IOT ENABLED WATER QUALITY MONITORING WITH PUMP AUTOMATION

Ms. Tejal Kamthe[1], Ms. Mayuri Shelar[2],
Ms. Afija Mujawar[3], Mr. Aditya Shirke[4],
Prof. Puja Johari[5]

1(Electronics & Telecommunication Engineering, Alard College of Engineering & Management, Pune, Email- tkamthe4577@gmail.com)
2(Electronics & Telecommunication Engineering, Alard College of Engineering & Management, Pune, Email - mayuri.shelar369@gmail.com)
3(Electronics & Telecommunication Engineering, Alard College of Engineering & Management, Pune, Email - afijamujawar@gmail.com)
4(Electronics & Telecommunication Engineering, Alard College of Engineering & Management, Pune, Email - adityashirke169@gmail.com)
5(Electronics & Telecommunication Engineering, Alard College of Engineering & Management, Pune, Email - pujanigam05k@gmail.com)

Abstract:

With the increasing concern over water quality, there is a growing demand for efficient and real-time monitoring systems to ensure the safety and sustainability of water resources. In response to this need, our research proposes an Internet of Things (IoT) based water quality monitoring system. The system employs sensors to measure various parameters such as TDS level, turbidity, dissolved oxygen, temperature, and conductivity in water bodies. These sensors are connected to a central IoT device, which collects the data and transmits it to a cloud-based platform for storage and analysis. The IoT water quality monitoring system offers several advantages over traditional monitoring methods. It provides real-time data, allowing for prompt detection of any anomalies or contamination events. Additionally, the system enables remote monitoring, eliminating the need for manual data collection and reducing human error.

Keywords — IoT, Dissolved Oxygen, Temperature, TDS, Cloud-Based

I. RESEARCH INTRODUCTION

Our research titled "IoT Water Quality Analysis & Pump Automation" focuses on leveraging Internet of Things (IoT) technology to enhance water quality monitoring and automate pump operations. Water quality is a critical aspect of environmental and public health management, and its monitoring is essential for ensuring safe and sustainable water resources. By integrating IoT devices and sensors with advanced analytics, this project aims to revolutionize the way water quality is assessed and managed in real-time. In recent years, IoT has emerged as a transformative technology, enabling the seamless integration of physical devices with digital systems. This project harnesses the power of IoT by deploying water quality sensors that continuously monitor parameters such as turbidity, dissolved oxygen, and temperature in bodies of water. These sensors provide real-time data streams that are transmitted wirelessly to a centralized database or cloud platform for analysis. The data collected from the IoT sensors undergoes sophisticated analysis using machine learning algorithms to detect patterns, anomalies, and trends in water quality. analytical approach allows for the early identification of potential contaminants or deviations from optimal water conditions. Moreover, the system can generate alerts or notifications to relevant authorities or stakeholders when water quality parameters exceed predefined thresholds, enabling prompt intervention and remediation. Furthermore, the project includes the automation of pump operations based on the analyzed water quality data. By integrating IoT with automated control systems, the project seeks to optimize water distribution processes. For instance, based on real-time water quality assessments, the system can automatically adjust pumping rates or activate specific treatment protocols to maintain water quality standards

