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Solar Powered IoT Water Purification System

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Abstract : *Access to clean water is essential, yet small water-treatment units often give the user no information about the condition of the water being processed, and many depend on a mains supply. This paper presents the design of a solar-powered, IoT-enabled water purification prototype. The treatment path consists of three stages in sequence: a 5-micron sediment filter, a 10-inch activated carbon (CTO) block filter and an ultraviolet (UV-C) chamber, followed by a clean-water storage tank. An ESP32 microcontroller acquires readings from an EC-0568 pH meter, a turbidity sensor, a TDS sensor, a water-temperature sensor and a tank water-level sensor, and sends them over Wi-Fi to a Blynk dashboard for remote observation. A solar panel, charge controller and 12 V rechargeable battery with a buck converter supply the system, demonstrating renewable-energy use at prototype scale. The selected 3 W panel is a demonstration-scale source and may not sustain continuous pump and UV operation, so the actual operating time will be measured and recorded. The prototype has no RO stage and is not intended to remove dissolved salts, and sensor readings alone do not certify water as safe to drink. The work serves as an educational platform that combines basic water treatment, embedded sensing, renewable energy and IoT monitoring.*

Keywords: Solar Energy, Internet of Things (IoT), Water Purification, ESP32, Blynk, UV-C Treatment, Water Quality Monitoring, Sediment and Carbon Filtration

I. INTRODUCTION

Access to clean water is essential for health, daily living and community development. Water collected from different sources can contain suspended particles, unwanted colour or odour, dissolved substances and microorganisms, and the quality of the source water can also change over time [1], [2]. A small water-treatment unit should therefore do more than pass water through a filter: it should provide a defined treatment sequence and allow the user to observe important water-quality indicators.

This paper proposes a solar-powered, IoT-enabled water purification prototype. The water-treatment section uses three stages in sequence: a sediment filter, an activated carbon block filter and an ultraviolet (UV-C) treatment chamber. The sediment cartridge is intended to reduce visible suspended matter such as sand, rust and fine particles. The carbon block stage is intended to improve taste and odour and reduce chlorine and selected organic compounds. The final UV stage is intended to inactivate susceptible microorganisms when the chamber is correctly selected, installed and operated at its rated flow [3].

An ESP32 microcontroller [4] forms the monitoring and control centre. It receives readings from five sensing elements: the selected EC-0568 pH meter, a turbidity sensor, a TDS sensor, a water-temperature sensor and a water-level sensor in the clean-water tank. The readings are sent over Wi-Fi to a Blynk IoT dashboard [5] so that the operator can view the measured values without standing beside the prototype.

The energy arrangement includes a solar panel, a solar charge controller and a rechargeable 12 V battery. A DC-DC buck converter provides a regulated 5 V supply for the ESP32 and compatible sensors. The pump and UV unit are treated as separate loads and must be supplied according to their actual voltage and current ratings. The selected 3 W

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solar panel is a small demonstration-scale source and should not be assumed to supply enough energy for continuous pump and UV operation.

The project is intended as an educational prototype that combines basic water treatment, embedded sensing, renewable-energy use and IoT monitoring. Sensor readings provide useful information about selected water-quality parameters, but they do not by themselves certify that water is safe to drink. Proper testing and validation are required before any drinking-water claim can be made.

II. PROBLEM STATEMENT

Small water-treatment arrangements are often operated without continuous information about the condition of the water being processed. A user may be able to see whether water looks clear, but appearance alone cannot indicate pH, dissolved-solids concentration or all forms of contamination. In addition, a basic filter unit may provide no convenient way to monitor the storage tank or review measurements over time.

A further challenge is the availability of electrical power. A treatment prototype that depends entirely on a mains supply may be difficult to demonstrate where a convenient supply is not available. A solar-assisted battery arrangement can demonstrate the use of renewable energy, but the power system must be matched to the actual consumption of the pump, UV chamber and electronics. The project therefore addresses the following practical needs:

- To arrange three treatment stages in a clear and maintainable sequence: sediment filtration, activated carbon filtration and UV treatment.
- To monitor selected water parameters (pH, turbidity, TDS and temperature) using sensors connected to an ESP32.
- To detect the water level in the clean-water storage tank and make that status available to the controller.
- To provide remote visibility of the measured values through a Blynk dashboard.
- To demonstrate solar charging and battery-based operation while keeping the limitations of a small solar panel in view.

