Smart Water Quality Monitoring for CKD Patients: An IoT-Driven Mobile Application

Wishalya Tissera
Faculty of Computing
Sri Lanka Institute of Information and Technology
Sri Lanka
wishalya.t@sliit.lk

Samadhi Rathnayake
Faculty of Computing
Sri Lanka Institute of Information and Technology
Sri Lanka
samadhi.r@sliit.lk

Perera J. P. M. L.
Faculty of Computing
Sri Lanka Institute of Information and Technology
Sri Lanka
it20226596@my.sliit.lk

Samarawila D.R.N.
Faculty of Computing
Sri Lanka Institute of Information and Technology
Sri Lanka
it20235260@my.sliit.lk

Isurika W.B.M.A.
Faculty of Computing
Sri Lanka Institute of Information and Technology
Sri Lanka
it20785192@my.sliit.lk

Marasinhge M.M.K.L.
Faculty of Computing
Sri Lanka Institute of Information and Technology
Sri Lanka
it20154226@my.sliit.lk

***Abstract*— In Sri Lanka, 20% of the population suffers from chronic kidney disease (CKD) due to exposure to contaminated water, particularly in rural areas. To address this, a proposed IoT-based water quality monitoring system for CKD patients in Sri Lanka uses machine learning (ML) to predict water quality. The system consists of hardware (IoT devices measuring temperature, pH, and oxygen levels) connected to a cloud-based platform for real-time data collection. The app component utilizes an ML algorithm trained on pre-tested water samples to identify changes in water quality and predict future trends. Results are displayed on a mobile application dashboard, providing real-time information. Benefits include early contamination detection, remote monitoring in rural areas, accurate predictions, and user-friendly access.**

Keywords—chronic kidney disease (CKD), water quality monitoring, IoT, machine learning (ML), contamination detection, real-time data collection, mobile application dashboard, early detection, remote monitoring, accurate predictions, user-friendly interface

I. Introduction

Chronic kidney disease (CKD) is a significant health concern in Sri Lanka, affecting a considerable portion of the population. Among the various risk factors contributing to CKD, exposure to contaminated water has been identified as a major concern. The poor water quality prevalent in many parts of the country is believed to play a role in the development and progression of this disease.

Efforts have been made to improve water quality monitoring in Sri Lanka, but there remains a need for real-time, accurate, and reliable systems to effectively address this issue. Fortunately, advancements in Internet of Things (IoT) and machine learning (ML) technologies present promising opportunities for enhancing water quality monitoring practices. By leveraging IoT devices, real-time data on crucial water quality parameters like temperature, pH, and dissolved oxygen can be continuously collected. ML algorithms can then analyze this data, enabling the identification of changes in water quality patterns and prediction of future trends. Although these technologies have proven successful in monitoring water quality in other countries, their implementation in Sri Lanka is still pending. To bridge this gap, a proposed IoT and ML-based water quality monitoring system aims to provide an efficient solution for kidney patients in Sri Lanka. The envisioned system will comprise a network of IoT devices strategically placed to continuously monitor essential water quality parameters. These devices will gather data and transmit it to a central platform for analysis. ML algorithms, trained on the collected data, will be responsible for detecting any deviations in water quality and making predictions regarding future trends.

One of the primary objectives of this system is to ensure the timely dissemination of critical information to kidney patients. By incorporating alerts and notifications, individuals can be promptly notified about any water quality issues that may impact their health. This feature empowers patients to take necessary precautions and adopt appropriate measures to manage their condition effectively.

The implementation of the proposed IoT and ML-based water quality monitoring system in Sri Lanka holds numerous potential benefits. Real-time monitoring will enable swift detection of water contamination, allowing for immediate intervention and prevention of CKD-related complications. Moreover, the system's remote monitoring capabilities are particularly advantageous for rural areas with limited access to clean water sources. By leveraging cloud-based platforms, water quality data can be collected and analyzed from various locations, facilitating a comprehensive understanding of the situation across the country.

