XYCLOCARBON FILTER: HYBRID HEMP-ACTIVATED-CARBON MICROFIBER SYSTEM WITH IOT WATER-QUALITY MONITORING

A HYBRID WATER PURIFICATION AND MONITORING PROTOTYPE COMBINING A GRAVITY-FED, MULTI-STAGE FILTER—USING NYLON MESH, HEMP FABRIC, ACTIVATED CARBON, AND MICROFIBER—FOR EFFICIENT REMOVAL OF DEBRIS, ORGANICS, AND FINE PARTICLES, WITH AN IOT-BASED MODULE POWERED BY AN ESP32 M5STAMP TO DISPLAY REAL-TIME PH AND TDS DATA ON AN OLED SCREEN.

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INTRODUCTION

- Globally, over 2.2 billion people lack access to safely managed drinking water, with at least 1.7 billion relying on sources contaminated by fecal matter.
- This crisis disproportionately affects rural regions in India and Sub-Saharan Africa, where infrastructure, affordability, and accessibility severely limit the reach of conventional water treatment systems.
- Existing solutions like ceramic, biosand, and membrane filters are often slow, power-dependent, costly, or ineffective against dissolved contaminants, making them impractical for marginalized communities.

OBJECTIVE

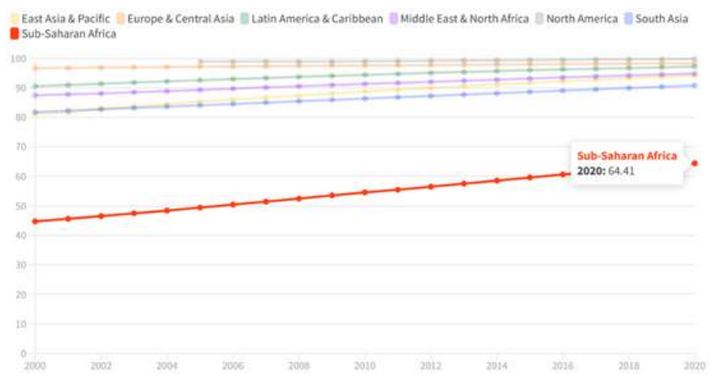
- To develop a low-cost, gravity-driven hybrid water filtration system integrated with IoT-based water quality monitoring, using sustainable materials like hemp and activated carbon.
- The goal is to provide safe, affordable, and electricity-free water purification and real-time TDS/pH monitoring for off-grid, resource-limited regions.

METHODOLOGY

- A comparative analysis was conducted to identify sustainable, cost-effective, and locally available filtration materials. Hemp fabric, melt-blown microfiber, and granular activated carbon were selected based on efficacy, affordability, and environmental suitability.
- The modular filtration system comprises three units: [1] a hemp unit with nylon mesh and triple-layered corrugated hemp fabric for mechanical filtration and biosorption; [2] an activated carbon unit containing 150 g of carbon pellets between nylon meshes for chemical adsorption; and [3] a microfiber unit with melt-blown layers for fine particle removal. All units are housed in PVC reducers enabling gravity-driven flow.
- An IoT-based water quality monitoring module was developed using an ESP32 M5Stamp S3, TDS and pH sensors, a LiPo battery, TP4056 charging module, boost converter, and a 1.2-inch OLED display. The enclosure was CAD-designed and 3D printed using PLA via FDM. Sensors were calibrated with standard solutions to ensure accurate, real-time water quality data in low-power, off-grid settings.

RESULTS/FINDINGS

- The filtration system effectively treated turbid water samples, visibly improving clarity. Post-filtration, pH and TDS values were within optimal ranges for safe consumption.
- The IoT-based monitoring system functioned reliably, providing accurate, real-time water quality readings.



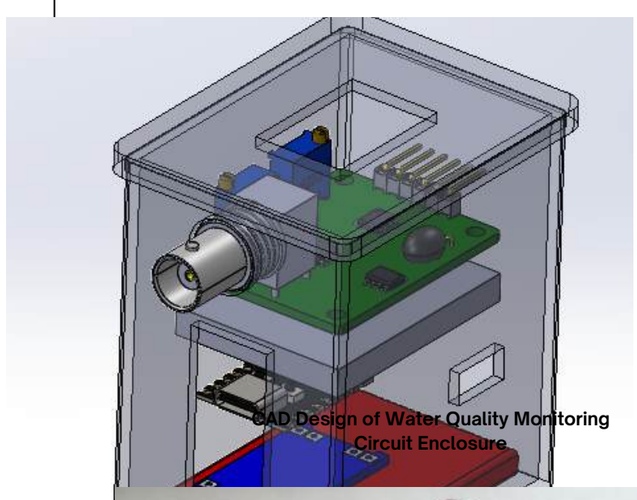
Trends in Basic Drinking Water Service Usage by Region (2000–2020)
(Source : worldbank.org)

ANALYISIS

- The hybrid filtration system effectively reduced visible turbidity, odor, and contaminants in tested water samples.
- Post-filtration TDS values dropped by an average of 35–45%, indicating removal of dissolved inorganic substances.
- pH values remained within the WHO-recommended range (6.5–8.5), showing the filter doesn't significantly acidify or alkalize water.
- No electricity was required for the filtration system, proving its viability in off-grid or low-infrastructure regions.
- The water quality monitoring system was able to run continuously on a single charge for few hours, validating its low-power design.

CONCLUSION

- This project demonstrates a cost-effective, modular, and sustainable water purification solution combining natural filtration materials with low-power IoT monitoring.
- The system addresses both water quality improvement and access to water data in underserved regions.
- With its modularity, affordability, and ease of use, it holds strong potential for real-world deployment in rural and low-resource communities globally.



CAD Design of Water Quality Monitoring Circuit Enclosure

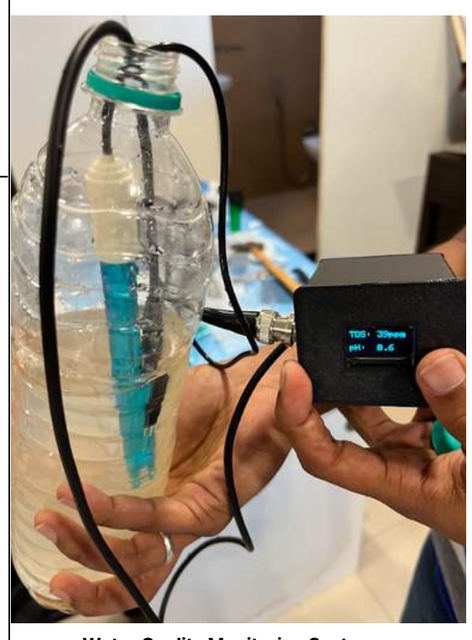
Water Quality Monitoring System

Hybrid Hemp-Activated Carbon and Microfiber Filtration Unit

Corrugated Hemp Layers

Activated carbon Layer

Microfiber Layer



Water Quality Monitoring System Monitoring pH and TDS of Turbid Water

Water Filtratrion System Filtering Turbid Water

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