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Solar Assisted Water Purification System Using IoT

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Abstract*: This study details the design and development of a solar-assisted, IoT-enabled water purification system utilizing monofilament woven fluorinated ethylene propylene filter pouches. The filter is fabricated as a porous pouch filled with activated carbon and is modularly stacked in a cylindrical filtration chamber. Water flows through this chamber using a twenty-four-volt pump, ensuring effective removal of physical and chemical impurities. To regulate the pH of the treated water, a post-filtration chamber with calcite and acidic ceramic media is employed, while ultraviolet light is applied to eliminate pathogenic microorganisms. The system operates entirely on solar energy, which enhances its off-grid applicability. A microcontroller-based IoT module, ESP32, monitors key parameters including pH, total dissolved solids, and flow rate, with values uploaded to a cloud server for remote tracking and data logging. Pre-filtration with a sediment filter removes coarse particles before the fluorinated ethylene propylene stage. The proposed system demonstrates high purification efficiency, low maintenance requirements, and adaptability for both household and community-level applications. It provides a sustainable, modular, and data-driven solution for decentralized water treatment, particularly in rural settings.

Keywords: Water purification, Fluorinated ethylene propylene, IoT monitoring, solar power, pH regulation, ultraviolet disinfection.

I. INTRODUCTION

Clean drinking water remains a fundamental necessity, yet over two billion people lack access to safely managed sources [1]. Traditional water purification methods, including reverse osmosis (RO,) chemical disinfection, and ion exchange, frequently encounter issues such as elevated costs, maintenance challenges, energy reliance, and chemical byproducts. In response, recent advancements have introduced environmentally resilient and sensor-integrated systems aimed at decentralized water treatment.

This paper proposes a multi-layered purification system utilizing monofilament woven fluorinated ethylene propylene (FEP) filter pouches, filled with activated carbon, to trap organic pollutants and reduce odor. These FEP pouches are modularly arranged in a cylindrical filtration chamber, enabling customizable scaling for various capacities. Post-filtration, the water passes through calcite and acidic ceramic beads, which work in combination to regulate pH levels. Finally, ultraviolet light disinfection ensures microbial safety.

Power is supplied by a solar photovoltaic panel, making the system energy-independent. An ESP32-based microcontroller is used to monitor pH, total dissolved salts (TDS,) and water flow, with data transmitted to the cloud for analysis. The system is prefaced by a sediment filter to eliminate coarse particles and reduce clogging risk.

This paper presents the overall system design, key materials used, component integration, and performance evaluation based on parameters such as purification efficiency, reliability, scalability, and energy consumption. This strategy not only endorses the United Nations Sustainable Development Goal 6, which focuses on clean water and sanitation, but also corresponds with Goal 7 by advocating for inexpensive and clean energy alternatives. By providing a sustainable, scalable solution to water purification, this study aims to address critical water quality challenges while enhancing access to safe drinking water in underserved communities.

II. LITERATURE SURVEY

To evaluate the feasibility and performance of monofilament woven FEP filters for water purification, various existing filtration and purification methods have been reviewed. The assessment focuses on five key parameters: cost, percentage purification, maintenance, reliability, and scalability is given in Table. I. Below are the major purification methods considered

A. Reverse Osmosis

Reverse osmosis is a recognized membrane separation process employed for desalination, industrial effluent concentration, and water reclamation. RO removes dissolved solids, organic contaminants, and microorganisms through a high-pressure membrane process. The system typically includes pretreatment, high pressure pumping, membrane modules, and post treatment stages. Common membrane materials include cellulose acetate and polyamide, configured in spiral wound or hollow fiber modules. Operating pressures generally range from 17 to 27 bar for brackish water and from

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52 to 69 bar for seawater. RO has been applied in areas such as distillery effluent treatment and potable water reuse. Pretreatment is a key determinant of long-term membrane performance, and the technology is valued for modularity and potential energy efficiency. However, earlier studies do not adequately address recent advancements in membrane materials, antifouling strategies, and energy recovery systems, which are crucial for sustainable operation [2].

