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Empowering Rural Water Plants with IoT-Enabled Automation and Control

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A R T I C L E I N F O

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A B S T R A C T

Access to clean drinking water remains a crucial challenge in many rural and public areas. Traditional coin-based water dispensers provide affordable water supply but lack features for monitoring water quality and system health. This project introduces an IoT-enabled automated water plant that integrates smart sensing, data monitoring, and control to ensure safe and efficient water distribution. Using NodeMCU (ESP8266) as the central controller, the system measures essential parameters such as pH, Total Dissolved Solids (TDS), and water level through sensors interfaced with an ADS1115 ADC module. Real-time data is displayed on an LCD and transmitted to a cloud platform for remote access via smartphones. The system also incorporates a coin acceptor and relay-controlled water pump for automated dispensing, ensuring fair water usage. Alerts are generated through a buzzer and cloud notifications whenever unsafe conditions occur. This IoT-based solution offers a reliable, low-cost, and energy-efficient approach to automate rural water systems, improving accessibility, safety, and sustainability.

1. Introduction

Providing clean and safe drinking water is still a major concern in many rural and public places. Most existing water plants and dispensing units operate without real-time monitoring of water quality, which means users often collect water without knowing whether it is safe for consumption. Studies have shown that continuous sensing of water parameters like pH and TDS can significantly improve safety by helping detect contamination at the earliest stage [1]. Research also highlights that filtration systems become more reliable when digital monitoring is used rather than depending only on manual inspection [2].
Cloud-based dashboards have made it possible for operators to view water-quality information remotely without being physically present at the water plant [3]. Wireless modules such as NodeMCU ESP8266 allow sensor data to be transferred to cloud platforms quickly and at low cost, which makes them suitable for rural installations [4]. However, most commercially available water vending machines require high installation and maintenance costs and are therefore not suitable for small villages and public spaces [5]. Low-cost circuits using Arduino have been developed to measure pH and TDS [6], but they do not control the distribution of water. Similarly, microcontroller-based coin-operated systems regulate the amount of water dispensed through coin validation, but they cannot check whether the water being dispensed is safe to drink [7]. IoT-based alert models are used to notify operators when water becomes unsafe, but these systems do not prevent dispensing during unsafe conditions [8].

2. Related Work

Several studies have contributed to advancements in automated water distribution and IoT-based quality monitoring. Forhad et al. proposed a real-time IoT system for monitoring pH and TDS levels, proving that cloud-integrated sensing can provide accurate water-quality evaluation without manual testing [1]. Talal et al. conducted a comprehensive review of IoT-based water monitoring platforms and highlighted that automation improves filtration consistency by reducing unnoticed contamination events [2].
Jan et al. investigated IoT-controlled motor automation and water-level tracking and demonstrated that remote supervision reduces service downtime in distributed water facilities [3]. Santos et al. implemented a complete sensing system using NodeMCU ESP8266 for water-level and environment monitoring, showing that wireless connectivity improves accessibility and data logging efficiency [4].
Irawan, et.al developed Comparative assessments of commercial water dispensing systems suggest that most available models lack integrated real-time quality monitoring and require costly installation and maintenance, limiting deployment in rural settings [5].
Febriani et al. introduced an Arduino-based pH and TDS measurement device and confirmed that low-cost embedded systems can deliver dependable results suitable for real-time analysis [6]. Mohan et al. designed a coin-operated water dispenser and showed that microcontroller-based coin validation provides a reliable mechanism for regulating water distribution through timed dispensing [7]. Moparthi et al. demonstrated that IoT-based alerting and GSM/MQTT communication models significantly improve the response time in identifying unsafe water conditions at treatment plants [8].

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3. Methodology and Implementation

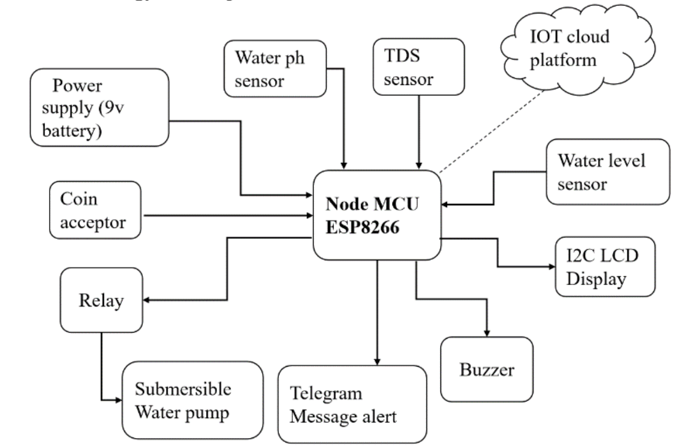

Fig. 1. Block diagram of the System

The block diagram represents an IoT-enabled Coin-Based Water Dispensing System using a NodeMCU ESP8266 as the central controller. The system integrates sensors, actuators, cloud connectivity, and user-interaction components to automate water dispensing based on coin insertion while continuously monitoring water quality and tank Implementation of Water Plant Monitoring System and Coin based water dispenser.

