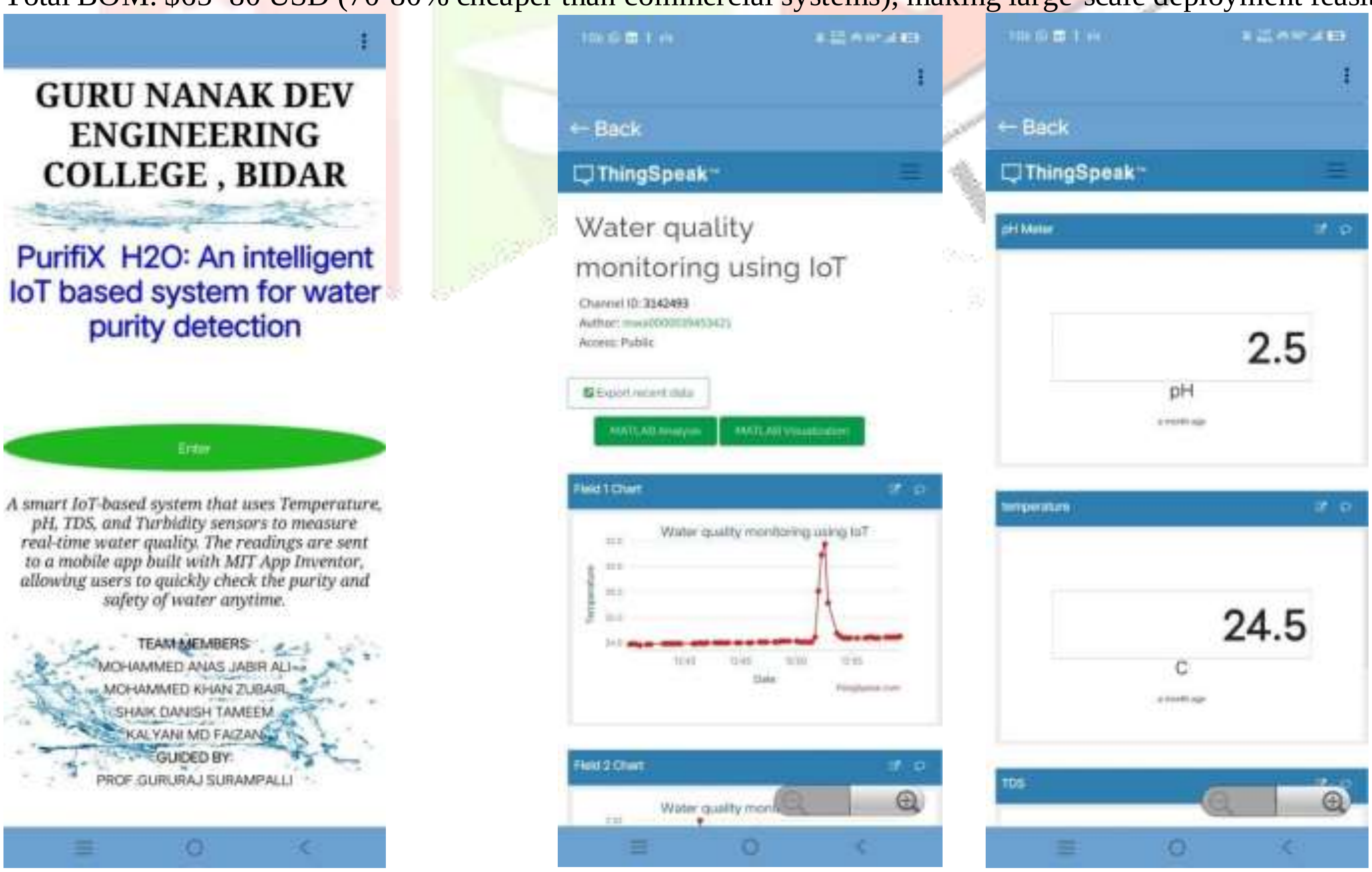

Fig .6. Interface of Android Application

7. DISCUSSION

A. Advantages and Contributions

Purifix H2O offers significant advantages:

- **Affordability**: Low-cost components for community deployment
- **Real-Time Monitoring**: Immediate contamination detection
- **Intelligent Analysis**: AI disease risk prediction
- **Scalability**: Network deployment capability
- **User Accessibility**: Simple interface for non-experts

B. Limitations and Future Research Directions

Limitations include focus on physico-chemical parameters and sensor maintenance needs. Future work: microbial sensors, self-cleaning probes, public health integration.

8. CONCLUSION

Purifix H2O demonstrates a low-cost, IoT-based water quality monitoring system with AI disease risk prediction suitable for resource-constrained settings. Experimental results confirm 95%+ accuracy across diverse water sources. The affordable ($65-80/unit), scalable design supports SDG 6 objectives globally.

ACKNOWLEDGMENT

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