Automated Rural Water Supply System

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Abstract. Automation into IoT-based water management systems like the Automated Rural Water Supply System tracks water usage in real-time, controls distribution, and monitors water quality in order to improve the efficiency of water distribution in rural areas [3]. The manual execution of tasks in the traditional water management systems leads to wastage, contamination and unreliable access to water. To systematically monitor vital parameters or outside instrumental damages like leakage, contamination and equipment failure, the system is furnished with IoT-based flow, pH and water level sensors [13]. Using an ESP8266 microcontroller, the automation of various system functions is achievable raising the reduction of required maintenance human resources and associated costs. Data-driven decision making combined with set algorithms towards maintaining resource control aids in post analytics, proactive infrastructure maintenance, and predictive alert systems to set up maintenance routines, and allocating resources based on demand towards better fulfilment of rural community needs [4]. LCD Displays helps to provide timely information towards the efficiency and reliability of the water management system. Also, while the system ensures an ease of access to clean water, it provides equitable access to it reducing issues towards poverty and inequality. Though faced with an issue dealing with costs towards installation, maintenance, efficient energy, and lack of smart device compatibility, Adaptive control over modern system enables the system aims to raise control and accuracy towards wastage reduction granting water security to rural areas. The overall features of the system aids in enabling sustainable and reliable smart water management [1].

Keywords: ESP8266, Flow sensor YF-S201, 20*4 LCD Display, PH Sensor, Water Level Sensor.

1 Introduction

Access to clean and reliable water is a fundamental necessity, yet many rural communities face persistent challenges in managing their water supply efficiently. In these areas, poor infrastructure, high maintenance costs, and inefficient water distribution often lead to wastage, contamination, and unreliable access. Traditional water management systems rely heavily on manual intervention, making them prone to errors and inefficiencies [5]. To address these challenges, the Automated Rural Water Supply System has been designed to integrate Internet of Things (IoT) technology, enabling real-time monitoring, automated control, and data-driven decision-making inadequate development in rural regions contributes to the high installation cost and low technical competency of maintenance. Compounding these challenges are the problems with device integration such as interoperability where different devices from different manufacturers do not seamlessly talk to one another. Even in the rural areas, there is an unexploitable technological underutilization due to a lack of understanding IoT's potential

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advantages. Apart from these, communities need to be protected from the risks of data breach and sensitive information such as water consumption. These factors present a trust hurdle towards community acceptance.

All these concerns bring into focus the requirement of resolving or at least simplifying problems while sustaining a trustworthy water supply. With the help of IoT technology, the water supply system is fully automated addresses the issue of securing and sustaining water resources while providing an intelligent all-encompassing solution to the problems mentioned earlier. This system IoT-based sensors as its components, enabling continuous real-time monitoring of water quality, tank water levels, and flow rates for timely detection of leaks, contamination, or equipment failures [3]. Reduction of human intervention in managerial automation and minimal human participation tends to reduce operational cost and human error. Besides, service delivery is further enhanced through informed decision-making by the stakeholders supported by resource allocation optimization enabled through advanced data analytics. The core part of this system is from a controlling device in the form of microcontroller units which are the ESP8266. Updates about the system can be viewed at any given time during its operation thanks to the LCD Display [13]. All these parts make an efficient, automated as well as a scalable solution for water management in rural areas. This project is unique in its fully integrated and data-driven method of water management system. Automated monitoring of tank levels, smart metering for water usage tracking, and remote data access ensure minimal wastage, timely maintenance, and enhanced water security. This technological innovation strengthens and creates a dependable water distribution system for rural areas which brings them closer to achieving consistent and long-term water security.

2 Literature Survey

2.1 Existing System

The traditional water delivery system, with several challenges, affects both its efficiency and reliability. These challenges often result in loss of water and water contamination, which can lead to future problems in people in rural areas receiving adequate clean water.

Manual Operation and Inefficiency: The existing system relies heavily on man intervention to monitor water levels, check for water quality, and regulate the supply of water. This creates delays in identifying problems which leads to water shortages, overflow and waste. There will also be an increase in human error as a result of manual operation, negatively affecting the reliability of the water supply [6].

