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A Review Paper on Design and Development of Smart Water Purifier with Thermoelectric Cooling

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Abstract

This project focuses on the development of a smart water purification and cooling system that provides clean drinking water at a controlled temperature. The proposed system integrates multiple water filtration techniques with sensors to monitor water temperature and tank level. A microcontroller, such as an ESP32 or Arduino, processes the sensor readings and controls the pump, solenoid valve, Peltier cooling module, and cooling fan according to the system requirements. The Peltier module cools the purified water through thermoelectric technology, eliminating the need for conventional refrigerants. The cooling process is automatically regulated based on the water temperature, helping to reduce unnecessary power consumption. This integrated design provides a compact, automated, and convenient solution for supplying purified and cooled drinking water in residential buildings, offices, educational institutions, and laboratories.

Keywords: ***Smart water purification, Peltier cooling, thermoelectric system.***

Introduction

The proposed project focuses on developing a smart water purification and cooling unit that provides clean drinking water at a suitable temperature. Water from different sources may contain suspended particles, dissolved impurities, and harmful microorganisms, making appropriate treatment necessary before consumption. Conventional systems usually perform purification and cooling separately, which can increase installation space, operating expenses, and maintenance requirements. To overcome these limitations, the proposed system combines water treatment and thermoelectric cooling in a single arrangement. Depending on the quality of the source water, purification may involve sediment filtration, activated carbon filtration, reverse osmosis (RO), and ultraviolet (UV) treatment. After purification, the water is collected in a storage tank and cooled using a Peltier module. When direct current is supplied, the module creates a temperature difference between its two surfaces, allowing heat to be extracted from the water and released into the surrounding environment through a heat sink and cooling fan. A microcontroller, such as an Arduino, manages the system using sensor readings. A temperature sensor monitors water temperature, a total dissolved solids (TDS) sensor estimates the concentration of dissolved substances, and a water-level sensor detects the amount of water available in the tank. According to programmed conditions, the controller operates the pump, solenoid valve, cooling module, and fan. An LCD display can show important operating information, including temperature, TDS readings, and tank level. Automatic control helps regulate cooling operation and may reduce unnecessary energy consumption. With suitable electrical protection and effective thermal management, this integrated system can offer a practical solution for providing purified and cooled drinking water in homes, offices, colleges, and laboratories.

Literature review

The study presented an IoT-enabled intelligent water-quality monitoring system for tourist safety using machine learning. The system monitored important water-quality parameters such as pH, turbidity, TDS, and temperature using sensors and an ESP32-based platform. The collected data was analysed using machine-learning techniques to assess water quality. The study demonstrated that IoT and machine learning can provide effective real-time monitoring and improve water-quality assessment.[1]

The study investigated high-performance integrated thermoelectric coolers for improved cooling applications. An integrated water-cooled thermoelectric cooling arrangement was developed to improve heat dissipation from the hot side of the thermoelectric module. The results demonstrated improved cooling performance compared with conventional thermoelectric cooling systems. This work is relevant to the proposed project because effective heat removal is important for achieving better performance from a Peltier-based water-cooling system.[2]