The proposed prototype is not designed to remove every possible contaminant. In particular, it does not contain an RO membrane and therefore is not intended to remove dissolved salts or reliably reduce TDS. Its purpose is to demonstrate a compact three-stage treatment arrangement with electronic monitoring, rather than to replace a certified household or community water purifier.

III. OBJECTIVES

A. Main Objective

To design and develop a solar-assisted, ESP32-based water purification prototype that combines three treatment stages with real-time monitoring of selected water-quality parameters and clean-water tank level through an IoT dashboard.

B. Specific Objectives

1. To construct a water path consisting of a sediment filter, an activated carbon block (CTO) filter and a UV-C treatment chamber.
2. To interface the selected EC-0568 pH meter with the monitoring arrangement, subject to confirming its liquid-water suitability and electrical interface.
3. To measure turbidity, TDS and water temperature using suitable sensor modules and display the readings through the ESP32.
4. To monitor the clean-water tank using a water-level sensor or float switch.
5. To transmit sensor readings from the ESP32 to a Blynk dashboard over Wi-Fi.
6. To use a solar panel, charge controller and 12 V rechargeable battery as the prototype's renewable-energy demonstration arrangement.

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7. To provide a controlled switching arrangement for the pump and UV unit, using a relay module selected for the actual load ratings.

C. Project Scope

The scope covers prototype assembly, sensor interfacing, basic data acquisition, IoT display and demonstration of the three-stage water path. It includes calibration checks for the sensors and functional checks of the pump, UV unit and tank-level detection. The project does not include an RO stage, automatic chemical dosing or laboratory certification of the treated water.

D. Design Considerations

The selected pH meter must be verified for liquid-water measurement and for a safe output interface before connection to the ESP32. Any analog signal presented to an ESP32 input must remain within the board's permitted voltage range. The UV chamber must be enclosed, correctly flow-rated and operated with suitable electrical and UV exposure protection.

IV. SYSTEM ARCHITECTURE

The architecture is divided into four connected sections: the solar power section, the water purification section, the sensing and control section, and the IoT monitoring section. The water path and the electrical/data paths are shown separately so that the treatment sequence can be understood without confusing it with the power and communication connections.