Inability to Monitor in Real-Time: Existing systems do not have real-time monitoring, so leaks, equipment malfunctions, or contaminated water can go undetected because they are not triggered automatically. This means issues are not identified until reactive action is required, when damage, interruption, or inconvenience are already present.

High Maintenance and Operational Costs: The Course maintenance of rural water systems should include periodic manual inspections that are costly and time-consuming. Additionally, labor-intensive water system management contributes to the operational cost of the water supplies, creating a situation where poor rural communities will have limited resources to maintain an effective system [6][12].

Water Quality Management: Proficiencies Automated pH probes, and other check for contamination, are paramount to ensure the safety of water through commercialization stage. In rural communities, waterborne diseases frequently arise, due to a result of poor monitoring and improper and infrequent actions to mitigate the risk from contaminated water [3].

Water Overuse and Waste: As there is not a flow control system and smart meters, water is wasted due to endless water distribution [11]. It is also hard to understand optimal usage and will continue not to be understood as tracking trends cannot occur and continued wasting can result in unsustainable resources [6][14].

Limited Accessibility and Remote Monitoring: The system is neither remotely accessible nor automated; it is only able to be operated and maintained in a pressured, physical environment. This leads to delayed action in managing water distribution appropriately, primarily when the areas being serviced are far apart and in rural areas. These constraints render the use of an IoT based automated system imperative to improve efficiency and conservation and ensure a reliable water supply to rural areas.

2.2 Gaps in Current Solutions

Even with efforts to improve rural water supply systems in Tanzania, there are several gaps in current coverage, blocking effective and sustainable management of water. Almost all existing solutions fall short in terms of automated water quality sensors, resulting in delayed detection of hazardous water conditions, and higher health risk to rural communities. The gaps represent the gaps in technology, infrastructure, monitoring, and accessibility, resulting in absence of technologically complete solutions [5].

Inadequate Water Quality Monitoring: While safe drinking water is of the utmost importance, most rural systems do not have a monitoring system for pH, contamination, and bacterial populations. Ramesh et al. (2022) proposed a low-cost water quality monitoring system, but reported sensor accuracy and network stability limitations [7]. Most solutions do not have automated water quality sensors, which leads to delayed detection of hazardous water conditions and increased health risk to rural communities [14].

Ineffective Use of Water and Unnecessary Water Waste: Presently, water use is not optimized for utilization causing unnecessary overuse of water. Water cannot be identified as wasteful without the use of smart meters or automated flow control, and therefore, water can be saved. There is also no predictive analysis that leads to appropriate management concerning seasonal water shortages [11].

Restricted Remote Control and Monitoring: Most of rural water systems do not offer remote control or monitoring and require an on-site visit for operation and maintenance. This creates logistical issues, particularly in rural areas where the systems are dispersed physically, and intervention is needed to avoid breakdown or loss of supply.

High Service and Maintenance: Costs and Maintenance Problems Regular manual maintenance and manual inspections are part of the operating cost of the system, thus complicating the system. Additionally, in many rural locations there might not be technical assistance to address technical failures, resulting in repair time and longer service interruptions [12].

Poor Data-Based Decision: Making Traditional systems do not apply advanced analyses of data for improved performance. Without data on water usage, system efficiency and demand estimates, decision-making is not efficient, resources are being wasted, and services are not dependable.

3 Proposed Methodology

3.1 Process flow

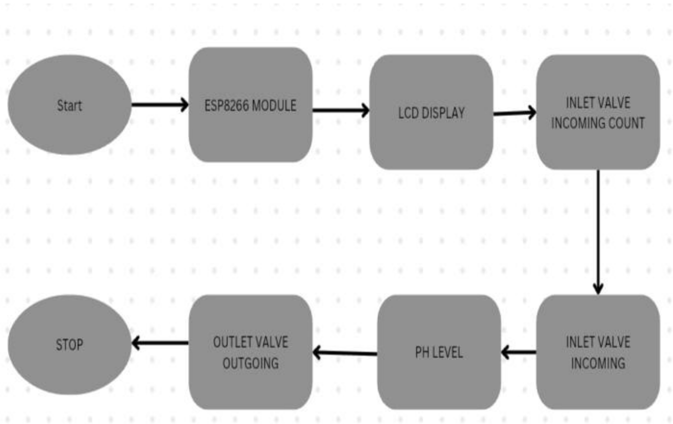

Fig. 1. Process flow of the proposed system.

