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Solar-Powered-Based Water Quality Monitoring System Using ESP32

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Abstract: *In this paper, a solar-based water quality monitoring and filtration system has been proposed. The system works automatically without any human intervention and is based on ESP32 technology. It monitors water quality by utilizing various sensors such as pH, TDS, turbidity, water temperature, and water level sensors. To ensure that there is no interruption in monitoring, a solar panel with battery backup is incorporated into the system. The water quality is determined on the basis of comparison of monitored parameters with predetermined safety limits. In case the water quality is found to be poor, automatic filtration takes place to enhance the water quality.*
Keywords: Solar Energy, Water Quality Monitoring, ESP32, Sensors, Filtration System, IoT, pH Sensor, TDS Sensor, Turbidity Sensor

Introduction

Water isn't just important—it's absolutely vital for people, farming, and industry alike. But with more factories dumping waste, farms sending runoff into rivers, and trash piling up in the wrong places, keeping our water clean has become a real challenge. Bad water can cause all sorts of health problems and mess with the environment, so regular monitoring isn't just a good idea—it's a must.

The thing is, the old-school way of testing water? It's slow, hands-on, and pretty much useless if you want updates in real-time. That's a big problem, especially in far-off communities that can't afford delays.

That's where this project comes in: a solar-powered water quality monitoring and filtration system. It's built around an ESP32 microcontroller and packs in sensors that keep an eye on pH, TDS, turbidity, temperature, and water level. The system checks these readings against safety standards, so you know if your water is safe or not.

If it turns out the water isn't up to scratch, the system automatically kicks on a filtration unit to clean things up. Thanks to solar power, the whole thing runs smoothly and doesn't guzzle electricity. Bottom line: this setup gives you reliable, around-the-clock water monitoring and filtration without breaking the bank. It's a practical fix for safer water, where it's needed most .

LiteratureReview

Researchers have been looking into water quality and ways to use alternative water sources in construction for a while now. Back in 2008, K. Nirmalkumar and V. Sivkumar tried using recycled wastewater in concrete and found that, as long as the water's treated, it doesn't really mess with the concrete's strength all that much.

R. A. Taha and his team (2010), who worked with brackish and production water. They looked at things like pH and TDS, tracked how strong the concrete turned out, and discovered you can use these non-fresh waters safely—as long as they stay within set limits.

M. Silva and **T. R. Naik** also jumped in, testing reclaimed wastewater in 2010. Their results showed the concrete's compressive strength actually improved over time if you stick to controlled conditions.

A few years later, in 2014, V. P. Kulkarni and colleagues checked out domestic wastewater and noticed the compressive strength changed based on the quality of the water they used.

R. A. More and **S. K. Dubey** followed up in the same year, comparing different water types and their impact on concrete. They agreed: most sources work just fine as long as you stay within the standards.

A. Kansal and his team (2007) looked at how to manage power in sensor networks that run on energy harvesting, stressing how crucial it is to use energy wisely when you're working with renewables like solar power.

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C. M. Vigorito and colleagues (2007) came up with adaptive control methods for wireless sensor networks that harvest energy. Their work pushes the idea that systems need to adjust on the fly, depending on how much energy they actually have.
Later on, **R. K. Kodali** and **L. Boppana** (2016) built a water quality monitoring setup for the IoT that uses sensors and wireless tech. Their system showed that, with embedded electronics, you can keep tabs on water quality in real time and do it efficiently.
All of this points to one thing—water quality really matters when it comes to safety and usability in construction. The catch is, most systems out there still focus on old-school analysis and batch testing. What's missing is a way to keep an eye on water quality all the time, and not just check after the fact. That's where the proposed system steps in.
It brings together real-time monitoring and an automatic filtration setup, so if something goes wrong, the system reacts rightaway.