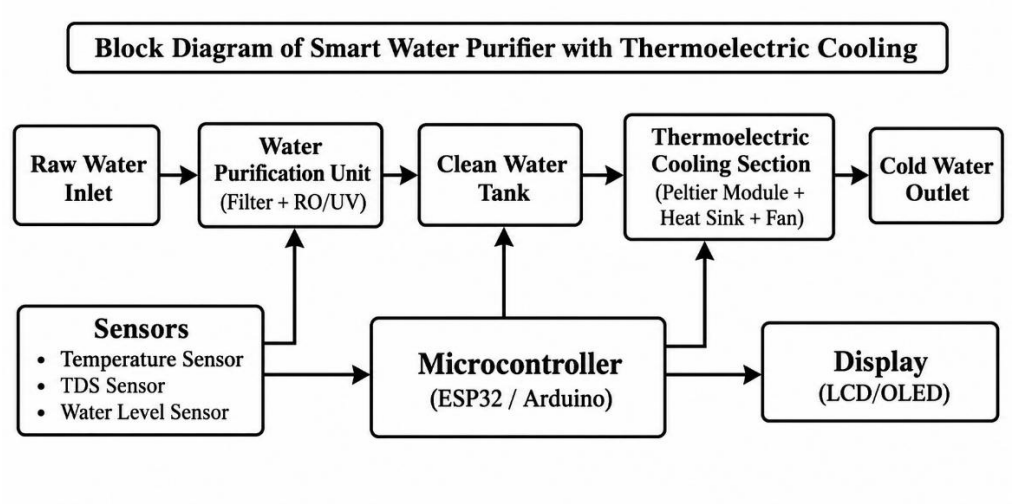
The study proposed an IoT and AI-driven framework for real-time water-quality assessment and intelligent purification recommendation. The system uses water-quality parameters such as pH, turbidity, TDS, and temperature and processes the collected data using an ESP32-based system. Artificial-intelligence techniques are used to assess water quality and recommend suitable purification methods. The study demonstrates the potential of combining IoT, sensors, and AI for intelligent water-treatment systems.[3]

The study developed a smart water-quality monitoring system using IoT wireless sensor networks. Different water-quality parameters were collected through sensors and transmitted using IoT technology for monitoring and analysis. Machine-learning techniques were also considered for predicting water-quality conditions. The research demonstrates the usefulness of wireless sensor networks for continuous water-quality monitoring and supports the integration of sensor-based monitoring into smart water systems.[4]

Methodology

The proposed Smart Water Purifier with Thermoelectric Cooling is developed by integrating water purification, sensor monitoring, microcontroller-based automation, and Peltier thermoelectric cooling. The complete methodology is divided into the following stages.

A. Block Diagram



B. Description

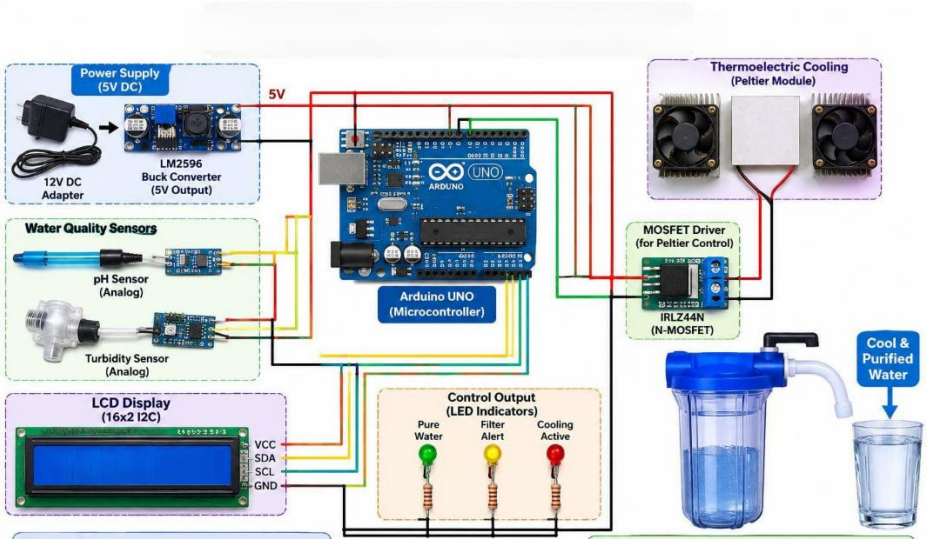
The developed system integrates water purification, automated water flow management, sensor-based monitoring, and Peltier-based cooling into a compact unit. Initially, raw water passes through the required filtration and treatment stages before being collected in a storage tank. Sensors measure the water temperature, dissolved-solids level, and tank water level, while the Arduino processes these readings and controls the connected devices. A thermoelectric module lowers the temperature of the purified water, and an LCD provides real-time information about the system's operating conditions. This integrated design aims to make purified and cooled drinking water readily available while simplifying operation and minimizing the need for manual control.

