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AquaPurge – Automatic Eco-friendly Smart System for Water tank Cleaning and Health Monitoring using Arduino Uno Wi-Fi Module

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Abstract

This paper presents the design and implementation of an automated water cooler cleaning system using Arduino Uno and IoT-enabled components. The system addresses the challenges of manual cleaning and hygiene maintenance in water coolers by introducing a timed, sensor-based mechanism to facilitate periodic water circulation and drainage. A small tub is integrated within the cooler, where water is temporarily pumped from the main tank for the cleaning process. An ultrasonic sensor continuously monitors the water level in the tub to detect when the cleaning cycle is complete. Upon reaching a low-water threshold, the system automatically shuts off the circulation pump and activates a solenoid valve to drain the used water back into the main tank. A two-hour interval timer governs the repetition of this process, ensuring consistent maintenance without manual intervention. A push-button interface is provided to initiate or reset the cycle. The system is microcontroller-driven and designed for low-power operation, with potential for remote monitoring through a Wi-Fi module. This approach improves hygiene, reduces human effort, and enhances the operational efficiency of water cooling systems in public and domestic settings.

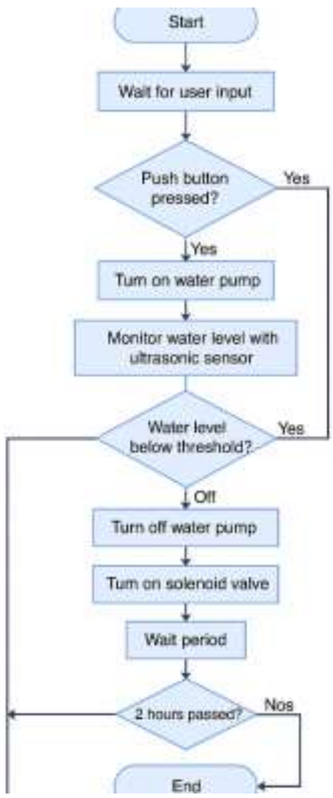
1. Introduction

Water coolers are essential appliances in various settings, including homes, offices, and public spaces, providing convenient access to drinking water. However, maintaining the hygiene of these systems poses a significant challenge, as manual cleaning is often neglected, leading to potential health risks. The integration of automation and Internet of Things (IoT) technologies offers a promising solution to enhance the maintenance and cleanliness of watercoolers.

Recent advancements in microcontroller-based systems have facilitated the development of automated water dispensing and monitoring solutions. For instance, Amarul and Ling (2025) designed an Arduino-based automatic drinking water dispenser aimed at minimizing water wastage and promoting sustainable water management practices. Their system incorporated present volume options and educational elements to raise awareness about sustainability and embedded systems.[1] Building upon such innovations, this study proposes an automated water cooler cleaning system utilizing an Arduino Uno microcontroller, ultrasonic sensors, a water pump, and a solenoid valve. The system is designed to perform periodic cleaning cycles every two hours, wherein water is circulated from the main tank to a small tub for cleaning purposes. An ultrasonic sensor monitors the water level in the tub, and upon detecting a low-water threshold, the system deactivates the pump and activates the solenoid valve to drain the used water back into the main tank. A push-button interface allows for manual initiation or resetting of the cleaning cycle. By automating the cleaning process, the proposed system aims to improve hygiene standards, reduce manual labor, and ensure consistent maintenance of water coolers. The integration of IoT components further enables remote monitoring and control, aligning with contemporary trends in smart appliance development.

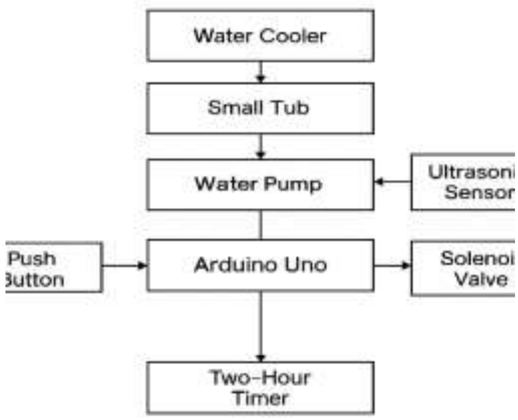
2. Algorithm

The proposed system follows a structured sequence controlled by an Arduino Uno microcontroller to automate the cleaning process of a water cooler. At system startup, all hardware components are initialized, including the water pump, ultrasonic sensor, solenoid valve, and input push button. The system initially enters an idle state and waits for a push button press, which serves as a user command to begin the cleaning process.