ResearchGap

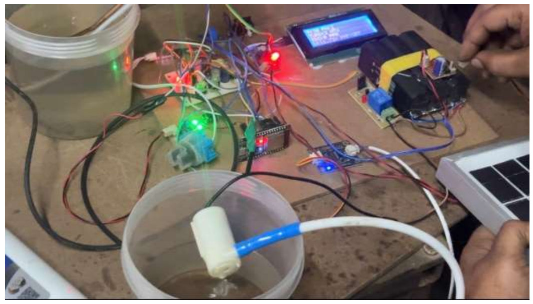
Most systems you'll find just stick to tracking water quality with sensors—like pH meters, TDS, or turbidity gauges. Some throw in IoT tech for real-time updates, and a handful run on solar power if they're meant for remote spots. But honestly, they usually just measure and show the data. That's it.
Hardly any of these setups actually do something about unsafe water when they spot it. If the water's bad, people still have to step in and fix things manually, which slows everything down and just isn't efficient.
On top of that, it's rare to see systems that mix energy-saving features with real-time automatic action. So, what's missing is a system that not only watches water quality nonstop but also steps in and fixes the problem automatically.
That's why there's a real need for something that brings together real-time monitoring and automatic filtration, especially with solar power in the mix. The system we're proposing covers this gap—it doesn't just spot unsafe water, it fixes it, and keeps things efficient and sustainable.

Methodology

The methodology of the proposed system is carried out through the following steps:

1. Design of a solar-powered system using a solar panel, charge controller, and rechargeable battery to ensure continuous and energy-efficient operation.
2. Selection of appropriate water quality sensors such as pH sensor, TDS sensor, turbidity sensor, temperature sensor, and water level sensor for measuring different parameters.
3. Interfacing of all sensors with the ESP32 microcontroller to enable real-time data acquisition.
4. Continuous collection of sensor data from the water source and transmission of values to the controller.
5. Calibration of sensor readings to ensure accurate measurement of water quality parameters.
6. Comparison of measured sensor values with predefined standard safe limits for each parameter.
7. Identification and classification of water as safe or unsafe based on threshold values.
8. Automatic activation of the filtration system when any parameter exceeds the safe limit.
9. Continuous monitoring of water quality even after filtration to ensure improvement in water condition.
10. Display of water quality status using indicators or display modules for user awareness.
11. Efficient utilization of solar energy to reduce power consumption and enable operation in remote areas.
12. Repetition of the entire process continuously for real-time monitoring and automatic control.

Result & Discussion



1. **Sensor Readings**
The system successfully measures water quality parameters such as pH, TDS, turbidity, temperature, and water level. The readings are obtained continuously and are stable under normal conditions.
2. **Water Quality Detection**
The measured values are compared with predefined safe limits. Based on this comparison, the system is able to accurately identify whether the water is safe or unsafe.
3. **Filtration Activation**
4. When the water quality parameters exceed the safe limits, the system automatically activates the filtration unit. This reduces the need for manual intervention.
5. **Performance of Filtration**
After filtration, the water quality parameters show improvement and move closer to safe limits, indicating effective operation of the filtration system.
6. **Real-Time Monitoring**
The system continuously monitors water conditions and updates the status in real time. This ensures immediate detection of unsafe water conditions.
7. **Power Efficiency**
The use of solar energy ensures continuous operation with reduced dependency on external power sources. The system works effectively even in low-power conditions.
8. **System Reliability**
The integrated system of sensors, controller, and filtration unit operates reliably for continuous monitoring and control.
Overall, the results demonstrate that the proposed system is effective in monitoring water quality and automatically improving it through filtration, making it suitable for real-time andremoteaplications.

Conclusion

1. The proposed system successfully implements a solar-powered water quality monitoring and filtration solution for real-time applications.
2. The integration of sensors such as pH, TDS, turbidity, temperature, and water level enables accurate and continuous measurement of water quality parameters.
3. The ESP32 microcontroller effectively collects and processes sensor data, ensuring reliable system performance.
4. The system compares measured values with predefined safe limits to determine whether the water is safe or unsafe.
5. Automatic activation of the filtration unit when unsafe conditions are detected reduces manual intervention and improves system efficiency.
6. The filtration process helps in improving water quality by reducing impurities and bringing parameters closer to safe limits.
7. Continuous monitoring ensures real-time detection of water contamination and immediate response.

8. The use of solar energy makes the system energy-efficient and suitable for remote and off-grid locations.
9. The inclusion of a rechargeable battery ensures uninterrupted operation even during low sunlight conditions.
10. The system provides real-time indication or display of water quality status, improving user awareness and decision-making.
11. The overall design is cost-effective, easy to implement, and scalable for different applications such as drinking water monitoring, agriculture, and water storage systems.
12. The proposed system overcomes the limitations of existing systems by not only monitoring water quality but also taking corrective action through automatic filtration.
13. The system contributes towards sustainable water management by combining renewable energy with automated monitoring and control.
14. The project demonstrates a practical and reliable approach for ensuring safe water availability in real-world conditions.

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