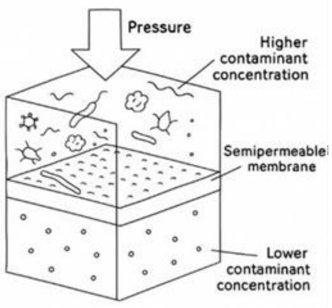

Fig. 1. Reverse Osmosis

B. Activated Carbon Filtration

Activated carbon filtration is a widely used adsorption method for removing suspended solids, organic compounds, and substances that cause taste and odor. Granular activated carbon (GAC) media, characterized by high surface area and a network of micro and mesopores, enables efficient contaminant removal through physical adsorption. Experiments with different GAC types in prototype water filters showed that greater surface area and favorable pore distribution produced larger reductions in turbidity, chemical oxygen demand (COD), total suspended solids and biochemical oxygen demand (BOD). When combined with ultraviolet (UV) disinfection, further reductions in COD and BOD were achieved, though turbidity and total suspended solids were not affected. These findings highlight the importance of selecting optimal GAC properties and the benefits of combining adsorption with disinfection in small scale water treatment systems [3].

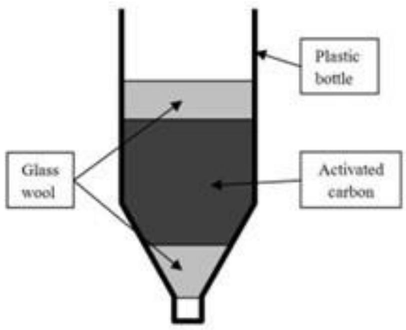

Fig. 2. Activated Carbon Filtration [3]

C. Ultrafiltration (UF)

Ultrafiltration is a pressure driven membrane process with pore sizes typically ranging from 0.001 to 0.1 micrometers and operating pressures between 0.1 and 0.8 MPa. It effectively removes suspended solids, colloids, bacteria, and many viruses, producing effluent turbidity values below 0.1 NTU. UF is compact, energy efficient, and suitable for automation, and it is used for drinking water purification, seawater desalination pretreatment, industrial wastewater treatment, and municipal water reuse. Hybrid processes such as powdered activated carbon combined with UF, coagulation combined with UF, and UF followed by RO improve dissolved organic matter removal and reduce membrane fouling. Nevertheless, fouling and lifecycle costs remain important challenges that require further research [4].

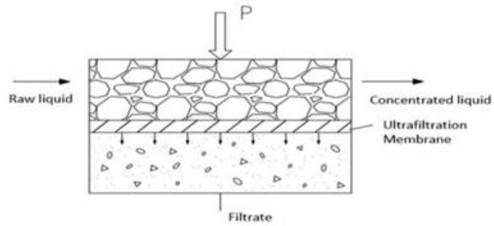

Fig. 3. Ultrafiltration [4]

D. Ceramic Filtration

Ceramic water filters are a sustainable point of use solution made using locally available clay and combustible materials. They provide effective turbidity reduction and significant bacterial removal through depth filtration and, when impregnated with silver, additional microbial inactivation. Performance is influenced by raw material selection, combustible particle characteristics, and firing conditions, which together determine pore size distribution and hydraulic conductivity. Conventional ceramic water filters are effective for bacteria and particulates but show limited virus removal and poor removal of dissolved chemical pollutants unless modified. Recent research indicates that surface modifications using compounds such as magnesium oxide, lanthanum, or zirconium hydroxide can improve virus capture and arsenic removal. Modifying the pore network with fibrous additives can also enhance flow rates while maintaining microbial removal efficiency. Key research needs include pore scale characterization, long term field data, and assessment of coating durability and safety [5].