3.1.1 20*4 LCD Display

The ARWWS is now a key player in the effective operation of water supply. It has the realtime monitoring which is shown by displaying key water parameters, and need not be connected to the internet so that it can made more available in a rural region. The LCD monitor would indicate important data including the amount of water remaining, flow rate, and total volume used, a function preventing under- or over-consumption. It also provides instant data about water quality parameters to make sure you never drink unsafe water. — Users also will be alerted with system warnings such as when a pump fails, there's a leak or low water, and pressure drops. The Arduino and ESP8266 boards are connected to the 20×4 LCD, which is constantly updated with the latest conditions. Integration offers a trustworthy technology driven water management to rural communities, complemented with a local monitoring and efficiency enhancement [9]. Fig. 1 depicts the process flow of the proposed system.

3.1.2 NODE MCU (ESP8266)

One of the key parts of this Automated Rural Water Supply System is the ESP8266 Wi-Fi module that allows for remote control and real-time water management. By having the microcontroller connect to the internet, it makes it super easy to communicate with web dashboards, mobile apps, and cloud platforms. The module collects data from sensors which measure water quality parameters, pressure, flow rate, and level. It then transmits the data to a cloud server for long range monitoring. The ESP8266 is responsible for smart automation controlling distribution systems, pumps, and valves as per the pre-set parameters. In order to save water and optimize operations, it can issue warnings and alerts when it detects irregularities such as low water, leaks or pollution. To ensure effective and sustainable water supply, the system framework has to support monitoring and control of rural water delivery networks in real time.

3.1.3 PH Sensor

Testing the acidity and alkalinity of water is critical in ensuring that water is safe to drink and use for farming. The pH sensor (which determines whether water is acidic or alkaline) is just as critical for detecting pollution, contamination, and chemical irregularities. It can then provide notifications or corrective measures, such as switching on a filtration or chemical process, if the pH exceeds the safe level. To reduce downtime and operational expenditures, the AI predictive maintenance model predicts when equipment may fail and the water quality becomes an issue, based on past data. To make continuous pH monitoring and transferring the measurement data to a cloud platform possible, the sensor is connected to microcontrollers such as Arduino and ESP8266 [14]. Automatic reactions, such as closing valves to dirty water conduits or modifying treatment equipment can be done thanks to IoT. The system is reasonable and sustainable for rural water supply, as it improves the safety of drinking water, avoids health risk, and ensures the quality [4].

3.1.4 BC547 TRANSISTOR

The BC547 can be used for switching and amplifying purposes in your Automatic Rural Water Supply System and gain some efficiency over the system's electronic devices. The BC547 is an NPN Bipolar Junction Transistor (BJT) widely used in common collector or common emitter configuration as it is a general purpose BJT, which consists of three layers of doped semiconductor with the applications of two junctions. One of the primary applications of your project is the relay pump/valve switch. The BC547 is an intermediate switch, because micro-controllers as Arduino / ESP8266 / PI are not capable to handle high power loads. If a tiny COLLECTOR-EMITTER current is allowed to flow, then a larger current is permitted to flow and this activates the relay to drive the water pump or the valveOtherwise, nothing operates. In sensor signal amplifier (such as: flow sensor, PH sensor, water level sensor) before amplification processing, it can also be used to connect the BC547 for amplification processing. Thanks to the addition of the BC547 transistor, your rural water supply system is more intelligent and efficient than ever before - the BC547 allows the low-power microcontrollers to safely drive high-power components, giving you a powerful water control system on which you can rely. It also has water management in real time and easy automation.