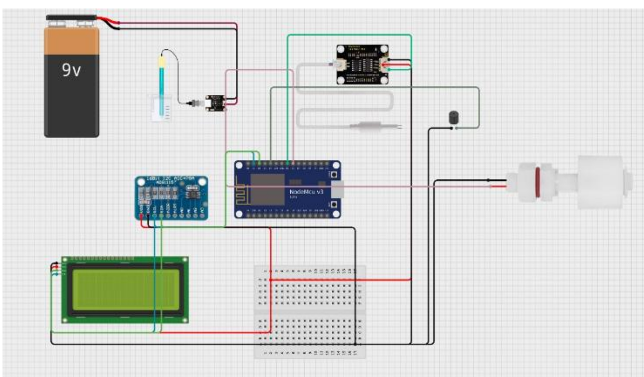

Fig. 2. Circuit diagram of water plant monitoring system.

The implementation of the IoT-Based Smart Plant Monitoring System and Coin-Based Water Dispenser focuses on integrating sensors, actuators, and IoT technology for efficient water management and automation. The smart plant monitoring system uses a NodeMCU ESP8266 as the central controller to interface with pH, TDS, and water level sensors. The analog signals from these sensors are converted into precise digital data through the ADS1115 16-bit ADC module, which communicates with the NodeMCU using the I²C protocol. The NodeMCU processes this data and displays real-time readings on a 16×2 I²C LCD display, providing users with instant updates on water quality and level. A buzzer is connected to alert users when pH or TDS levels cross safe limits or when the water level becomes too low or too high. The Wi-Fi feature of the NodeMCU allows seamless connectivity to cloud platforms like Blynk, enabling users to view live parameters remotely from their smartphones. The entire system is powered by a 9V battery, ensuring portability and energy efficiency.

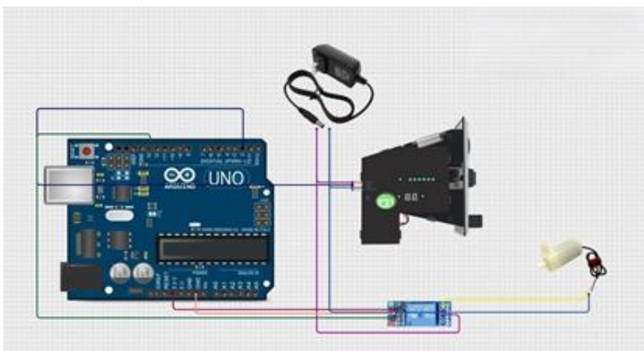

Fig.3. Circuit diagram of coin based water dispenser

In the coin-based water dispenser, the implementation involves connecting a coin acceptor module to a microcontroller such as NodeMCU or Arduino. When a valid coin is inserted, the coin acceptor generates a pulse signal, which the microcontroller detects and processes. The controller then activates a relay module that powers the water pump or solenoid valve for a specific duration, allowing controlled water dispensing. The LCD display shows the coin count, remaining balance, and dispensing time, while a buzzer provides alerts for invalid coins or completion of dispensing. The use of a relay ensures electrical safety and isolation between the low-voltage control circuit and the high-voltage pump system. A system operates on the principle of mechanization automation. Where an embedded controller receives input from a coin acceptor module, validates the coin, and triggers an valve or pump to dispense water.

Each coin corresponds to a predefined volume of water, enabling a pay-per-use model.

Both systems emphasize modular design and can be customized according to user requirements. For example, the smart plant monitoring system can be enhanced by adding soil moisture sensors and automated irrigation control. Similarly, the coin-based water dispenser can be upgraded to accept digital payments or RFID cards. These projects combine the benefits of IoT connectivity, automation, and user-friendly operation to create smart water management solutions. They are ideal for implementation in rural areas, public places, and small agricultural fields.

The use of affordable components makes these systems cost-effective and easy to maintain.