Working

The proposed smart water purifier with thermoelectric cooling is designed to combine water treatment, automatic monitoring, and cooling in a single system. Initially, untreated water is supplied through an inlet and passed through a series of filtration processes, including sediment filtration, activated carbon filtration, and RO or UV treatment, depending on the required water quality. These stages help reduce suspended materials, unwanted substances, dissolved salts, and harmful microorganisms. The treated water is then collected in a separate storage tank fitted with a water-level sensor to monitor the quantity of available water. Temperature, TDS, and water-level sensors are used to collect information about the water and system conditions. All sensor signals are provided to the Arduino microcontroller, which analyses the readings and controls the connected devices according to the programmed instructions. A pump and solenoid valve are used to regulate water movement through the system. The cooling arrangement consists of a Peltier module, heat sink, and

cooling fan. When electrical power is supplied to the Peltier module, it creates a temperature difference between its two surfaces. The cold surface absorbs heat from the stored purified water, while the hot surface transfers heat to the surrounding environment through the heat sink and fan. The temperature sensor continuously provides water temperature readings to the Arduino, allowing the controller to activate or deactivate the cooling arrangement according to the selected temperature setting. An LCD display is also connected to the controller to provide information about temperature, TDS level, water availability, and cooling operation. In this way, the proposed arrangement provides an integrated solution for water purification, quality monitoring, automatic water management, and thermoelectric cooling, making the system convenient and reducing the need for separate purification and cooling equipment.

A. *Circuit Diagram*



The circuit layout shows how the different electrical components of the smart water purifier are connected. The Arduino UNO works as the central controller and collects data from the temperature, TDS, and water-level sensors. It manages the pump, solenoid valve, and Peltier module with the help of suitable driver circuits. The cooling unit uses a heat sink and fan to release unwanted heat. A 16×2 LCD is used to display sensor readings and system information. Overall, the circuit enables automatic water monitoring, flow management, and cooling**.**

Advantages

1. One device for two jobs: water is cleaned and chilled inside the same enclosure, so the user needs no separate purifier and refrigeration unit.
2. Small footprint: the cooling element is a thin ceramic plate, so the unit fits on a table or wall mount.
3. No refrigerant involved: cooling comes from electric current alone, so there is no gas charge to refill or leak.
4. Nothing mechanical to wear in the cooling stage: without a compressor, the only moving parts are the fan and the circulation pump.
5. Quiet enough for classrooms and libraries: the only sound is airflow from the heatsink fan.

Future Scope

This project covers the design and construction of a compact, self-contained unit that cleans drinking water and chills it in the same enclosure. Depending on the quality of the incoming supply, the purification stage can combine a sediment filter, an activated carbon filter, and either reverse osmosis or ultraviolet disinfection. Three sensors track the condition of the system: a TDS probe for dissolved solids, a temperature sensor for the stored water, and a level sensor for the tank. An ESP32-based controller reads these inputs and decides when to run the pump, open or close the solenoid valve, and power the Peltier cooling assembly. The cooling stage can be refined by matching the Peltier modules, heatsink size, and fan capacity to the tank volume, so the target temperature is reached with less electrical energy. The design also leaves room for later upgrades, including WiFi-based remote monitoring, automatic assessment of water quality, adaptive control of the purification stages, solar power, and smarter energy management. With these additions, the unit could serve homes, offices, colleges, laboratories, and any other place that needs clean, cold drinking water.

Conclusion

This project proposes a single compact unit that purifies drinking water and then chills it, replacing the usual pair of separate machines. Raw water passes through sediment, activated carbon and RO/UV stages into a clean-water tank, where a Peltier-based cooling section with a heatsink and fan lowers its temperature. An ESP32 controller reads the water temperature, TDS value and tank level, and uses them to run the pump, solenoid valve, Peltier modules and fan without manual supervision. Since cooling stops once the setpoint is reached, electrical energy is spent only when the water needs chilling, and safeguards such as dry-run shutdown, hot-side overheat cutoff and a TDS-based filter warning make daily use safer. Thermoelectric cooling is less efficient than compressor cooling and suits small to moderate volumes, but it offers silent, refrigerant-free operation, fine temperature control and a compact build, which is a sensible balance for a college, office or laboratory dispenser.

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