3.1.5 Mangetic Float Level Sensor

To accurately measure the water levels in tanks, reservoirs, and pipes, your Automated Rural Water Supply System needs a magnetic float level sensor. Through the prevention of overflows, shortages, and pump dry running, the sensor helps ensure effective water management. The foundation of the magnetic float level sensor is a floating magnet that rises and falls in response to the water level. A Hall-effect sensor or reed switch is triggered when the float moves, and the Arduino and ESP8266 microcontrollers receive the inputs. For local monitoring, this data can be shown on an LCD screen; for distant monitoring, it can be sent to a cloud platform. Automatic Pump Control: This feature minimizes the need for human intervention by turning the pump on when the water level is low and off when it is full. Water conservation aids in identifying and stopping water waste brought on by leaks or excessive use. System Alerts – Gives warnings or alerts in case of very low water levels, ensuring uninterrupted supply. By incorporating a magnetic float level sensor, your project is a smart, automated, and efficient water management system, encouraging sustainability and reliability for rural communities [10].

3.1.6 Inlet/Outlet Value

Role of Inlet and Outlet Valves in the Automated Rural Water Supply Systemin the Automated Rural Water Supply System, inlet and outlet valves have a vital role in ensuring efficient water flow, avoiding wastage, and maintaining a constant supply. Inlet and outlet valves are automatically controlled by IoT-based sensors and microcontrollers Arduino, ESP8266 to control water flow based on real-time monitoring. The inlet valve regulates water supply from the main supply, e.g., a borewell or municipal supply, to reservoirs, storage tanks, or pipes. It is controlled in conjunction with water level sensors magnetic float level sensors to avoid overflow by closing when the tank is full. It also avoids dirty water entering the system if filtration or treatment is employed. The outlet valve regulates water supply, discharging water from storage to household pipes, irrigation systems, or community supply lines. It avoids dry running by closing when water levels are extremely low, to avoid pump damage. With automated pump control, it optimizes energy efficiency and minimizes manual intervention.

4 System Architecture

4.1 Hardware Integration

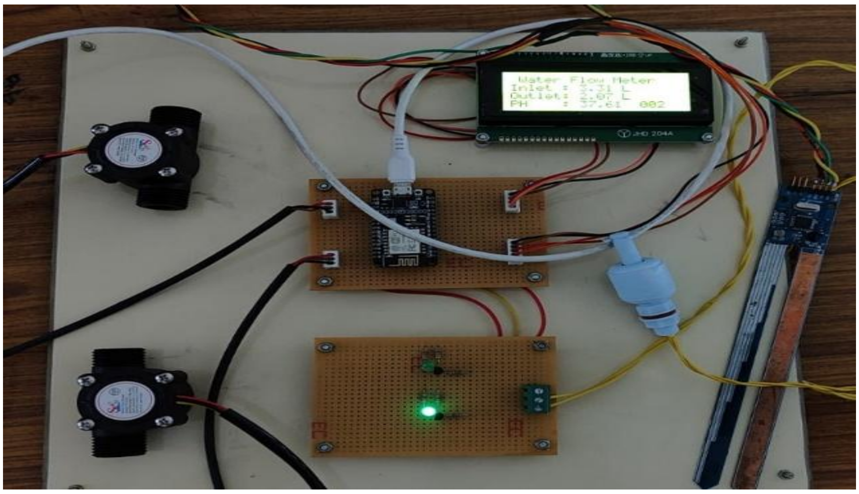

Fig. 2. Hardware Prototype.

The Automated Rural Water Supply System is an all-inclusive system that relies on IoT-enabled sensors, microcontrollers, actuators, communication modules, and power supply modules to provide live monitoring and efficient water distribution. The microcontroller unit (MCU) as shown in fig. 2 processes incoming sensor data, automates valve operation, and controls pumps. Examples of microcontrollers include the ESP8266, ESP32, and Arduino Uno/Mega, with the ESP32 chosen due to its dual-core processor, built-in Wi-Fi/Bluetooth, and memory that can be increased by using an SD card. The system contains sensors for real-time monitoring, which include magnetic float level, flow, pH, turbidity, and temperature sensors [13]. These sensors help to provide relevant information needed for automated water management through the prevention of water wastage and s steady supply. In addition, hydraulic actuators contribute to effective water flow regulation and include solenoid valves, relay modules, and pump controllers. Real-time communication and monitoring displays are provided through LCD displays for local monitoring, Wi-Fi or GSM modules for remote monitoring, and buzzer/LED indicators to alert the user of any critical water levels or system faults [2].