II. PROPOSED INTEGRATION –

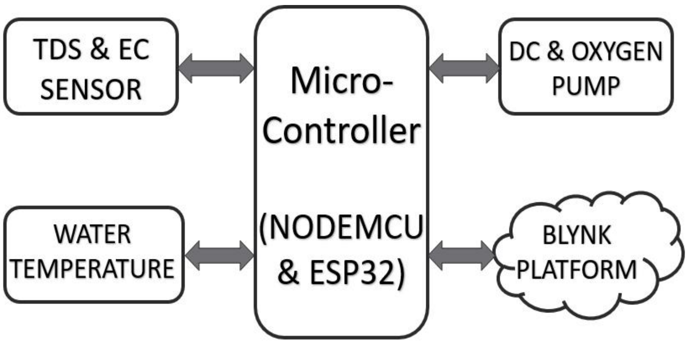

Fig 1: Research Block Diagram Integration

Our idea titled "IoT Water Quality Analysis & Pump Automation" aims to develop a comprehensive system that integrates IoT technologies to monitor water quality parameters and automate water fetching using DC pumps. The system incorporates sensors for Total Dissolved Solids (TDS), Electrical Conductivity (EC), and Temperature to continuously assess water quality in real-time. The block diagram for this project begins with the sensor module, which includes TDS, EC, and Temperature sensors. These sensors are strategically placed within the water source to capture relevant data. The TDS sensor measures the concentration of dissolved solids in water, providing insights into its overall quality. The EC sensor measures the water's ability to conduct electricity, offering further indicators of water purity. The Temperature sensor monitors the water temperature, which is essential for certain water quality assessments. Next in the block diagram is the microcontroller unit, which serves as the brain of the system. This unit collects data from the sensors and processes it for analysis. The microcontroller is programmed to make decisions based on predefined thresholds for each parameter. For instance, if the TDS or EC levels exceed safe limits, indicating poor water quality, the microcontroller triggers an alert for corrective action. The IoT component of the system involves wireless communication (like Wi-Fi or Bluetooth) to relay the sensor data and system status to a cloud-based platform. This platform could be a custom-developed application or an existing IoT service. By leveraging the cloud, users can remotely access real-time water quality data and receive alerts on their smartphones or computers. Additionally, the block diagram includes the DC pump control mechanism. Based on the analyzed water quality data, the microcontroller automatically controls the DC pumps responsible for water fetching. For example, if the water quality is deemed acceptable, the microcontroller activates the DC pump to fetch water. Conversely, if the water quality is below standard, the pump remains inactive, preventing the extraction of contaminated water. In summary, this project merges IoT technology with water quality analysis and automation. By deploying sensors to monitor key parameters and integrating smart control of DC pumps, the system not only ensures efficient water management but also promotes public health by preventing the use of compromised water sources. The block diagram visually encapsulates the interconnectedness of these components, showcasing a streamlined approach to water quality monitoring and pump automation.

III. METHODOLOGY USED –

Our idea titled "IoT Water Quality Analysis & Pump Automation" aims to develop a system that integrates sensors for Total Dissolved Solids (TDS), Electrical Conductivity (EC), and Temperature with DC pumps for water fetching, all managed through Internet of Things (IoT) technology. The methodology for this project encompasses several key steps to achieve the desired outcomes.

Firstly, the hardware setup involves selecting appropriate TDS, EC, and temperature sensors capable of accurate and reliable measurements in water environments. These sensors will be integrated into a microcontroller unit such as Arduino or Raspberry Pi, which will serve as the central processing unit for data collection and analysis. Next, the sensor nodes will be deployed strategically within the water sources or distribution points to continuously monitor water quality parameters. The nodes will be programmed to collect data at predefined intervals, ensuring real-time updates on water conditions. Simultaneously, DC pumps will be interfaced with the microcontroller to automate the water fetching process based on sensor readings. For instance, if the water quality deteriorates beyond predefined thresholds (e.g., excessive TDS or EC levels), the system will trigger the DC pump to stop, preventing contaminated water from being fetched. The IoT aspect of the project involves setting up a wireless communication network, such as Wi-Fi or Bluetooth, to enable remote monitoring and control. This network will allow users to access real-time sensor data and pump status through a user-friendly interface, accessible via mobile apps or web platforms. During the development phase, rigorous testing will be conducted to validate the accuracy and reliability of sensor readings and the responsiveness of the pump automation system. Calibration procedures will be implemented to ensure that sensor data remains consistent and accurate over time. Lastly, the entire system will be assembled into a compact and weatherproof enclosure suitable for outdoor deployment. Installation procedures will be documented to guide end-users in setting up and maintaining the IoT water quality analysis and pump automation system effectively.

IV. EVALUATION MODEL –

The evaluation model comprises four fundamental elements: TP (True Positive), TN (True Negative), FP (False Positive), and FN (False Negative). TP denotes correctly identified actual samples, while TN represents accurately predicted negative samples. FP signifies the misprediction of positive samples, and FN denotes the misprediction of negative (or non-predicted positive) samples. Equations (1)–(4) encompass metrics such as Accuracy, F1-score, and Receiver Operating Characteristic (ROC) used to assess model performance. Accuracy gauges the alignment between predicted and actual outputs by computing the ratio of correctly predicted values to total predictions. The F1-score, a harmonic mean, combines precision and recall to gauge model accuracy. Recall measures the model's sensitivity to positive results, while specificity signifies the percentage of negative (undrinkable water) identifications. A higher area under the ROC curve (closer to 1) indicates better model performance. The Random Forest (RF) model, an essential tool in classification, integrates bootstrap aggregation and randomization. It comprises multiple decision trees without interdependencies, with each tree labeling new data points independently. RF excels in handling high-dimensional datasets with scattered or continuous data, processing them directly without normalization. RF employs weak learners like Classification and Regression Trees (CART) to select features and combines them to form a robust learner.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

