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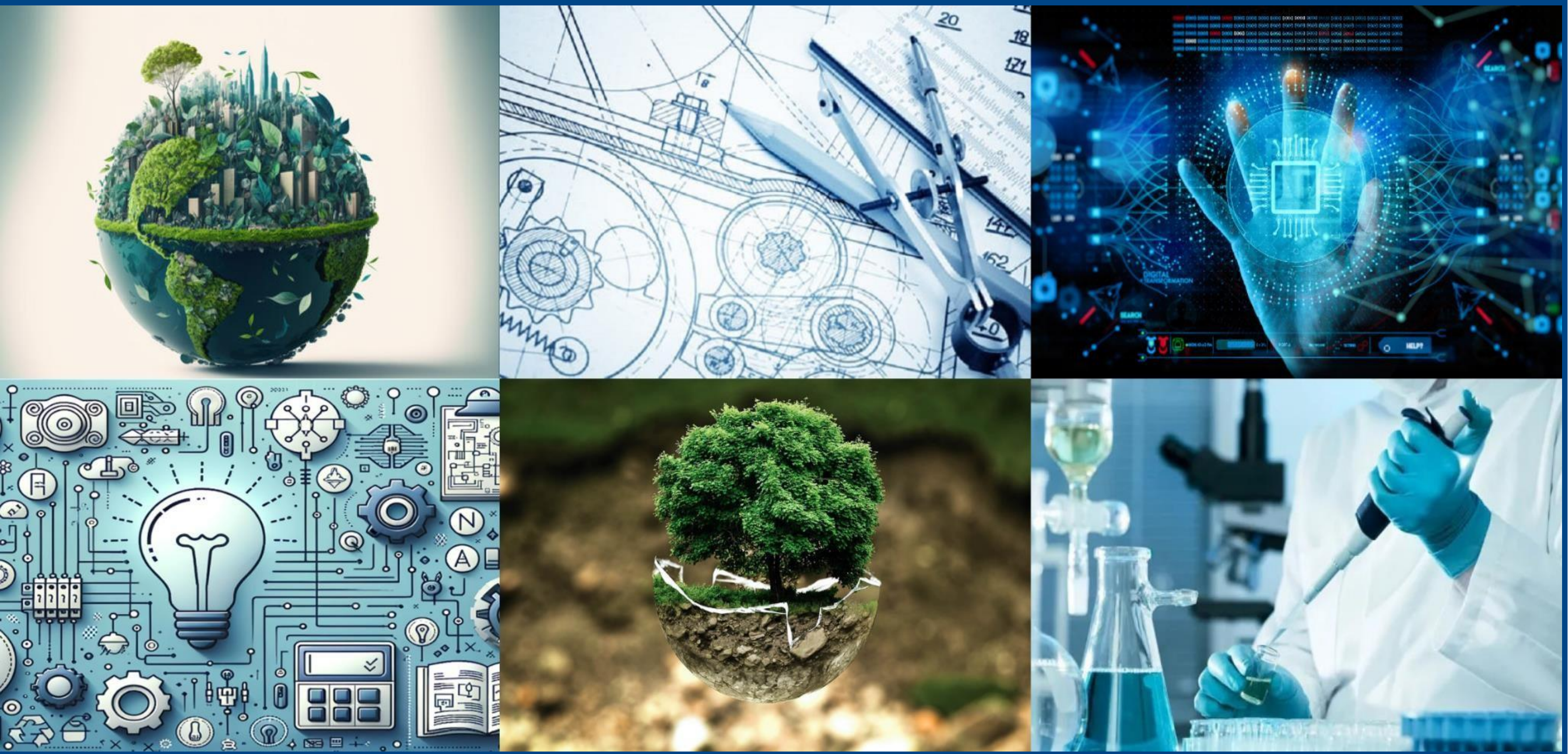

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Organized by

Mookambigai College of Engineering, Keeranur, Tamil Nadu, India

Sustainable Floating Desalination Unit Powered By Waves for Disaster-Prone Shores

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ABSTRACT

Coastal communities globally experience life-threatening water shortages during disasters when infrastructure is compromised and power grids go down. Traditional desalination plants shut down exactly when they are required. This project creates a sustainable floating desalination unit that uses ocean wave energy to generate safe drinking water without any electricity, an independent water source desperately needed in emergencies.

It merges wave-powered mechanical pressure generation with reverse osmosis desalination technology into one portable platform. An oscillating flap in the surface acts on a pump connected to a hydraulic intensifier that produces the high pressure required for seawater desalination. This feeds a validated industrial-grade reverse osmosis membrane that filters out salts, bacteria, viruses and contaminants — turning seawater into fresh drinking water that meets World Health Organization standards.