The ML algorithms employed in this system are expected to provide accurate predictions regarding water quality, enabling proactive measures to be taken to address potential issues before they escalate into serious problems. Additionally, the user-friendly mobile application dashboard will provide an intuitive interface for kidney patients to access real-time water quality information effortlessly. This interface will facilitate the seamless retrieval of data, ensuring that patients remain informed about the state of the water they consume.

To evaluate the effectiveness and performance of the IoT and ML-based water quality monitoring system, field trials will be conducted, and user feedback will be actively sought. This evaluation process will enable further improvements to be made to the system's design, enhancing its usability and effectiveness. Ultimately, the successful implementation of this system has the potential to revolutionize water quality monitoring practices in Sri Lanka, making a substantial positive impact on the lives of kidney patients and the overall population.

II. Literature Review

In their 2022 research publication, Yogendra Kumar and Siba K Udgata detailed their work on utilizing machine learning techniques at the edge device for identifying alarming events in water quality. Their research aimed to create an edge device that could sense water quality parameters, identify changes in water quality relative to baseline parameters, generate alert signals triggered by changes in water quality parameters surpass their threshold values, and classify various types of contamination. Three water quality indicative methods, namely the Weighted Arithmetic Index, NSF Water Quality Index, and user feedback, were employed to calculate water quality. Employing the Support Vector Machine (SVM), a lightweight machine learning model was developed based on these water quality indexes. The alarming events were clustered to identify different types of disturbing events. The research yielded promising results, showcasing the potential of machine learning at the edge device for intelligent detection of alarming events in water quality [1].

In 2022, Amara Parangama and his team studied in Sri Lanka to investigate potential causative factors for chronic kidney disease (CKD) in the North Central Province (NCP). The NCP region has reported the greatest incidence of chronic kidney disease (CKD) patients and fatality rate. in the country, with suspicions that specific water quality measures in drinking water may contribute to the issue. The study involved analyzing water samples collected from shallow wells that provide drinking water to both chronic kidney disease (CKD) patients and non-patients in the area of NCP region, testing for various parameters like chemical species including Cadmium, Sodium, Calcium, Fluorine, and Chlorine. Initial analysis revealed that most of the water quality parameters tested did not exceed the drinking water quality standards set by the World Health Organization (WHO). Factor analysis techniques were then used to investigate critical water quality parameters that could cause CKD. The results indicated that water samples from CKD patients showed higher Na, Cl, Mg, F, and Ca levels, grouped into one factor and identified as hydro-geologically originated. Another factor consisting of N and P, which could be attributed to nutrients from fertilizers, was also identified, in contrast, cadmium (Cd) was classified as a distinct element. On the other hand, water quality measures in samples obtained from non-CKD patients was unable to categorized into any specific group [2].

In 2021, Dinithi Weerasingha and her team presented a research paper CKD in Sri Lanka. Over the past two decades, CKD has emerged as a significant global health concern. Sri Lanka has been impacted by the rapid rise of CKD of unknown etiology (CKDu) in agricultural regions. The paper presents a model of an ANN. that utilizes he physical and chemical characteristics of soil in agricultural zones. to determine the form of CKD. The study compares the performance of the Multilayer Perceptron (M.L.P.) ANN model with Decision Tree and Support Vector Machine (SVM) models in terms of accuracy, precision, recall, Root Mean Squared Error (R.M.S.E.), and Mean Absolute Error (M.A.E.). The findings reveal that the ANN model demonstrates superior performance of classification and prediction in identifying the type of disease, which is crucial for the early detection and management of CKD and its etiologies in Sri Lanka [3].

In 2023, Andrew OMAMBIA and his team proposed a system for monitoring water quality and pilferage using IoT and machine learning technologies. Safe water access is considered a fundamental human right and contamination, leakages, and pilferage often occur in water supply systems. The proposed system aims to address these challenges by monitoring water quality and detecting pilferage and wastage using machine learning algorithms. Water is primarily sourced from pipes and springs located around towns and consumed by consumers. The system will enable decision making using machine learning algorithms [4].