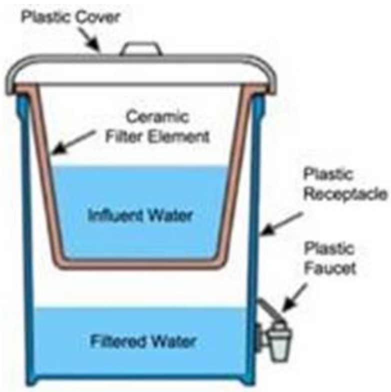

Fig. 4. Ceramic Filtration [9]

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E. *UV Purification*

Ultraviolet (UV) irradiation is a chemical free disinfection method that inactivates microorganisms by damaging their nucleic acids. The germicidal UV C band, which spans approximately 200 to 280 nm with peak effectiveness near 254 nm, is most effective. UV systems, which may use low pressure high output, or medium pressure lamps, are designed based on fluence, defined as intensity multiplied by exposure time. Performance depends strongly on reactor design and the optical properties of the water, such as turbidity and UV transmittance. UV disinfection provides rapid inactivation of bacteria, protozoan cysts, and many viruses, has a small physical footprint, and produces no chemical by products. However, it does not provide residual protection in distribution, is sensitive to particle shielding and lamp reliability, and requires validated fluence assessment for performance assurance. Current research focuses on fluence determination for polychromatic sources, development of reliable on-site verification methods, and the use of emerging UVC LED technologies [6].

Fig. 5. UV Purification [10]

F. *Monofilament Woven FEP Filters (Proposed Method)*

Fluorinated ethylene propylene (FEP), a perfluorinated copolymer, offers excellent chemical and thermal stability combined with strong hydrophobicity, making it attractive for harsh environment separations and membrane distillation applications. Recent fabrication techniques include electrospinning blends of FEP with polyvinyl alcohol followed by sintering, producing ultrafine fibrous porous membranes with tunable porosity, water contact angle of about 124 degrees, and entry pressures near 0.18 MPa. These membranes demonstrated vacuum membrane distillation fluxes of approximately 15.1 $L \cdot m^{-2} \cdot h^{-1}$ with salt rejection close to 98 percent. Alternatively, coatings of FEP and polytetrafluoroethylene foams applied to woven substrates create microporous, mechanically robust surfaces with tunable pore size and air permeability, showing superior abrasion resistance compared with expanded PTFE laminates. These fabrication strategies suggest two approaches for woven FEP membranes: coating FEP foam onto a woven substrate to produce a durable porous surface, or electrospinning FEP fibers onto a woven support followed by sintering to create submicron pores with high hydrophobicity. Critical research needs include controlling pore size for liquid phase filtration, demonstrating resistance to wetting under hydraulic loads, and assessing fouling and long-term water purification performance. Performance [7].

III. FEP AS A FILTER MATERIAL

Fluorinated ethylene propylene (FEP) is a melt-processable fluoropolymer that combines chemical inertness, hydrophobicity, and mechanical durability. Unlike conventional filter polymers such as polyester or polypropylene, FEP does not undergo hydrolysis or leach additives under operating conditions, ensuring long-term chemical stability in water treatment environments. These attributes make it suitable as a structural and functional medium in advanced filtration assemblies.

A. *Comparison with Existing Techniques*

Traditional media such as polyester and polypropylene are more economical and easier to process, making them preferred for large-scale commercial filters. However, their susceptibility to chemical degradation and limited tolerance to aggressive cleaning shorten service life. FEP, although more expensive, offsets these drawbacks with extended durability, stability under harsh conditions, and the ability to undergo repeated cleaning cycles. Thus, while polyester is suited for cost-sensitive mass use, FEP offers advantages in specialized systems where reliability and long operating intervals are essential.