$$Recall = Sensitivity = \frac{TP}{TP + FN}$$

$$Precision = \frac{TP}{TP + FP}$$

$$F1 - score = \frac{2 * Precision * Recall}{Precision + Recall}$$

Fig 2: Evaluation Formulae for Precision & Sensitivity

A. TDS (Total Dissolved Solvents)

Total Dissolved Solids (TDS) is a crucial water quality parameter that refers to the total amount of dissolved inorganic and organic substances present in water. These substances can include minerals, salts, metals, cations (positively charged ions), anions (negatively charged ions), and other organic compounds. The composition of TDS in water can vary widely depending on the water source and surrounding geological and environmental factors. Common components of TDS include calcium, magnesium, sodium, potassium, chloride, sulfate, carbonate, and nitrate ions. Organic substances such as pesticides, herbicides, and industrial pollutants can also contribute to TDS. TDS levels are significant indicators of water quality and can impact various aspects of water use and consumption. High TDS concentrations can affect the taste, odor, and appearance of water, making it unpalatable for drinking and other domestic uses. Additionally, elevated TDS levels can lead to scale formation in pipes and water appliances, reducing their efficiency and lifespan. In terms of health implications, while TDS itself is not necessarily harmful, elevated levels of specific ions within TDS can pose health risks. For example, high concentrations of sodium or chloride can be detrimental to individuals with certain health conditions, such as hypertension or kidney disease. Furthermore, the presence of certain contaminants within TDS, such as heavy metals or organic pollutants, can have adverse health effects upon ingestion. Monitoring TDS levels is essential for ensuring water quality and safety. Water treatment processes like reverse osmosis, distillation, and ion exchange are commonly employed to reduce TDS concentrations in drinking water to acceptable levels. Regulatory standards and guidelines exist to define safe TDS levels for different water uses, including drinking water standards established by health and environmental agencies.

Fig 3: TDS~EC~TEMP. readings

B. DS18B20 (Water Temperature)

The DS18B20 is a digital temperature sensor known for its accuracy, simplicity, and ease of use in various applications. Developed by Maxim Integrated, this sensor operates on the 1-Wire protocol, enabling multiple sensors to be connected to a single microcontroller pin, simplifying wiring and integration into electronic systems. One of the key features of the DS18B20 is its high precision. It can measure temperatures ranging from -55°C to +125°C with an accuracy of ±0.5°C within this temperature range. This level of accuracy makes it suitable for applications where precise temperature monitoring is critical, such as in medical devices, industrial automation, environmental monitoring, and HVAC systems. The DS18B20 sensor communicates temperature data digitally through the 1-Wire interface, which reduces the complexity of the wiring required. This interface allows several DS18B20 sensors to share the same data line, enabling efficient temperature monitoring in multi-sensor setups. Each DS18B20 sensor has a unique 64-bit serial code assigned during manufacturing, which helps in identifying and addressing specific sensors on the 1-Wire bus.Another advantage of the DS18B20 is its low power consumption, which is beneficial for battery-operated devices or applications where power efficiency is crucial. The sensor can operate in a wide voltage range (3.0V to 5.5V) and consumes only a minimal amount of power during temperature conversion, typically around 1.5mA. Integration of the DS18B20 sensor into microcontroller-based projects is straightforward due to the availability of libraries and example codes for popular platforms like Arduino, Raspberry Pi, and ESP8266/ESP32. These resources simplify the process of reading temperature data from the sensor and incorporating it into various projects and prototypes.