In 2019, Sathira Hettiarachchi, Divan Proboshena, Hashan Rajapaksha, and Lakshan Stembo put forth a solution to address the pressing need for comprehensive research on sustainable water-quality management systems. As population growth and environmental pollution continue to escalate, the demand for such systems has become increasingly apparent. The proposed solution is a cutting-edge innovative water quality management system incorporating predictive capabilities. This system enables frequent monitoring of water quality measures at water treatment facilities. through a user-friendly IoT device while identifying points of water leakage within the water distribution network using crowdsourcing and visualization techniques. Notably, the proposed system boasts a remarkable 99% accuracy in predicting upcoming changes in water quality, along with calculating the corresponding purification costs. The design features a digital dashboard that provides concise information on leaks, customer feedback, patterns of water quality, and costs related to purification in a summarized manner [5].

The literature survey reveals that there are already many IoT and ML based water quality monitoring systems being used around the world, including in neighboring countries such as India. These systems have been shown to be effective in improving water quality monitoring and reducing the risk of waterborne diseases. However, there is a lack of research on the implementation of such systems in Sri Lanka, particularly for the specific needs of kidney patients. Therefore, the proposed research will contribute to the existing literature by exploring the feasibility and effectiveness of a water quality evaluating/monitoring system for kidney patients in Sri Lanka.

III. Methodology

The purpose of this methodology is to outline the steps involved in developing and implementing a real-time water quality monitoring system specifically designed for individuals who want to test their daily consuming water. The system comprises hardware components, including IoT devices, and software components, including a cloud-based platform and a mobile application. The methodology will cover the following key areas: hardware setup, data collection and transmission, cloud-based processing and analysis, machine learning model development, and mobile application integration.

A. *Hardware Setup*

- Selection of IoT Devices: Research and identify IoT devices capable of measuring parameters relevant to water quality, such as temperature, pH, and dissolved oxygen. Focus on devices suitable for personal use and capable of providing accurate measurements for daily consuming water.

- Installation and Calibration: Assist users in installing the IoT devices at their homes or desired locations where they consume water. Provide guidelines and instructions on device calibration to ensure accurate and reliable measurements.

- Data Collection and Transmission: Configure the IoT devices to collect water quality data from the user's daily consuming water. Implement a reliable data transmission mechanism, such as wireless communication protocols or Bluetooth, to securely transmit the collected data to the cloud-based platform.

B. *Cloud-Based Processing and Analysis*

- Data Storage and Management: Set up a cloud-based infrastructure capable of securely storing and managing the incoming water quality data from the IoT devices. Implement data privacy measures to ensure the confidentiality of user data.

- Data Preprocessing: Apply necessary preprocessing techniques to the incoming water quality data, such as outlier detection and removal, normalization, and feature scaling. These techniques will ensure the data is in a suitable format for analysis and modeling.

- Contaminant Detection: Develop algorithms and mathematical formulas to detect potential contaminants in the water based on the collected parameters. This can involve statistical analysis, threshold-based methods, or machine learning techniques to identify abnormal or unhealthy water conditions.

C. *Machine Learning Model Development*

- Training Data Collection: Collect a diverse and representative dataset of water quality samples that have been tested for various contaminants. This dataset will serve as the training data for the machine learning model.

- Feature Extraction: Extract relevant features from the water quality data collected by the IoT devices. These features may include temperature, pH, dissolved oxygen levels, and any additional parameters deemed important for contaminant detection.

- Model Development: Train a machine learning model, such as a classification or anomaly detection model, using the collected training data and the extracted features. This model will learn patterns and relationships between the water quality parameters and the presence of contaminants.

- Model Evaluation: Evaluate the trained machine learning model using appropriate evaluation metrics, such as accuracy, precision, recall, and F1-score. Fine-tune the model if necessary to optimize its performance in detecting contaminants accurately.

D. *Mobile Application Integration*

- User Interface Design: Design a user-friendly mobile application interface that allows individuals to monitor the real-time water quality data from their IoT devices. Emphasize simplicity and clarity in presenting information to users.

- Real-Time Monitoring: Integrate the cloud-based platform with the mobile application to provide users with access to real-time water quality information. Display the measurements from the IoT devices and indicate whether the water is safe or potentially contaminated.

- Alert System: Implement an alert system within the mobile application that notifies users if the detected water quality indicates potential contamination. The alerts should provide clear instructions on how to respond and seek further assistance if necessary.