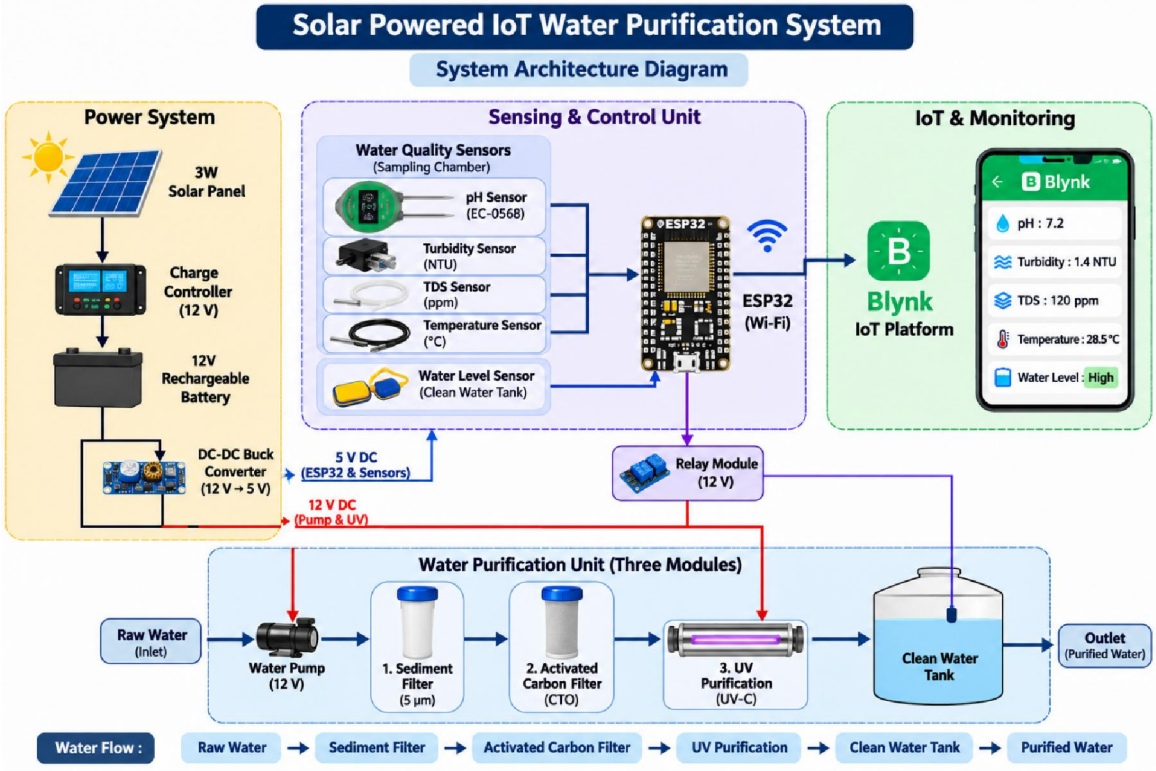


Fig. 1. System architecture of the Solar Powered IoT Water Purification System

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In the water path, raw water is moved by the pump through the sediment cartridge, then through the CTO activated carbon cartridge, and finally through the UV-C chamber before entering the clean-water tank. The tank-level sensor reports the stored-water condition to the ESP32.

In the electrical path, the solar panel feeds a compatible charge controller, which manages charging of the 12 V battery. The battery supplies the low-voltage electronics through a regulated buck converter. The pump and UV chamber are switched through an appropriately rated driver or relay arrangement and powered only from a supply that matches their specifications.

The sensor outputs are read by the ESP32, which formats the readings and sends them over Wi-Fi to Blynk. The dashboard presents the values for pH, turbidity, TDS, temperature and tank level.

V. DESCRIPTION OF SYSTEM COMPONENTS

The major components of the prototype and their functions are summarised in Table I and described in the following subsections.

TABLE I: Major Components of the Proposed System

Section	Component	Function
Solar power	3 W solar panel; solar charge controller	Collects solar energy and regulates battery charging
Energy storage	12 V rechargeable battery; DC-DC buck converter	Stores energy; provides regulated 5 V for the ESP32 and sensors
Water treatment	5-micron PP spun sediment cartridge	Reduces visible suspended particles
Water treatment	10-inch CTO activated carbon block	Reduces chlorine, taste, odour and certain organics
Water treatment	UV-C chamber	Inactivates susceptible microorganisms
Sensing	EC-0568 pH meter; turbidity, TDS and temperature sensors	Measure selected water-quality parameters
Sensing	Float switch or level sensor	Detects clean-water tank level
Control	ESP32; relay module	Acquires data, connects to Wi-Fi and switches pump and UV loads
IoT	Blynk dashboard	Displays readings and tank status remotely

A. Solar Power and Battery Unit

The solar panel provides energy to the charging system. A charge controller compatible with the panel and the 12 V battery chemistry regulates the charging process and helps protect the battery. The battery stores energy for operation when sunlight is weak or unavailable. A DC-DC buck converter reduces the battery voltage to a regulated 5 V rail for the ESP32 and other compatible electronics. The 3 W panel is retained as the selected demonstration component, but its limited output means that the available energy may be insufficient for the pump and UV load. Actual operating time must be measured and the panel size increased if the loads require it.

B. Three-Stage Water Purification Unit

Stage 1 - Sediment filter: A 5-micron PP spun sediment cartridge is used as the first barrier for suspended particles. It helps reduce the amount of visible particulate matter entering the later stages and protects downstream components from rapid clogging.

Stage 2 - Activated carbon filter: A 10-inch CTO activated carbon block cartridge is used as the middle stage. It can help reduce chlorine, unwanted taste and odour, and certain organic compounds, depending on the cartridge specification and water chemistry. It is not a universal chemical-removal stage.

