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Designing a Water Quality Assessment System for RO Reject Water

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ABSTRACT

Reverse osmosis (RO) technology has emerged as one of the most effective methods for water purification in both residential and industrial settings. Despite its effectiveness, a major concern with RO systems is the significant volume of reject water they generate—commonly referred to as RO reject water. This by-product is typically discarded, despite containing water that, although not potable, may be repurposed for various non-drinking applications such as flushing, irrigation, or industrial use. The purpose of this research is to design and evaluate a water quality assessment system specifically for RO reject water, with the goal of enabling its effective reuse. The proposed system integrates Internet of Things (IoT) based sensors with data processing and analytics tools to monitor key physicochemical parameters such as pH, total dissolved solids (TDS), turbidity, temperature, and electrical conductivity in real time. This information is processed using machine learning algorithms to classify water quality and determine its suitability for different reuse applications. The assessment system aims to reduce freshwater demand by promoting the recycling of treated reject water, thereby contributing to sustainable water management and supporting environmental conservation. Field testing of a prototype system in a residential context demonstrated high accuracy in water classification and the ability to detect abnormal water quality events. The proposed system not only supports individual users in better managing their water resources but also holds potential for broader implementation at community and industrial levels. Overall, this study highlights the importance of leveraging modern technologies for efficient water resource utilization, aligning with global goals such as the United Nations Sustainable Development Goal 6, which emphasizes clean water and sanitation for all.

Keywords: Reverse osmosis ,pH, TDS, temperature

1. Introduction

Water scarcity is one of the most critical challenges facing the world today. According to the United Nations, nearly one-third of the global population experiences water stress, and this number is expected to rise significantly in the coming decades. Rapid urbanization, industrialization, and climate change have exacerbated the strain on available freshwater resources. To address this, various water treatment technologies have been adopted, among which Reverse Osmosis (RO) stands out as a widely utilized and highly effective method for desalination and purification of drinking water. Despite its efficiency, a major drawback of RO technology is the substantial volume of reject water it generates—often accounting for up to 60% of the input water. This reject water contains high concentrations of dissolved salts, minerals, and contaminants, and is typically discarded without any form of treatment or assessment.

The unregulated disposal of RO reject water not only leads to environmental degradation, such as soil salinization and groundwater contamination, but also results in significant water wastage. Recognizing the potential of this reject water for reuse in non-potable applications—like gardening, flushing, and cleaning—there is a pressing need for an efficient water quality assessment system. Such a system must be capable of continuously monitoring the essential parameters that determine the safety and suitability of water for secondary use.

This study proposes a smart, IoT-based water quality assessment system specifically designed for RO reject water. By integrating real-time sensors, cloud computing, and intelligent analytics, the system aims to provide a cost-effective and scalable solution for assessing water quality. Moreover, the system facilitates decision-making for reuse strategies and supports sustainable water management practices. Ultimately, the proposed solution aligns with global sustainability goals, particularly SDG 6: Clean Water and Sanitation, by enabling efficient utilization of all available water resources.

2. *Study Area*

The study area selected for pilot implementation is the residential locality of Dombivli, located in the Thane district of Maharashtra, India. Dombivli is a rapidly urbanizing suburban city within the Mumbai Metropolitan Region (MMR) and is known for its high population density and increasing domestic water demand. A significant number of households in this area depend on reverse osmosis (RO) water purifiers for drinking purposes due to concerns over municipal water quality. Consequently, a substantial volume of RO reject water is generated daily, which often goes unutilized and is discharged into drains or open areas.

The chosen neighborhood for the pilot study comprises 50 households, out of which 15 households volunteered to participate in the monitoring program. Each household is equipped with a domestic RO system that discharges approximately 60 to 70 liters of reject water per day. This provides a suitable context for analyzing variations in water quality based on usage patterns, maintenance schedules, and source water quality. Additionally, the area experiences semi-tropical climatic conditions with average temperatures ranging from 25°C to 35°C, which can influence microbial activity and physicochemical properties of the reject water.