Furthermore, both setups promote sustainable water usage and reduce wastage through intelligent control mechanisms. The smart plant system ensures plants receive water of optimal quality, preventing damage due to impurities, while the coin-based system allows pay-per-use water access, making it suitable for community use. These systems can also be linked to cloud analytics for data logging and predictive maintenance. The combination of IoT, sensors, and automation demonstrates how technology can transform traditional water systems into smart, efficient, and sustainable models. Overall, the successful implementation of these projects shows a strong step toward smarter living and responsible resource management.

4. Working Principle

The paper combines water-quality monitoring and coin-based dispensing in a single automated system. The core controller is the NodeMCU ESP8266, which receives power from a 9V supply shared with all components through a common ground. The pH sensor measures the acidity of the water, while the TDS sensor detects the amount of dissolved solids. Both sensors generate analog signals that need to be converted to digital form. Since the NodeMCU has only one analog input pin with a limited voltage range, their outputs are fed to an external ADS1115 module. This 16-bit ADC operates through the I²C interface and sends accurate digital readings to the NodeMCU for processing.

A float switch is included to determine whether the water tank is full or empty. The switch provides either a HIGH or LOW signal, allowing the controller to check the current tank level instantly The NodeMCU collects data from the pH, TDS, and water-level sensors and displays the readings on a 16×2 LCD. A buzzer alerts users whenever the water quality parameters exceed safe limits or when the water level becomes too high or too low. The water dispensing unit uses a coin acceptor to validate inserted coins. After verification, the controller activates a relay to operate the water pump for a fixed duration based on the coin value. The pump automatically stops after dispensing the required amount of water, helping to reduce wastage and ensure efficient water distribution.

5. Results and Discussion

The developed prototype was tested under different operating conditions to evaluate its performance. The pH and TDS sensors provided stable readings, which were displayed accurately on the LCD through the ADS1115 module. The NodeMCU successfully sent sensor data to the cloud, allowing water quality and tank levels to be monitored remotely. The buzzer and Telegram alerts worked as expected whenever abnormal conditions were detected. The coin acceptor correctly identified valid coins, and the relay-operated pump dispensed water for the specified time. The LCD showed the required information clearly, making the system easy to use. Overall, the system performed effectively in monitoring water quality, controlling water dispensing, and providing timely alerts.

STEP 1: Before Initialization

Fig.4. Model before initialization of a coin

The image shows the front view of the project model consisting of two main user-interface components: the coin acceptor module and the 16×2 LCD display. The coin acceptor and LCD display are mounted on the front panel of the enclosure for easy access and visibility. The coin acceptor is placed on one side of the panel, where it validates inserted coins and sends a signal to the controller to start the water dispensing process. An indicator LED shows the operating status of the module.

The LCD display is positioned on the front panel to show water quality readings, system status, and dispensing information. Its backlight helps users view the displayed data clearly. This arrangement allows users to interact with the system easily and supports smooth operation during water dispensing.

STEP 2: After Initialization

Fig. 5. During the initialization of coin

The coin slot is mounted on the outer body of the system so that users can easily access it from the front.

1. Acts as the input device through which the user initiates the water dispensing process.
2. Detects and verifies the inserted coin before allowing the system to operate.
3. Sends a signal to the controller when a valid coin is accepted.
4. Ensures that water is dispensed only after successful coin validation.
5. Helps regulate and control the amount of water dispensed.
6. Prevents unauthorized use of the system.
7. Reduces water wastage by allowing dispensing only after payment.
8. Supports a pay-per-use model suitable for public and rural locations.
9. Eliminates the need for continuous manual monitoring.
10. Improves the overall convenience and usability of the water dispensing system.
11. Provides a reliable and automated method for user interaction.
12. Contributes to efficient management of drinking water resources.

Fig.6. MultiCoin Acceptor showing the name of inserted coin.

When a coin-based water dispensing system is powered ON, the coin acceptor module undergoes a short initialization or self-calibration process. This process ensures that the device is ready to correctly identify and validate coins based on their size, weight, and metal composition.

- The first coin channel being recognized.
- A system OK status indicating initialization completed
- This means that the coin acceptor is now stable and ready to accept a coin input.
- Coin Channels and Display:
- Modern coin acceptors support multiple coin types (channels). Each channel corresponds to a pre-programmed currency value.

Example:

- Channel 1 → ₹1
- Channel 2 → ₹2
- Channel 3 → ₹5

When initialized, some acceptors show the last activated channel or a default channel number, which is why you see 5 on the display.

pH and TDS values that stored in IoT cloud platform via blynk app:

Fig. 7. Blynk Web Page.

The IoT-based Water Quality Monitoring System was able to measure, process, and upload water quality data to the cloud platform successfully. The recorded sensor values were displayed correctly on the monitoring dashboard, confirming proper communication between the sensors, controller, and cloud service.