Once triggered, the water pump activates and circulates water from the main cooler tank into a small cleaning tub. Simultaneously, the ultrasonic sensor monitors the water level within the tub in real-time. When the water level drops below a predefined threshold, signaling the end of the cleaning phase, the system shuts off the pump to prevent overuse. Immediately following this, the solenoid valve opens to release the used water, either back into the main tank or into a disposal outlet. A short wait period ensures complete drainage, after which the valve is closed. The system then enters a passive timing phase, during which it tracks a 2-hour interval. Once this period elapses, the cleaning cycle restarts automatically without needing further user input. The push button remains active during all stages, allowing manual reactivation of the process at any time. This automation enhances operational efficiency, promotes hygiene, and reduces the need for manual intervention in water cooler maintenance.

3. Block Diagram :-



The block diagram provides a comprehensive overview of the automated water cooler cleaning system, outlining the interaction between various components controlled by an Arduino Uno microcontroller. At the foundation of the system is the main water cooler tank, which tores the water used during normal cooler operation as well as for the cleaning cycle. Connected to this tank is a water pump, which is electronically controlled through a digital output pin of the Arduino. When activated, the pump draws water from the main tank and directs it into a small cleaning tub, which serves as the temporary reservoir for cleaning purposes.

An ultrasonic sensor is positioned above the small tub and functions as a non-contact water level detector. It continuously measures the distance between the sensor and the water surface, thereby determining the water level in real time. The sensor transmits this data to the Arduino, which processes the input to make decisions about the system's next actions. If the sensor detects that the water level has dropped below a defined threshold—signaling that the cleaning cycle has completed or the tub is empty—the Arduino initiates the next phase of the cycle.

At this point, the Arduino deactivates the water pump and activates a solenoid valve, which is responsible for draining the used water from the tub. The solenoid valve is electrically operated and remains open for a short, predefined duration to ensure that all used water is discharged either back into the main cooler tank or into a waste outlet, depending on the system design. After this delay, the Arduino switches off the solenoid valve to prevent unnecessary water loss.

To enable automated operation, the Arduino features an internal two-hour timer implemented in software. Once a complete cleaning cycle finishes, the system enters a waiting state, counting down the two-hour interval before restarting the process. This ensures periodic cleaning without requiring manual intervention. Additionally, a push utton is included in the system as a user interface. Pressing the button allows manual initiation of the cleaning cycle at any time, overriding the timer if needed. This adds flexibility to the system by allowing on-demand cleaning.

In essence, the block diagram illustrates a smart and responsive control loop that ensures the water cooler remains clean through timed automation and sensor-based monitoring. The integration of actuators (pump and valve), sensors, user input, and control logic through a single microcontroller allows for an efficient and low-maintenance hygiene solution tailored for water dispensing systems

4. System Requirement :-

The design and implementation of the *AquaPurge* system require a combination of electronic components, microcontroller hardware, power regulation modules, and basic mechanical elements. The following outlines the essential hardware and software components necessary for building and operating the self-cleaning water cooler mechanism.

4.1 Hardware Requirements

- **Arduino Uno WiFi (Rev2):** Serves as the primary control unit for automating the cleaning process and enabling future wireless communication capabilities.
- **12V DC Water Pump:** Transfers water from the main cooler tank to a small overhead tub for the cleaning cycle.
- **Ultrasonic Distance Sensor (HC-SR04):** Monitors the water level in the tub to determine the start and stop conditions for the pump and valve.
- **12V Solenoid Valve:** Discharges used water from the tub back into the main tank after cleaning.
- **2-Channel Relay Module:** Allows the microcontroller to safely switch high-power devices (pump and valve) using low-voltage control signals.
- **12V to 5V Step-Down Converter:** Regulates power supply from 12V to 5V for Arduino and sensor modules.
- **TIP122 Transistor and IN4007 Diode:** Supports electrical isolation and protects the system from voltage spikes due to inductive loads.
- **Push Button:** Provides manual control to initiate the cleaning cycle.
- **Power Adapter (12V, ≥2A):** Supplies necessary electrical power to the pump, valve, and other modules.
- **Small Water Tub:** Positioned above the main tank, used as the intermediate container for the cleaning process.

4.2 Software Requirements

- **Arduino IDE:** Open-source platform used to develop, compile, and upload control code to the Arduino Uno WiFi board.