On a daily basis, the unit generates sufficient fresh water to supply a small community in an emergency situation, operating around the clock so long as waves persist. Multi-stage filtration preserves the system parts and post-treatment chlorination ensures total microbiological security. Our preference for portability and simplicity allows emergency response teams to quickly deploy it without specialized technical knowledge.

The system releases brine at levels far less concentrated than traditional desalination plants, reducing environmental harm. Through renewable, grid-agnostic freshwater production, it tackles water security for hundreds of millions of people living in disaster-prone coastal areas where climate change is increasingly imperiling conventional sources of water.

I. INTRODUCTION

Water is one of the most precious natural resources, but becomes dangerously scarce in times of disaster such as floods, tsunamis and coastal emergencies. In such cases, power outages frequently impact traditional water purification and delivery networks, depriving communities of safe drinking water.

This project proposes a sustainable desalination system that utilizes ocean wave energy to power RO desalination without any electricity. The system utilizes mechanical generated pressure from wave motion to operate reverse osmosis desalination, providing fresh, potable water even when the infrastructure is down.

Built for quick response in emergency situations, the unit is mobile and can be set up by laymen. and then debris filtration proceeds to wave powered pumping that pressurizes seawater through RO membranes that filter out salts, bacteria and chemical contaminants. A last chlorination step kills any remaining pathogens – making it WHO drinking water safe.

By coupling renewable wave energy with proven desalination and disinfection technologies, this innovation offers dependable, autonomous freshwater for coastal communities–especially in the moments when large-scale infrastructure and fuel supplies are compromised.

1.1 SCOPE

- Modular off-grid and sustainable desalination system for emergency usage.
- Portable and easily assembled by non-technical persons.
- Production of potable water for immediate requirement.
- Design and develop modular floating desalination system utilizing wave energy.
- Off-grid, energy-efficient operation harnessing wave power as clean and reliable source.
- Minimize dependence on conventional electricity and reduce environmental impact.

II. DESIGN SPECIFICATIONS AND COMPONENTS

2.1 Wave Energy Converter Assembly

The primary energy capture mechanism is a hinged wave flap assembly, designed to harness oscillating wave motion converting it into hydraulic energy. Key design considerations centered on durability, corrosion resistance, and ease of local manufacture. The assembly is fabricated from mild steel with an epoxy coating to withstand marine environments.

Specifications:

- Dimensions: 1200 mm length × 400 mm width × 1000 mm height
- Submerged depth: 1000 mm to optimize wave capture
- Manufacture: Welded frame assembly using TIG/MIG welding suitable for standard workshops
- Wave frequency synchronization: 0.125 Hz (7.5 cycles/min)

2.2 Reciprocating Pump System

Mechanical linear motion of the wave flap is converted to hydraulic fluid flow via a reciprocating pump. Emphasis was placed on precision machining to ensure reliability and efficiency in irregular wave conditions.

Specifications:

- Cylinder bore diameter: 50 mm with lathe boring accuracy of ±0.2 mm
- Stroke length: 200 mm
- Material: Mild steel coated with hard chrome plating for wear resistance, available via local suppliers
- Operating frequency aligned with wave motion (0.125 Hz)

2.3 Hydraulic Intensifier System

Achieving the high pressures necessary for seawater reverse osmosis requires pressure intensification. The intensifier employs differential piston sizes to multiply hydraulic pressure mechanically.

Specifications:

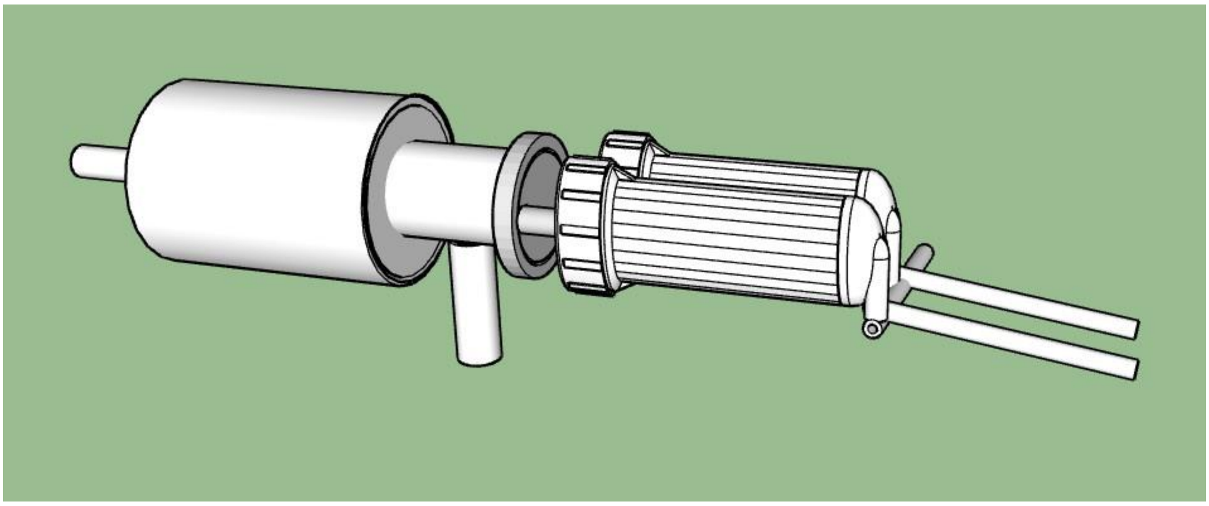
- Low-pressure piston diameter: 120 mm (machined to ±0.2 mm tolerance)
- High-pressure piston diameter: 50 mm
- Intensification ratio: approximately 6:1, obtained through geometric area ratios
- Operating pressure target: 60 bar (6.0 MPa), suitable for seawater RO membranes
- Stroke length: 150 mm

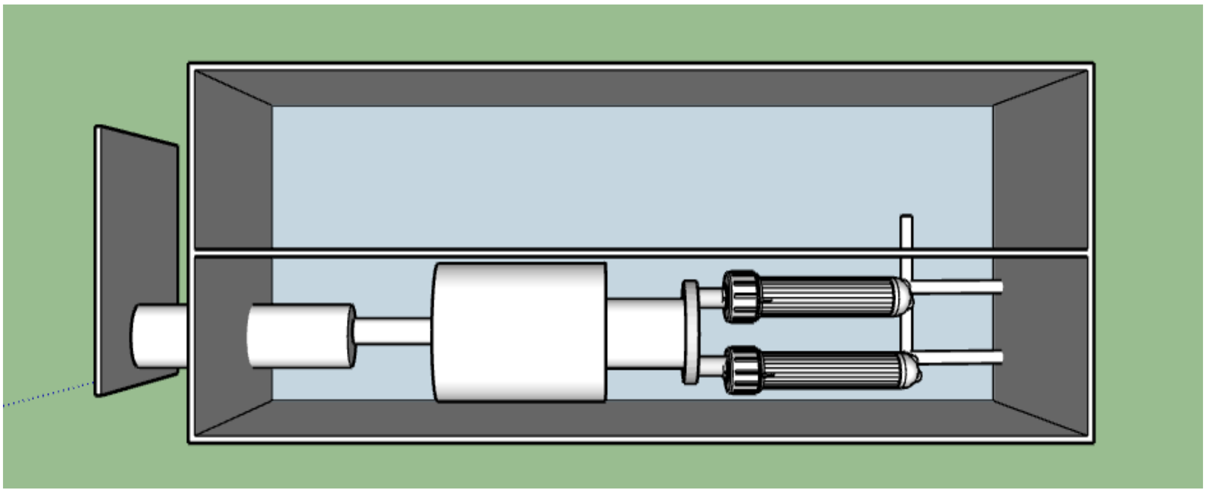
2.4 Reverse Osmosis Membrane Unit

The QuenchSea RO membrane unit uses an advanced industrial reverse osmosis membrane specifically designed for seawater desalination with a triple pre-filtration system to ensure extended membrane lifespan and high water quality.

- **Operating Pressure:** Hydraulic system internally builds pressure up to **55-60 bar** to initiate reverse osmosis effectively.
- **Membrane Capacity:** Produces approximately 6 liters per hour (144 liters/day) under ideal conditions, suitable for 10-15 persons.
- **Triple Pre-Filtration:** Includes ultrafiltration (removing particles as small as 0.01 microns), microfiltration, and an activated carbon filter to remove suspended solids, bacteria, viruses, microplastics, and improve taste.
- **Salt Rejection:** Efficiently removes salts and contaminants to achieve potable water with Total Dissolved Solids (TDS) below 1000 mg/L, with post-polishing potentially reducing TDS to 50–100 mg/L, fully compliant with WHO standards.
- **Membrane Lifespan:** Dependent on feed water quality; triple filtration and pretreatment extended life up to 3-5 years typical, reducing fouling risk.
- **Operational Notes:** Manual or hydraulic pumping drives the system; includes easily replaceable cartridges for filters and membranes.