- pH Value (7.86):

1. The measured pH value of 7.86 indicates that the water is slightly alkaline.
2. This value falls within the acceptable range for drinking water.
3. The result confirms that the pH sensor is functioning correctly and providing reliable measurements.

- TDS Value (15 ppm):

1. The recorded TDS value of 15 ppm indicates a very low concentration of dissolved solids in the water.
2. Such a low reading suggests that the water has undergone effective purification.
3. The TDS sensor successfully detected and transmitted the water quality

data.

- Overall Performance:

1. The system successfully monitored water quality parameters and updated the data to the cloud for remote access.
2. Sensor readings were displayed clearly on the monitoring dashboard, making observation and analysis easier.
3. The results indicate that the system can be used for continuous water quality monitoring in homes, rural areas, and public water supply systems.
4. Remote monitoring helps users track water conditions and take necessary action when required.
5. pH is a measure of the acidity or alkalinity of water on a scale of 0 to 14.
6. A pH value of 7 represents neutral water.
7. Values below 7 indicate acidic water, while values above 7 indicate alkaline water.
8. For drinking water, the recommended pH range is 6.5 to 8.5, which helps maintain water quality and safety.

pH value	Water Quality	Explanation
6.5-8.5	Ideal / Acceptable Range	Water in this range is safe, neutral to slightly basic, and suitable for drinking.

Total Dissolved Solids (TDS) Value

Total Dissolved Solids (TDS) indicate the amount of dissolved minerals and salts present in water. TDS is usually measured in parts per million (ppm) or milligrams per liter (mg/L).

TDS is an important factor in determining water quality. For drinking water, a TDS range of 50–150 ppm is generally considered suitable. Low TDS may indicate a lack of essential minerals, while high TDS can affect taste and may suggest the presence of excess dissolved substances.

Maintaining TDS within the recommended range helps ensure good water quality and makes the water suitable for daily consumption..

TDS Level(ppm)	Water Quality Classification
0-50 ppm	Low-Mineral/Very soft water
50-150 ppm	Excellent
150-250 ppm	Good
250-350 ppm	Fair
350-500 ppm	Poor/High TDS
Above 500 ppm	Unsuitable for drinking

Dispensing of water:

Fig.8.Water Dispensing from the Tank.

The system uses a coin-based mechanism for controlled water dispensing. When a valid coin is inserted, the coin acceptor sends a signal to the NodeMCU controller. The controller activates a relay to start the water pump, which runs for a fixed time based on the coin value. After dispensing the required amount of water, the pump automatically stops. This approach helps ensure efficient water distribution while reducing water wastage. The automated operation reduces manual intervention and makes the system simple and convenient for users. Through IoT connectivity, system information such as water dispensing activity and pump status can also be monitored remotely, improving overall management and maintenance.

Water Level Monitoring and Alert System

The system is equipped with a water level monitoring unit that continuously tracks the amount of water available in the storage tank. Whenever the water level reaches a critical low level, exceeds the specified limit, becomes empty, or reaches full capacity, the buzzer is activated to provide an immediate warning. These alerts help prevent overflow, avoid dry running of the pump, and reduce unnecessary power consumption. The monitoring data can also be accessed remotely through the IoT platform, allowing operators to observe tank conditions and system performance from any location. By combining automated dispensing, level monitoring, and remote supervision, the system provides a reliable and efficient solution for water distribution in rural and public water supply applications.

6. Conclusion.

Conventional water dispensing systems often lack facilities for monitoring water quality and system status, which can result in unsafe water usage, water wastage, and delayed detection of operational issues. To overcome these limitations, the developed system combines water quality monitoring, water level detection, automated dispensing, and IoT-based communication into a single platform. The system continuously measures important water quality parameters such as pH and TDS, while also monitoring the water level in the storage tank. Sensor data is processed through the NodeMCU ESP8266 and ADS1115 module, enabling accurate measurement and wireless transmission of information. Notifications generated through cloud services and Telegram help operators respond quickly to abnormal conditions, ensuring timely maintenance and improved system reliability. The coin-operated dispensing mechanism provides controlled access to water by allowing dispensing only after successful coin validation. The relay-controlled pump operates for a predefined duration, ensuring fair distribution and reducing unnecessary water consumption.Testing of the prototype confirmed accurate sensor readings, dependable alert generation, stable communication, and consistent water dispensing performance. The results demonstrate that the system is capable of providing safe, efficient, and automated water distribution, making it suitable for rural water plants and other public water supply applications.

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