B. *FEP Filament Process and Pore Size*

Recent research demonstrates that ultrafine FEP porous membranes can be fabricated using an electrospinning–sintering approach with a sacrificial carrier polymer. By adjusting sintering temperature and blend ratio, pore sizes can be tuned within the micron range. Studies report distributions between 0.5 and 5 μm at lower sintering conditions, narrowing as temperature increases. Membranes produced at 300 °C achieved porosity of approximately 62.7%, hydrophobicity with a water contact angle near 124°, and a liquid entry pressure of approximately 0.18 MPa, confirming that FEP can be engineered to balance permeability with mechanical integrity.

TABLE I. COMPARISON BETWEEN WATER PURIFICATION METHODS

Parameters	*Reverse Osmosis*	*Ultrafiltration*	*Activated Carbon*	*Ceramic Filtration*	*UV Purification*	*Monofilament Woven FEP*
Cost	High	Moderate	Low	Low	Moderate	Moderate - High
Purification Efficiency	95-99 %	90-95 %	70-85 %	85- 95 %	90-95 %	95-98 %
Maintenance	High	Moderate	Low	Low	Low	Low - Moderate
Reliability	High	Medium - High	Medium	Medium	High	High
Scalability	Medium	Medium	High	Low - Medium	Medium	High

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C. Design Proceedings

In the present work, woven monofilament FEP is fabricated into pouch-shaped enclosures filled with granular activated carbon (GAC). These pouches are vertically stacked within a cylindrical housing to form a modular filtration unit. The woven FEP layer provides structural containment while engineered pore sizes in the range of 1–5 µm hold the GAC securely and allow water to pass through confined flow paths. This arrangement maintains contact between water and the carbon while regulating flow under hydrostatic pressure, thereby enhancing removal of impurities.

Fig. 6. Stacked FEP Filter

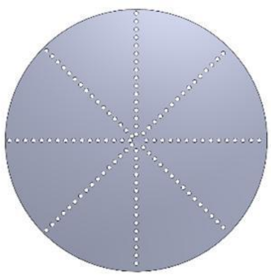

Fig. 7. FEP Pouch

The combined FEP–GAC system delivers dual performance: adsorption of organics, taste, and odor by GAC, and fine particle retention by the FEP structure. Compared with conventional filters, the system achieves equivalent cleaning efficiency with a modest reduction in fine particulate capture but with the added benefits of chemical stability, longer service life, and reduced maintenance requirements. The modular design allows straightforward replacement of individual pouches, improving scalability and operational efficiency. In this way, FEP serves as both a durable structural layer and an active contributor to consistent filtration performance.

IV. SYSTEM DESIGN

The complete system is organized as three tightly coupled subsystems: the Purification Subsystem, the Solar Power Subsystem and the IoT Monitoring Subsystem. Water enters the system through a controlled inlet and is first measured by a flow meter that provides a pulse or digital output to the controller for volumetric accounting and flow regulation. A primary sediment stage immediately downstream protects downstream elements by removing coarse suspended solids. The core purification stage comprises vertically stacked pouches made from woven monofilament FEP that contain GAC. These pouches act as containment and flow-regulating elements: their engineered microporosity (tunable in the 1–5 µm range) secures the GAC and produces confined flow paths driven by available hydrostatic head or a low-power delivery pump. A downstream pH/TDS correction chamber containing calcite and ceramic polishing media adjusts mineral balance and performs additional mechanical/microbial polishing. The final treatment step is UV disinfection housed in a dedicated chamber sized to meet the residence time required for the target UV dose. Valves and a bypass line are provided to allow isolation of modules during maintenance and to permit a backwash path where required.