- **WiFiNINA Library (optional):** Facilitates wireless communication for potential IoT integration, such as remote monitoring or cloud-based control.
- **Simulation Tools (e.g., Proteus, Tinkercad):** Useful for circuit verification before physical implementation.

4.3 Functional Requirements

- The system must detect the absence of water in the cleaning tub and respond by deactivating the pump and activating the solenoid valve.
- The cleaning cycle must be initiated either manually (via push button) or automatically at fixed intervals (e.g., every 2 hours).
- The system must reliably control 12V components using safe switching techniques.
- Real-time water level detection must be accurate and robust under normal environmental conditions.

4.4 Environmental and Operational Constraints

- **Operating Voltage:** 5V (logic), 12V (actuators).
- **Temperature Range:** 0°C to 50°C.
- **Relative Humidity:** 20% to 90%, non-condensing.
- **Water Protection:** Electronic components exposed to moisture should be enclosed in water-resistant housing.

5. System Development :

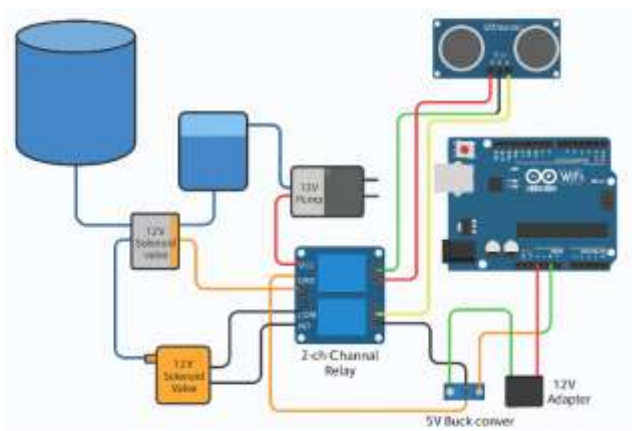
The *AquaPurge – Smart Water Cooler Self-Cleaning System* integrates sensor-based automation with real-time control to enhance water hygiene and reduce manual cleaning efforts. This section outlines the development of the complete system including its architecture, operational workflow, microcontroller programming, and hardware integration.

5.1 System Architecture

The system consists of a modular combination of hardware components driven by an Arduino Uno WiFi microcontroller. A **12V DC water pump** circulates water from the cooler tank into a **small overhead tub**. An **ultrasonic sensor** measures the water level in the tub to determine when cleaning is complete. A **solenoid valve** is then opened to return water from the tub back into the cooler. This process can be initiated manually with a **push button** and automatically repeats every two hours.

5.2 Working Procedure

1. When the user presses the push button or the 2-hour timer elapses, the system begins.
2. The pump activates to transfer water from the main tank to the upper tub.
3. The ultrasonic sensor monitors the tub's water level.
4. Once the water level drops below a threshold (e.g., <20 cm), the pump is turned off.
5. The solenoid valve is activated, draining the remaining water into the cooler tank.
6. The system resets and waits 2 hours before repeating the process.



5.3 Arduino Uno WiFi Code

```
cpp
CopyEdit
const int pumpRelayPin = 6;        // Relay for pump
const int valveRelayPin = 8;       // Relay for solenoid valve
const int trigPin = 9;             // Ultrasonic TRIG
const int echoPin = 10;            // Ultrasonic ECHO
const int buttonPin = 2;           // Push button input

long duration;
int distance;
bool systemRunning = false;
unsigned long lastRunTime = 0;
const unsigned long interval = 7200000; // 2 hours in milliseconds

void setup() {
  pinMode(pumpRelayPin, OUTPUT);
  pinMode(valveRelayPin, OUTPUT);
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  pinMode(buttonPin, INPUT_PULLUP);

  digitalWrite(pumpRelayPin, LOW);
  digitalWrite(valveRelayPin, LOW);
}

void loop() {
  if (digitalRead(buttonPin) == LOW || millis() - lastRunTime >= interval) {
    systemRunning = true;
    lastRunTime = millis();
  }

  if (systemRunning) {
    digitalWrite(pumpRelayPin, HIGH);  // Start pump

    while (true) {
      distance = getDistance();

      if (distance > 20) {  // Water level is low
        digitalWrite(pumpRelayPin, LOW);   // Stop pump
        delay(1000);
        digitalWrite(valveRelayPin, HIGH); // Open valve
        delay(5000);                       // Drain time
        digitalWrite(valveRelayPin, LOW);  // Close valve
        break;
      }

      delay(500);
    }

    systemRunning = false;
  }
}
```