IV. RESULTS AND DISCUSSION

The ongoing research on the real-time water quality monitoring system for individuals who want to test their daily consuming water has yielded promising results thus far. This section presents the anticipated outcomes based on the current stage of the research.

The hardware setup phase involved the selection of suitable IoT devices capable of measuring parameters relevant to water quality, such as temperature, pH, and dissolved oxygen. Initial testing of the IoT devices has demonstrated their ability to collect accurate and reliable data from the daily consuming water sources. Calibration procedures have been implemented to ensure precise measurements and improve the overall performance of the system.

In the cloud-based processing and analysis phase, a robust infrastructure has been established to securely store and manage the incoming water quality data. The data preprocessing techniques, including outlier detection, normalization, and feature scaling, have been implemented successfully. These techniques will enhance the accuracy of the subsequent analysis and contaminant detection.

The development of the machine learning model is still in progress. A diverse dataset of water quality samples, tested for various contaminants, has been collected for training the model. Feature extraction methods have been applied to extract relevant features from the water quality data collected by the IoT devices. These features, such as temperature, pH, and dissolved oxygen levels, will be crucial in training the model to identify potential contaminants accurately.

Preliminary evaluations of the machine learning model show promising performance. However, further fine-tuning and optimization are still underway to enhance the model's accuracy in detecting contaminants. Evaluation metrics, including accuracy, precision, recall, and F1-score, will be used to assess the model's performance and ensure its reliability.

The mobile application integration phase is yet to be completed. However, the user interface design is being developed with simplicity and clarity in mind, ensuring users can easily monitor real-time water quality data from their IoT devices. The integration of an alert system within the mobile application will notify users promptly if potential contamination is detected in their consuming water.

V. Conclusion and Future Work

The proposed IoT and ML-based water quality monitoring system for chronic kidney disease (CKD) patients in Sri Lanka shows great promise in addressing the pressing issue of water contamination. By leveraging IoT devices to continuously monitor essential water quality parameters and using machine learning algorithms for analysis and prediction, the system aims to provide real-time, accurate, and user-friendly access to critical water quality information.

The ongoing research has made significant progress in the hardware setup, cloud-based processing and analysis, and the development of the machine learning model. Initial testing of the IoT devices has demonstrated their capability to collect accurate data, and the cloud-based platform has been successfully established to store and manage this data securely. Preprocessing techniques have been implemented to ensure the data is in suitable format for analysis, and a diverse dataset for training the machine learning model has been collected.

The machine learning model is showing promising results in detecting potential contaminants in water samples. Further fine-tuning and optimization are underway to enhance the model's accuracy and reliability. Once completed, the model will play a crucial role in early detection and prediction of water quality issues, empowering CKD patients to take proactive measures for their health.

The mobile application integration phase is still in progress, with a focus on developing a user-friendly interface and an alert system to provide real-time water quality information to users. This component will be pivotal in ensuring that individuals have easy access to the data and are promptly notified of any potential water quality issues.

Future work involves conducting field trials and seeking user feedback to evaluate the system's effectiveness and usability in real-world scenarios. The feedback obtained will enable further improvements to be made to the system's design, ensuring that it meets the specific needs of CKD patients in Sri Lanka.

Additionally, exploring ways to expand the system's capabilities to include other water quality parameters and contaminants will be essential. Collaborating with water quality experts and health professionals can provide valuable insights to enhance the system's accuracy and impact.

References

[1] S. K. U. Yogendra Kumar, "Machine learning model for IoT-Edge device based," IEEE, 2022.

[2] N. J. M. A. B. Amara Paranagama, "WATER QUALITY PARAMETERS IN RELATION TO CHRONIC KIDNEY DISEASE IN SRI LANKA," IEEE, 2021.

[3] B. K. B. K. S. G. Dinithi Weerasinghe, "Identifying the Type of Chronic Kidney Disease," IEEE, 2021.

[4] B. M. A. W. Andrew OMAMBIA, "Water Quality Monitoring Using IoT & Machine Learning," IEEE, 2019.

[5] D. P. L. S. H. R. Sathira Hettiarachchi, "An Integrated Platform of Water Quality," IEEE, 2019.