IoT-Based Predictive Maintenance and Monitoring System for Water Purifiers

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ABSTRACT

This work will involve the design of an IoT based, machine learning driven, proactive maintenance and monitoring system for water purifiers. There are various types of sensors: pressure, pH, vibration, temperature, flow, and turbidity will be fitted to the system to continuously check the status of filters, pumps functioning. Cognitive models of Long Short- Term Memory (LSTM) networks and Gradient Boosted Trees (e. g., XGBoost) will classify sensor signals to identify future failures and performance loss anticipation. The methodology uses LSTM for time series data and the XGBoost for fail-safe classification of failure patterns. The system will comprise an application interface that will provide real-time alert and comprehensive notice for maintenance purposes. The expected result is increased service duration of the purifiers, lowered maintenance expenses, and constant availability of filtered water through a solution that is conscious and anticipative of potential problems while keeping the purifiers at maximum efficiency and reliability.

Keywords: Predictive Maintenance, IoT sensors, LSTM, XGBoost, Real-Time Monitoring, Component health, Mobile alert

INTRODUCTION

The scope of this project is, therefore, to design an intelligent monitoring system for water purifiers using modern technologies such as IoT monitored sensors and machine learning algorithms. The overall purpose is the assessment of real time health and performance of vital parts of the purifier system [1]. This is because the system is capable of tracking other measurable parameters like flow rate, pressure, temperature or efficiency of the filters to possible blind spots of early stages of wear, failure or reduced efficiency [2].

When potential issues are identified, the system will generate predictive maintenance alerts, which will be sent directly to a user's mobile device or other connected platforms [3].

This preventive strategy allows planned maintenance activities to take place long before a part fails, thus reduce the possibility of expensive replacements or long-haul duration. The use of real time data analysis and intelligent prediction not only improves the dependability and effectiveness of water purification system but also serves to lengthen the useful life of the purification system [4]. This solution aims to enhance user experience so as to allow continuous availability of clean and safe drinking water, besides cutting on the cost of frequent maintenance and enhancing sustainability of the system [5,6].

OBJECTIVES

1. To study and analyze existing water purifier maintenance system.
2. To propose and innovative solution leveraging IoT and machine learning.
3. To design and implement a predictive maintenance system.
4. To compare the proposed system with traditional approaches.
5.

LITERATURE REVIEW

Table 1: Literature survey of IoT-enabled water purifiers

Sr. No.	Paper Title	Publisher and Published Year	Methodology	Limitations
01.	"Design & Implementation of Smart RO Purifier for Remote Monitoring using IoT Sensor"	*IEEE, 2023*	The methodology uses sensors and smartphone connectivity to monitor and optimize water purification dynamically.	● Inefficiency might be experienced ● As the system evolves complexity, the maintenance required can also increase.
02.	"IoT Enabled RO Water Filter Indicator"	*IEEE, 2022*	The methodology integrates IoT-based monitoring, real-time data collection, and remote user accessibility to design and implement the Water purification system prototype for residential use.	● Reliance on IoT requires constant internet connectivity for seamless monitoring and control. ● Hardwiring the purifier into the system reduces flexibility for upgrades or replacements.

03.	"IoT-Based Real-Time Water Quality Monitoring System in Water Treatment Plants (WTPs)"	*Heliyon (Nov., 2024)*	IoT-sensors with PLC for real-time monitoring.	• Requires frequent maintenance. • High initial costs for sensor installation.
04.	"Experimental Study on the Filtration Characteristics and Sediment Distribution Influencing Factors of Sand Media Filters"	*MDPI (Dec., 2023*)	Effects of filter materials and head loss in sand media filters.	• Research scope remained restricted since variation in raw water and sediment has not been previously investigated widely.
05.	"Smart IoT-Based Water Treatment with a SCADA System Process"	*AGU Publications (Aug., 2023)*	A hybrid of IoT, SCADA and Deep Belief Networks.	• High implementation costs. • Dependency on reliable internet.
06.	"Real-Time Internet of Things(IoT)-Based Water Quality Management System"	*ScienceDirect (Jan., 2020)*	IoT sensors and cloud computing.	• Potential connectivity issues • Sensor calibration needs.
07.	"Water Purifier Quality Monitoring Using IoT"	*IJIRT (July, 2020)*	IoT-based real-time water quality monitoring system integrating.	• Limited to basic water parameters. • Dependent on consistent sensor calibration.

08.	"Characterization of Turbidity Water Sensor SEN0189 on the Changes of Total Suspended Solids in the Water"	*IOP Publishing (Feb., 2019)*	Evaluated the SEN0189 turbidity sensors with Arduino.	• Limited to laboratory-scale experiments and predefined sediment particle sizes (<60 µm). • Application to real- world water sources with mixed contaminants requires further validation.

1. Potential Connectivity Issues.
2. The primary disadvantage of the sensor technology is high initial costs for installation of the sensors.
3. The only include those that are easy to measure here are some of the basic water parameters.
4. Limited Research Scope.
5. Currently, most research studies are restricted to laboratory-scale experiments.