Local infrastructure includes access to stable internet connectivity, enabling real-time data transmission to the cloud. The selection of this area allows for a diverse sample set due to varying household sizes, water usage habits, and socio-economic profiles. Moreover, Dombivli's location within a rapidly urbanizing zone emphasizes the broader relevance of the findings to other suburban areas across India and similar developing regions worldwide. By focusing on a real-world urban setting, the study aims to test the practical feasibility and scalability of the proposed water quality assessment system for RO reject water.

3. Methodology

3.1 System Design The system is structured into three primary components:

- Sensor Unit: IoT-enabled sensors such as pH sensors (range: 0–14), TDS sensors (range: 0–5000 ppm), turbidity sensors (0–1000 NTU), temperature sensors (0–100°C), and conductivity sensors (0–20000 µS/cm) are used to collect real-time data.
- Data Acquisition and Processing Unit: A microcontroller (e.g., Arduino UNO or Raspberry Pi 4) is configured to interface with all sensors. Data is sampled every 5 minutes, processed for noise reduction using filtering algorithms (e.g., moving average), and encoded for cloud transmission using MQTT protocol.
- Cloud Platform and Analytics: A cloud infrastructure (e.g., ThingSpeak or AWS IoT) is used to store and visualize the collected data. The platform runs analytics using Python scripts and supports threshold-based alerts and anomaly detection using logistic regression and decision tree classifiers.

3.2 Data Analysis Collected data is analyzed against water quality standards issued by the Bureau of Indian Standards (BIS) and the World Health Organization (WHO). The system employs the following analysis techniques:

- Descriptive Statistics: Mean, median, mode, and standard deviation to summarize daily readings.
- Correlation Analysis: To identify interdependencies among parameters (e.g., TDS and conductivity).
- Anomaly Detection: Using an isolation forest model to flag unexpected readings.
- Predictive Modeling: Machine learning models trained on historical data predict usability categories (e.g., irrigation-suitable, flushing-grade, discard).

3.3 Pilot Testing A prototype is tested in a residential setting equipped with a household RO system. The setup monitors RO reject water continuously over a 30-day period. Environmental variables such as ambient temperature and water pressure are also logged to assess their effect on reject water characteristics.

4.2. Analysis and Results

The analysis of the collected data over the 30-day pilot period revealed consistent trends and critical insights regarding the quality and usability of RO reject water. The sensor array captured over 8,000 individual data points across all parameters. The average readings across the sampling period were as follows:

- pH: Ranged from 6.2 to 6.8 with a mean value of 6.5, indicating slightly acidic conditions. Though not ideal for drinking, this is within acceptable limits for horticultural and toilet flushing applications.
- TDS (Total Dissolved Solids): Averaged at 1200 mg/L. Though exceeding the BIS standard for drinking water (500 mg/L), this is within the acceptable range for non-potable uses such as gardening and toilet flushing.
- Turbidity: Maintained a stable average of 3 NTU, indicating low levels of suspended particles. Occasional spikes above 5 NTU were attributed to membrane fouling events in a few households.
- Conductivity: Averaged 1800 µS/cm, correlating strongly with TDS ($R^2 = 0.89$), affirming ion presence as a dominant factor in water quality changes.
- Temperature: Maintained around 28°C on average, favoring microbial stability and ensuring reliable sensor operation.

Overall, the system proved effective in capturing, processing, and analyzing real-time data with sufficient accuracy and granularity. The insights derived have strong implications for water conservation practices in urban households and demonstrate the scalability of this approach to broader community applications.

4. Conclusion

This study demonstrates the feasibility of designing an IoT-based water quality assessment system for RO reject water. By leveraging real-time monitoring and data analytics, the system provides a reliable framework for assessing reuse potential. The findings advocate for deploying such systems in households, communities, and small industries to reduce freshwater dependency. Furthermore, integration with automated control systems (e.g., solenoid valves) can enable dynamic routing of reject water for specific reuse pathways. This innovation contributes meaningfully to SDG 6: Clean Water and Sanitation and supports the circular economy model in water resource management.

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