6. Future Development

The current design of the AquaPurge system demonstrates a reliable, low-cost method for automating the cleaning cycle of a water cooler. However, the system has the potential to be enhanced in several meaningful ways to increase functionality, efficiency, and user accessibility. The following are proposed areas for future development:

1. Integration with IoT Platforms

One of the most promising enhancements is connecting the system to an Internet of Things (IoT) platform. By doing this, users can monitor the cleaning cycles, receive maintenance alerts, and control the system remotely using a smartphone or web interface. IoT integration can also allow data logging, which can help analyze cleaning frequency, water usage, and device performance over time.

2. Mobile App or Web Dashboard

To support remote monitoring and control, a dedicated mobile application or web-based dashboard can be developed. This interface can display real-time water levels, system status (active, idle, or error), and upcoming scheduled cleaning routines. Notifications could be implemented for users to receive alerts in case of sensor malfunction or water shortage.

3. Solar-Powered Operation For off-grid locations or areas with unstable electricity supply, the system could be powered using solar energy. A small solar panel with battery storage can make the solution more sustainable and usable in rural or remote areas. This would align the project with green energy initiatives.

4. Advanced Water Quality Monitoring

In future versions, additional sensors can be integrated to monitor parameters such as water temperature, turbidity, and pH levels. This would transform the system from a simple cleaning mechanism into a more intelligent purification and quality-monitoring unit, ensuring the water is not only clean but also safe to drink.

5. Voice Assistant Integration

With the growth of smart home technologies, integrating voice control via platforms such as Amazon Alexa or Google Assistant can enhance user convenience. Users could initiate a cleaning cycle or check water status using simple voice commands.

6. Automated Fault Detection

By incorporating self-diagnosis capabilities, the system can detect issues such as pump failure, valve blockage, or sensor disconnection. These faults can be reported to the user immediately, reducing downtime and improving reliability.

7. Modular Design for Commercial Use

A future version could offer a modular structure that can be customized based on tank size, number of tubs, or frequency of usage. This would make the system scalable and suitable for larger commercial setups such as offices, schools, and hospitals.

8. Self-Cleaning Nozzles and Filter Integration

Additional improvements could involve self-cleaning spray nozzles or filters that clean themselves after every cycle, minimizing user intervention and extending component lifespan.

9. Data Analytics and Machine Learning

The long-term data collected through IoT features can be analyzed using machine learning algorithms to predict cleaning requirements, schedule preventive maintenance, or optimize the cleaning cycle for specific usage patterns.

10. Compliance with Health and Safety Standards

Future development may also include certifying the system under public health standards for drinking water equipment. Ensuring regulatory compliance will enable the system to be deployed in public or regulated environments with confidence.

7. Future scope

The AquaPurge system, in its current form, offers a reliable and cost-effective solution for automating the cleaning of water coolers. However, there exists significant potential for future enhancements that can elevate its functionality and user experience. Integrating the system with IoT technology can enable remote monitoring, real-time status updates, and smart scheduling through mobile applications. Incorporating advanced water quality sensors could transform it into a more comprehensive water safety system, capable of analyzing temperature, turbidity, or pH levels. Solar power integration may make the system more sustainable and suitable for deployment in remote or off-grid locations. Further, implementing automated fault detection, self-cleaning nozzles, and voice assistant compatibility can increase the system's reliability and accessibility. With the ability to scale for larger or commercial setups and adapt to user behavior using data analytics, the AquaPurge system holds strong promise as a future-ready, smart water maintenance solution.

8. Conclusion

The AquaPurge system presents a practical and innovative approach to automating the cleaning process of water coolers, addressing key challenges in hygiene, manual maintenance, and water conservation. By utilizing an Arduino Uno WiFi module in combination with ultrasonic sensors, relays, a water pump, and a solenoid valve, the system performs efficient cleaning cycles with minimal user intervention. The inclusion of a push-button interface and timed operations ensures ease of use and reliability. Throughout the development, emphasis was placed on affordability, simplicity, and scalability, making the solution accessible for both domestic and commercial applications. With promising possibilities for future upgrades, such as IoT integration and smart monitoring, AquaPurge stands as a forward-looking solution that contributes to public health and sustainable water management.