4.1.1 System Block Diagram

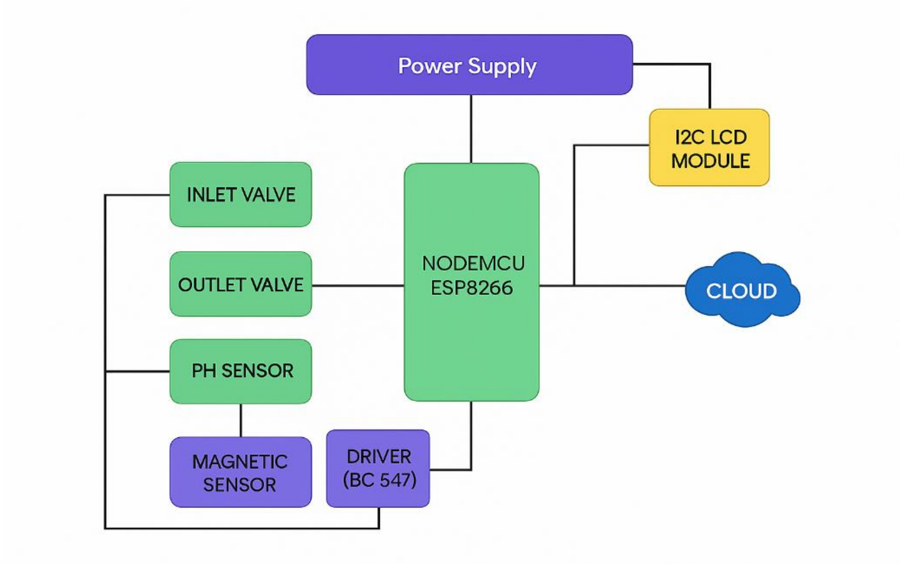

Fig. 3. IoT-Based Water Quality Monitoring System.

4.2 Software Implementation

Blynk, a prominent provider of water supply systems, has recently included a Wi-Fi ESP8266 module into their Automated Rural Water Supply System [2]. This unique software architecture coordinates the different sensors to enable the users with wireless control over the web by establishing remote monitoring and automation [9]. The Automated Rural Water Supply System code uses C/C within Arduino IDE to process the sensors, which allows the system to automate decisions based on prior programmed conditions. There are also cloud connections that can be made with Blynk, giving time stamped logged data in real-time, analytics and remote monitoring [7]. Fig. 3 shows the IoT-Based Water Quality Monitoring System.

5 Future Scope

The Automated Rural Water Supply System has more possibilities for future developments directed towards better efficiency, sustainability, and scalability. Future developments will be possible in several key areas as technology advances in the areas of rural water usage, distribution and management [5]. Future development for the Automated Rural Water Supply System will build on the predictive functionalities and expand to smart water distribution networks. Connected with further developments in renewable energy sources like solar powered pumps, sustainable functionality of the system will further improve [1].

Predictive Maintenance with AI: Future developments for AI and Machine Learning will be able to predict equipment failure, leaks, and contamination risks before anything goes wrong. AI-enabled platforms or applications will be used to analyze this data and provide alert notification systems to assist with elimination of downtime and maintenance costs [7]. Increased cloud integration will allow for remote access and control from anywhere that allows authorities to monitor, analyze, and adjust a community's water distribution from a co-located facility in real time [10].

Improved Water Quality: Monitoring Future iterations of the system could integrate higher quality sensors that will monitor for heavy metals, microbial contaminants, and also provide turbidity readings and turbidity readings in real time. These added components will help provide a more thorough and accurate water safety evaluation to ensure clean and safe drinking water [4].

Renewable Energy Utilization: In order to be more environmentally friendly, solar or wind power would be used as a source of power to the invention to limit a need for an external sources of power. This will in turn enhance the efficiency and accessibility of the system in restricted space condition under low power supply [1].

Smart Water Distribution: The work has also the potential to extend the system such that it would automatically share the water in real time as it is demanded to achieve a better allocation of resources as reported in [15]. Smart meters can also be applied to monitor personal consumption and facilitate water to be distributed effectively and without waste [8].