IV. 3D REPRESENTATION





V. MULTI-STAGE PRETREATMENT AND FILTRATION

The integrated triple filtration system is designed to protect the membrane from fouling and maximize operational lifespan:

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1. **10 mm Stainless Steel Mesh:** Primary filter to capture large particles and debris, locally fabricated with stainless steel housing.
2. **50 Micron Cartridge Filter:** Secondary filtration for sand, silt, and organic matter using commercial-grade replaceable cartridges.
3. **0.01 Micron Ultrafiltration Membrane:** Tertiary barrier to remove bacteria, viruses, parasites, and microplastics, ensuring microbiologically safe feed for RO.

This triple filtration system distinguishes the QuenchSea membrane-based system from conventional single or double-stage pretreatment approaches, offering enhanced durability and consistent performance.

VI. SYSTEM PORTABILITY AND PERFORMANCE

The system is optimized for emergency response with portability and rapid deployment capabilities as primary goals.

- **Footprint:** 1200 mm × 400 mm to fit shipping and aerial transport constraints.
- **Weight:** Approximately 70 kg.
- **Modularity:** Designed for assembly/disassembly within 2 hours, facilitating fast redeployment.
- **Water output:** 148-168 liters per day under optimal wave conditions.
- **Seasonal availability:** Average output around 120–130 liters/day accounting for downtime.
- **System efficiency:** Estimated 65–75% conversion from wave energy input to potable water output.

VII. COMPARATIVE SYSTEM ANALYSIS

Metric	Conventional RO	Diesel-Powered RO	Solar RO	Wave-Powered Unit
Production (liters/day)	100	150	120	168–192
Energy Source	Grid (unavailable)	Diesel fuel	Solar panels	Wave energy
Operating Cost (INR/m³)	150–200	180–250	120–150	90–120
Deployment Time (hours)	8–12	6–8	4–6	2–3
Operational Emissions	None (non-op)	2–3 kg CO_2/day	Near zero	Zero
System Weight (kg)	50	120	80	35–45
Maintenance Interval	Weekly	Every 3 days	Monthly	Monthly
20-Year LCOW Estimate (INR)	N/A	200/m³	140/m³	105/m³

VIII. WATER QUALITY PERFORMANCE - DESALINATION PERFORMANCE

Parameter	Input (Seawater)	Output (Permeate)	WHO Standards
TDS	35,000 ppm	300-500 ppm	<1,000 ppm
Salt Rejection	-	98.6-99.4%	>97% (industry)
Bacteria/Viruses	Present	Removed	0 CFU/100ml
Microplastics	Present	Removed (0.01µm filter)	-
Taste Rating	Salty	Excellent-Good	Palatable

IX. TECHNICAL ADVANTAGES

- **Energy Independence:** The system operates fully off-grid, making it ideal for disaster zones where power infrastructure is compromised.
- **Local Fabrication:** All major components are manufacturable using standard Indian workshop capabilities, ensuring easy maintenance and replication.
- **Modularity and Scalability:** The modular design permits scaling capacity from 100 to 600 liters per day through parallel deployment.
- **Rapid Deployment:** The system can be deployed and made operational within 24–48 hours post-disaster.
- **Portability:** Lightweight and compact design facilitates transport to remote and inaccessible coastal areas.
- **Extended Membrane Life:** Advanced pretreatment reduces membrane fouling, increasing operational lifespan by 40–60%.
- **Low Operational Costs:** Operating expenses are significantly lower than those for diesel-based units.

X. LOCAL FABRICATION AND VIABILITY

- Piston bores manufactured via lathe machining to ±0.2 mm tolerance, within standard workshop capabilities.
- Assembly using TIG/MIG welding methods common in Indian fabrication shops.
- Availability of hard chrome plating locally for pump durability.
- Modular construction using bolted fasteners minimizes specialized weld requirements.
- Ease of maintenance through field-replaceable cartridges, seals, and membranes using stocked spare parts.

XI. CONCLUSION

This initiative is a well-rounded and the most practical answer possible to the urgent need of supplying drinking water to those coastal communities that disasters have impacted. The method that has been developed is a combination of wave energy, the latest desalination technology and local prototyping that will operating an efficient, eco-friendly and quickly deployable source of drinking water.

The hybrid idea not only has the capabilities of that but it can also bring huge savings of costs, allow for greater independence of operation and prolong the lifetime of the system by combining water supply with climate adaptation and disaster resilience measures. Further, the research will include solar-wave hybrids to enhance annual performance, improvements in membrane materials, and enlarging field deployments especially to cyclone prone coastal areas in Tamil Nadu.

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