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Stage 3 - UV-C treatment: The UV chamber is installed after the two cartridge filters and before the clean-water tank. UV treatment depends on lamp output, exposure time, water clarity, flow rate and correct maintenance [3]. The chamber should remain enclosed to prevent direct exposure to UV-C radiation.

C. Sensors and Controller

The pH meter indicates how acidic or alkaline the water is. The project uses the EC-0568 unit; its suitability for liquid-water measurement and its electrical output must be confirmed with the supplier or its datasheet before integration. The turbidity sensor estimates cloudiness caused by suspended particles, and the TDS sensor estimates the concentration of dissolved solids, commonly displayed in ppm. The temperature sensor records water temperature, which can help interpret some sensor readings, and a float switch or suitable level sensor detects the clean-water tank level.

The ESP32 collects the sensor readings and manages the control logic. A relay module may switch the pump and UV load, but the relay contacts and driver circuit must be rated for the actual voltage, current and switching characteristics of each device.

D. Blynk IoT Dashboard

The ESP32 uses Wi-Fi to send readings to Blynk [5]. The dashboard can show the latest pH, turbidity, TDS and temperature values along with the tank-level state. It is intended for observation and demonstration, and sensor values should be calibrated and labelled with units so that the displayed information is meaningful.

VI. WORKING METHODOLOGY

Solar energy is collected by the panel and supplied to the compatible charge controller, which charges the 12 V battery according to the battery's charging requirements.

The battery supplies the electronics through the 12 V-to-5 V buck converter. Separate protected power wiring is provided for the pump and UV unit according to their rated requirements.

When the system is enabled and water is available, the pump moves raw water through the sediment filter, CTO carbon filter and UV chamber in the specified order.

The sensors take measurements from the selected sampling point. The pH, turbidity, TDS and temperature readings are acquired by the ESP32, while the tank-level sensor reports the clean-water tank condition.

The ESP32 processes the sensor values and prepares them for display. Basic range checks and sensor-fault handling can be added so that missing or invalid readings are not presented as valid measurements.

The ESP32 connects to Wi-Fi and updates the Blynk dashboard, so the user can view the latest readings and tank-level status remotely when the network connection is available.

The operator checks the filter condition, sensor calibration, battery state and UV operating condition during testing. Filter cartridges and the UV lamp are maintained according to their manufacturers' service guidance.

VII. EXPECTED RESULTS

The completed prototype is expected to demonstrate a working three-stage water-treatment path in which raw water passes through a sediment cartridge, an activated carbon block cartridge and a UV-C chamber before entering a clean-water storage tank. The arrangement is expected to reduce visible suspended particles and improve some taste- and odour-related characteristics, while the UV stage provides a final microbial-treatment step when operated under its specified conditions.

The ESP32 is expected to acquire readings from the pH meter, turbidity sensor, TDS sensor and temperature sensor, together with the water-level status. These values are expected to appear on the Blynk dashboard over Wi-Fi, allowing the operator to observe the system remotely. The solar charging section is expected to demonstrate charging of the 12 V battery and regulated supply to the low-voltage electronics.

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During testing, the project should produce a record of sensor readings before and after treatment where appropriate. These readings can be used to observe changes in turbidity and other measured parameters. The project should also demonstrate whether the selected battery and 3 W panel can support the intended demonstration cycle. If the pump and UV unit consume more energy than the panel can replenish, the limitation should be recorded and a larger panel or separate power source considered.

VIII. CONCLUSION

This project brings together a compact water-treatment arrangement, renewable-energy demonstration, embedded sensing and IoT monitoring in one prototype. Its value lies in making the treatment sequence and selected water-quality measurements visible to the user, rather than relying only on the appearance of the water. The ESP32 and Blynk dashboard provide a convenient way to observe the operating condition, while the solar-battery arrangement introduces practical considerations about energy storage and load management.

The prototype will provide a useful platform for learning how filtration stages, sensors, microcontroller interfaces and remote monitoring work together. Careful calibration, electrical protection and water-quality validation will be essential when evaluating its actual performance.

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