Cloud-Based Remote Monitoring: Enhancing cloud penetration will permit remote accessibility and control from any location such that for better monitoring and analysis of water distribution, police officers enhance and optimize water in potable time [15]. This will further the decision-making and response mechanism [3].

6 Simulation of Monitoring Device

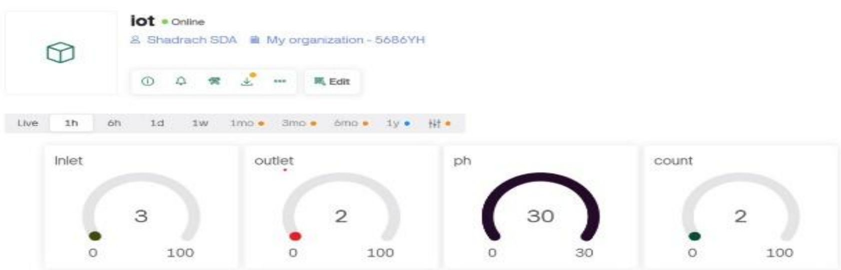

Fig. 4. Simulation results in Laptop.

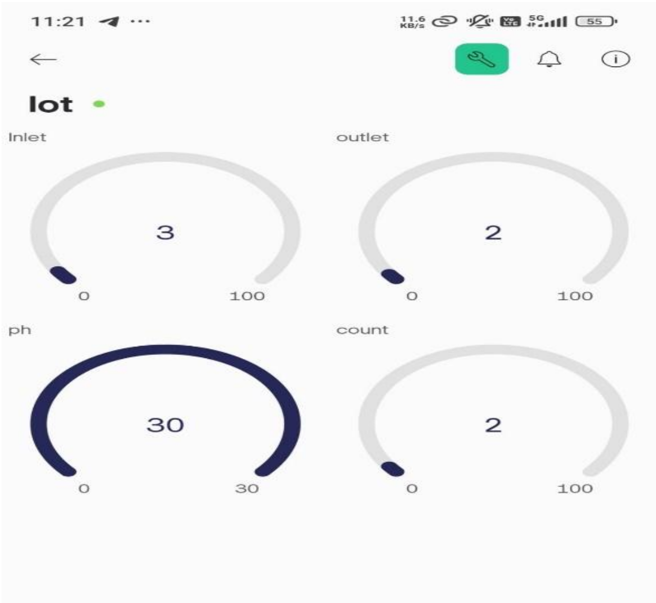

Fig. 5. Simulation results in Mobile.

Mobile and Android-based user interfaces for monitoring water levels [9]. Simulation results in Laptop and mobile are shown in fig.4 and 5 respectively.

Table 1. Simulation readings of ORP sensor with a respect to PH.

pH	ORP (mV)
6.09	800
7.39	584
7.43	476
7.41	260
7.42	44
7.39	-170
7.49	-494
7.28	-818

Negative value indicates as reducing agent. High value of pH and negative value of ORP makes water good for use. The simulation readings of ORP sensor with a respect to PH is shown in table 1. Table 2 gives the water quality parameters standard value.

Table 2. Water Quality Parameters Standard Value.

Parameter	Quality Range	Units
Ph	6.5-8.5	pH
ORP	650-800	mV

7 Conclusion

The “Automated Rural Water Supply System” is an unprecedented answer to the problems such as shortage of water, inefficiency of water transport, and difficulty of water supervision in the countryside. That such system is conducive to less water waste and to a safe and sustainable water supply, by combining the IoT technology, real-time monitoring and automation. By making use of sensors, microcontrollers, and cloud-based systems, it is able to interact with the environment and control water throughput while maintaining steady levels of quality and availability. Automatic pumps and valves can be used for water to be released based on demand considerably saving human effort and preventing resource wastage [13].

The inclusion of Wi-Fi modules means that the device can also be monitored over the cloud using services like Blynk. AI-enabled analytics and a move towards smart metering and renewable energy integration are likely to advance its capabilities even more. This inexpensive, scalable solution provides a rural community with a dependable, technology-based supply of water, playing a large role in the pursuit of sustainable water management and worldwide conservation [8].

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