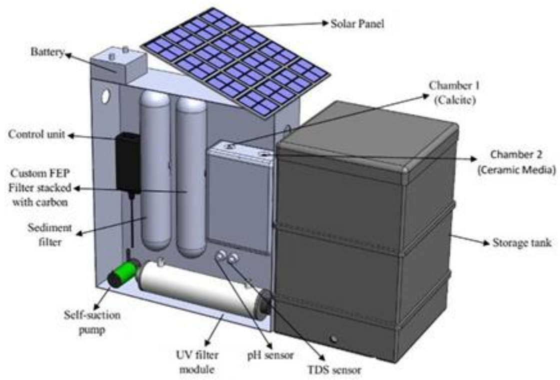

Fig. 8. System Design

A. Purification Subsystem

Raw water is routed through a primary sediment cartridge followed by a modular array of woven FEP pouches filled with GAC. The pouches retain carbon and provide fine containment; downstream, a calcite/ceramic media chamber conditions pH and polishes particulates. A UV chamber provides final disinfection. Solenoid valves at the inlet, correction chamber and storage outlet permit automatic isolation for maintenance or on fault conditions. Sensors (flow, pH, TDS, level) are used to trigger control logic such as initiating the correction stage, disabling pumps on a full tank, or issuing fault messages when flow is absent.

1) Calculation of Flow Rate:

Example: The system purifies 40 liters a day.

$$= \frac{\text{Water purified per day}}{\text{24 hours}}$$

$$= \frac{40}{\text{24 hours}}$$

$$= \frac{\text{2 litre}}{\text{hour}}$$

B. IoT or Control Subsystem

A central microcontroller reads the flow sensor, pH probe, TDS sensor and the storage-level sensor, executes control logic, and actuates solenoid valves, pump relay and UV relay. The controller issues a diagnostic alert when the flow sensor indicates no flow during expected pumping. Data are transmitted to a cloud dashboard for remote monitoring and maintenance scheduling. Local alarms and status indicators

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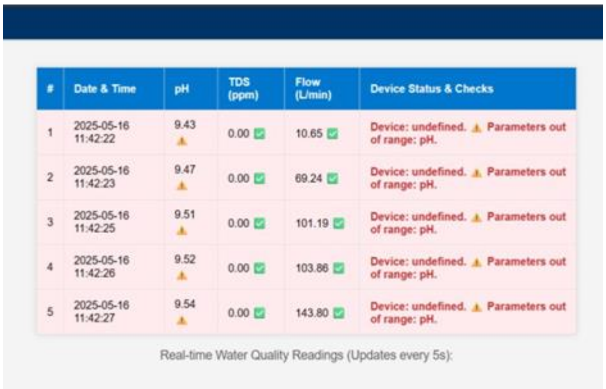
provide immediate on-site feedback [11].



#	Date & Time	pH	TDS (ppm)	Flow (L/min)	Device Status & Checks
1	2025-05-16 11:42:22	9.43	0.00	10.65	Device: undefined. Parameters out of range: pH.
2	2025-05-16 11:42:23	9.47	0.00	69.24	Device: undefined. Parameters out of range: pH.
3	2025-05-16 11:42:25	9.51	0.00	101.19	Device: undefined. Parameters out of range: pH.
4	2025-05-16 11:42:26	9.52	0.00	103.86	Device: undefined. Parameters out of range: pH.
5	2025-05-16 11:42:27	9.54	0.00	143.80	Device: undefined. Parameters out of range: pH.

Real-time Water Quality Readings (Updates every 5s):

Fig. 9. Cloud Monitoring and Data Logging

C. Solar Power Subsystem

The solar power subsystem employs a 200 W, 24 V photovoltaic module coupled with a 24 V, 20 Ah battery pack to provide a sustainable and uninterrupted power source for the purification unit. The battery offers an effective storage capacity of 480 Wh, which is sufficient to operate the pump and control electronics required to maintain a flow rate of 2 L/min, even during periods of low solar irradiance or night-time operation. The solar panel can recharge the battery within 4–5 hours of peak sunlight, ensuring daily autonomy and continuous functionality of the system. By integrating solar energy harvesting with efficient storage, the subsystem not only meets the operational energy demand but also enhances the sustainability of the purification setup by minimizing reliance on grid electricity and reducing environmental impac*t.*

V. Conclusion

The proposed water purification system integrates fluorinated ethylene propylene as a woven containment medium with granular activated carbon, demonstrating its potential as a durable and chemically inert material for advanced filtration. When combined with conventional treatment stages including sediment removal, pH and total dissolved solids correction, and ultraviolet disinfection, the system ensures comprehensive removal of physical, chemical, and biological contaminants. The incorporation of solar power provides complete energy independence, while the IoT subsystem enables real-time monitoring, automated control, and predictive fault detection, thereby improving reliability and user accessibility.