ARCHITECTURE DIAGRAM OF IOT-ENABLED WATER PURIFIERS

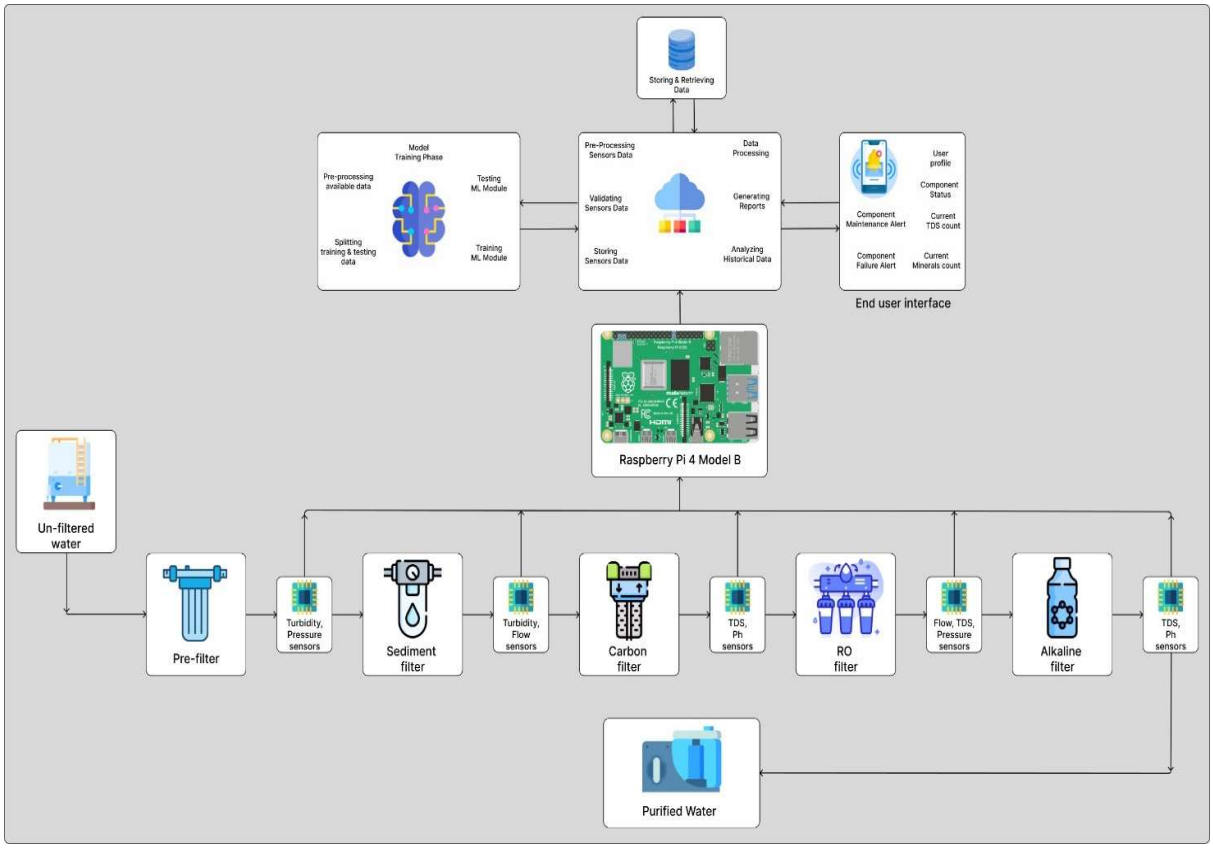

Fig. 1 System Architecture of IoT-Enabled Water Purifier

EXPECTED OUTCOMES

This IoT application includes IoT sensors as the core of a smart monitoring system with a mobile application and a web application. He also said that IoT sensors are useful as they provide real time data concerning the operational efficiency of the purifier and identify existing problems [8]. The mobile application allows receiving instant notification, creating user's profiles and gives detailed information about purifiers which facilitate use and require proactive approach to maintenance [9]. At the same time, the web application is an informative panel that provides system and performance statistics, user registration features since it allows the user and administrator to interact conveniently [10].

1. **Component Health Data:**
   Data in the form of alerts about health and performance status of the elements like filters, pumps, RO membrane and etc on the health status dashboard.
2. **Maintenance Recommendations:**
   Some action recommendations derived from the suggested system analysis for maintenance, including recommendation for part replacement and the related guidelines.

3. **Failure Prediction Alerts:**
   Forecast of possible failures in some of the component, with additional information such as type of component, time to failure estimate, and criticality rating.

4. **Mobile Notifications:**
   Notifications delivered to the user's mobile device that precisely inform the user of when to expect maintenance of an asset.

5. **System Status Reports:**
   Overall system status consolidated reports, filter life reports, and water quality index containing data about the current pH and TDS in the water.

CONLUSION

The implementation of an IoT-based predictive maintenance and monitoring system for water purifiers represents a significant advancement in ensuring water quality and operational efficiency. By leveraging real-time data collection, intelligent analytics, and cloud-based monitoring, such systems can proactively identify potential issues before they lead to failures, thereby reducing downtime, maintenance costs, and health risks associated with impure water. This approach not only enhances user convenience and trust but also contributes to sustainable water management practices. As IoT technology continues to evolve, its integration into household and industrial water purification systems will become increasingly vital for smarter, safer, and more reliable water usage.

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