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Automated Solar-Hydro-Powered Oil-Water Emulsion Treatment for Sustainable Irrigation: A Dual-Stage Membrane and Air Diffuser Approach

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ISE · CHE · 3 · ME

Introduction & Background

Problem statement

An automated solar/wind-powered system converts diesel oil–water emulsions into irrigation-quality water with low energy consumption.

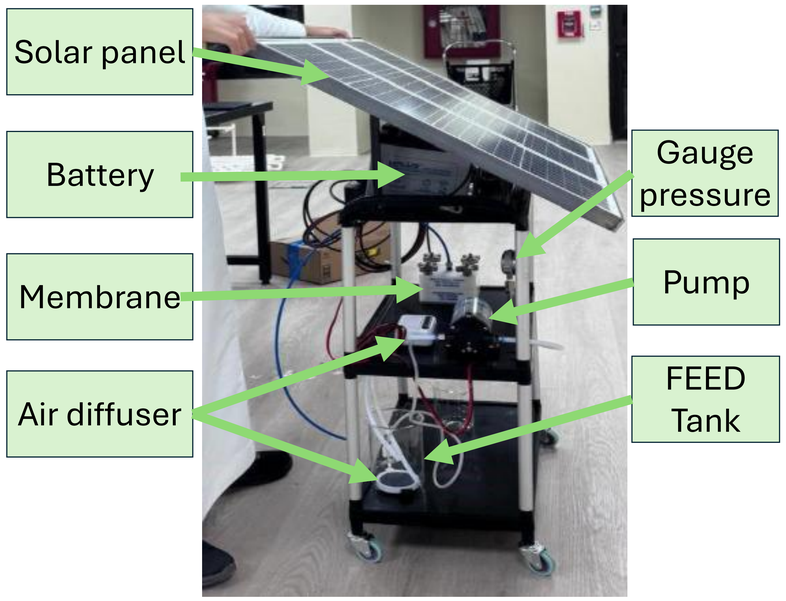
Constraints

100% solar + wind + battery (no fossil reliance)
Footprint ≤ 2 m²
Initial cost ≤ SR 10,000
Monthly OPEX ≤ SR 100
90% recovery from treated emulsion
Servicing interval ≥ 1 month

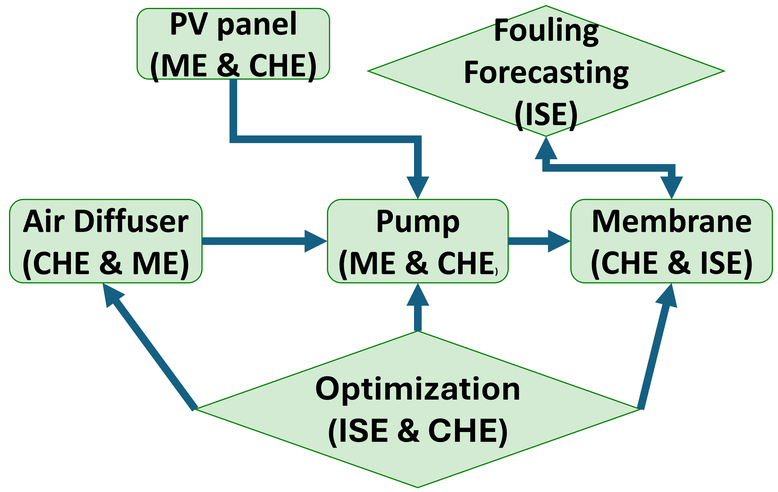
Specifications

System footprint ≤ 2.0 m × 1.0 m	Effective treatment of organics up to C_6
Centrifugal pump ≥ 0.5 m³/h @ 1–2 bar ΔP	Pump flow ≥ 50 L/h, energy ≤ 1.5 kWh/day (20–35 °C, 1 atm)
≥ 60% automated operation & level control	≥ 90% hydrocarbon removal with automated flow, temperature, and membrane control.
≥ 90% removal efficiency	Achieve TDS ≤ 2000 mg/L and oil ≤ 25 mg/L via membrane–air diffuser treatment.
The permeate quality must meet ≤ 2000 mg/L TDS and ≤ 25 mg/L oil.	≥ 80% energy recovery using integrated turbine–pump system.

Prototype Design



Final Design Block Diagram



Testing & Validation

T(min)	Q(ml/s)	Cpermate (mg/l)	removal effecincy
15.000	168.000	1.953	0.980
30.000	80.000	1.533	0.985
45.000	50.667	1.267	0.987
60.000	36.000	1.053	0.989
75.000	27.200	1.033	0.990
90.000	21.333	1.000	0.990
105.000	17.143	0.967	0.990
120.000	14.000	0.933	0.991

Conclusion

The Automated Solar-Hydro-Powered Oil–Water Emulsion Treatment System provides a compact, off-grid solution for produced-water reuse. The air-diffuser plus ceramic membrane stages remove >90% of hydrocarbons and deliver irrigation-quality water with >90% recovery. Energy use stays below 1.5 kWh/day with ~80% energy recovery, showing a scalable, fossil-free approach for treating produced water in remote areas.