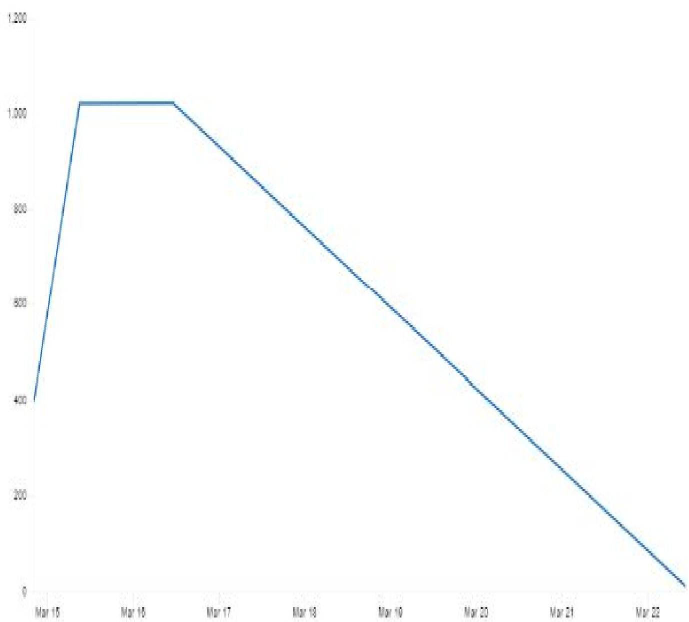

Fig 4: DS18B20 Temperature Statistics

V. RESULTS

Our idea titled "IoT Water Quality Analysis & Pump Automation" integrates advanced sensor technology with automated pumping systems to ensure efficient water management. The system incorporates Total Dissolved Solids (TDS), Electrical Conductivity (EC), and temperature sensors to continuously monitor key water quality parameters. The TDS sensor measures the concentration of dissolved solids in water, providing insights into its purity and suitability for various applications. Simultaneously, the EC sensor measures the water's ability to conduct electricity, which correlates with its mineral content and overall health. These sensors work in tandem to assess water quality in real-time, enabling prompt interventions if deviations from desired standards are detected. Temperature sensors complement this analysis by monitoring the water's thermal characteristics. Fluctuations in temperature can indicate environmental influences or potential contamination, prompting immediate corrective actions if necessary. To automate the water pumping process, DC pumps are integrated into the system. These pumps are activated based on the data received from the sensors, ensuring that water is fetched and distributed efficiently when quality parameters meet desired thresholds. For instance, if the TDS or EC levels indicate suitable water quality, the DC pumps are triggered to initiate water fetching, optimizing resource usage and minimizing manual intervention. The IoT infrastructure enables remote monitoring and control of the entire system through a user-friendly interface. Users can access real-time data and receive alerts via a web or mobile application, allowing for timely responses to changing conditions. Historical data logging also facilitates trend analysis and long-term water quality assessment. Overall, the "IoT Water Quality Analysis & Pump Automation" project represents a significant advancement in water management technology. By leveraging IoT capabilities alongside precise sensor measurements and automated pumping mechanisms, the system enhances water quality monitoring and resource efficiency, contributing to sustainable and reliable water supply systems.

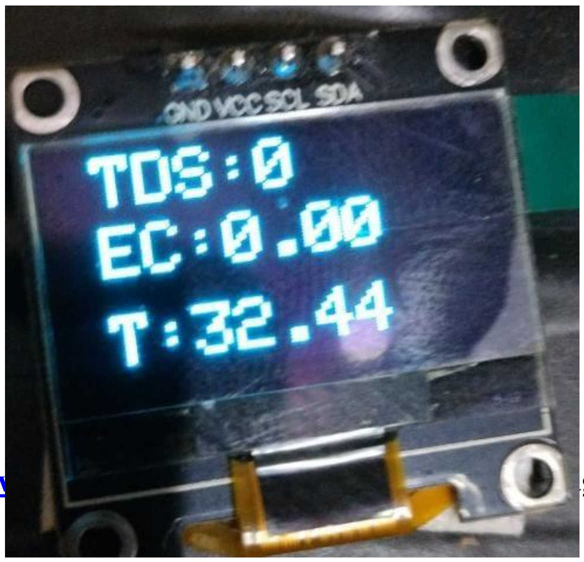

Fig 4: OLED Readings

VI. CONCLUSION

In conclusion, the implementation of an IoT-based water quality monitoring mechanism utilizing NodeMCU, TDS sensor, EC sensor, and temperature sensor presents a transformative approach safeguarding water resources. This innovative system harnesses the power of interconnected devices to provide real-time data on crucial water quality parameters. By integrating NodeMCU as the central processing unit, alongside specialized sensors for TDS, EC, and temperature measurement, the mechanism offers a comprehensive solution for monitoring water quality across various environments. Through continuous data collection and analysis, stakeholders can swiftly detect fluctuations in water quality, enabling prompt intervention to prevent contamination or degradation. Moreover, the scalability and flexibility of IoT technology allow for seamless integration with existing infrastructure, facilitating widespread adoption and accessibility. By empowering communities, authorities, and organizations with actionable insights, this solution fosters informed decision-making and proactive measures to ensure the preservation of clean water sources. As we navigate the complexities of environmental sustainability, IoT-based water quality monitoring emerges as a critical tool in our arsenal. Its potential to revolutionize how we manage and protect water resources underscores the importance of embracing technological innovation in addressing global challenges. Moving forward, concerted efforts to refine and expand such mechanisms hold the promise of a future where clean water is not just a necessity, but a fundamental human right upheld through cutting-edge advancements in science and technology.

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