Although fluorinated ethylene propylene involves a higher initial material cost compared with traditional filter media, its long-term durability, resistance to degradation, and compatibility with modular architectures offer advantages in terms of lifecycle, serviceability, and maintenance. Power and battery evaluations confirm that the system can be operated sustainably using compact photovoltaic arrays and appropriately sized energy storage units, supporting deployment in both grid-independent and resource- constrained environments. Overall, the integration of fluorinated ethylene propylene with solar and IoT technologies establishes a scalable and efficient approach to safe water provision, contributing to sustainable development objectives.

REFERENCES

[1] WHO, "Drinking-water," World Health Organization, 2022. [Online]. Available :https://www.who.int/news-room/fact- sheets/detail/drinking-water.

[2] M, Garud & Kore, Sunanda & S, Kore & S, Kulkarni. (2011). A Short Review on Process and Applications of Reverse Osmosis. Universal Journal of Environmental Research and Technology2249 0256. 1. 233-238.

[3] Siong, Y. & Atabaki, Mehdi & Idris, Jamaliah. (2013). Performance of activated carbon in water filters. Water Resources.

[4] Li, Xiangmin & Jiang, Lei & Li, Haixiang. (2018). Application of Ultrafiltration Technology in Water Treatment. IOP Conference Series: Earth and Environmental Science. 186. 012009. 10.1088/1755-1315/186/3/012009.

[5] Yang, Haiyan & Xu, Shangping & Chitwood, Derek & Wang, Yin. (2020). Ceramic water filter for point-of-use water treatment in developing countries: Principles, challenges and opportunities. Frontiers of Environmental Science & Engineering. 14. 10.1007/s11783-020-1254-9.

[6] Ashok, Abhijeet & Khedikar, Isha. (2016). Overview of Water Disinfection by UV Technology -A Review. 10.13140/RG.2.2.30976.25608.

[7] K. Chen, H. Ling, H. Liu, W. Zhao, and C. Xiao, 'Design of Robust FEP Porous Ultrafiltration Membranes by Electrospinning-Sintered Technology', Polymers, vol. 14, no. 18, 2022.

[8] Chen, Miaomiao & Zhang, Yue & Wu, HaiBo & Liu, Li & Wang, Hong. (2022). A study on fluorinated ethylene propylene/polytetrafluoroethylene foam coating composite as potential flue gas filtration materials. Journal of Industrial Textiles. 51. 152808372091137. 10.1177/1528083720911374.

[9] McBean, Edward & Huang, G. & Li, Yongping & Li, Yanfeng & Yang, Aili & Fu, Haiyan. (2018). Ceramic Water Filters as a Response Technology to Geo-Hazards. The Global Environmental Engineers. 5. 1-8. 10.15377/2410-3624.2018.05.1.

[10] Parveen, Saima & Malviya, Arti. (2022). Analytical Review on Membrane Water Filter using Different Materials to Prevent Microbial Activities. Journal of Pure and Applied Microbiology. 16. 10.22207/JPAM.16.4.68.

[11] Forhad, H., Uddin, M., Chakrovorty, R., Ruhul, A., Faruk, H., Kamruzzaman, S., Sharmin, N., Jamal, A., Haque, M., & Morshed, A. (2024). IoT based real-time water quality monitoring system in water treatment plants (WTPs) (p. 10). Heliyon.