https://doi.org/10.31705/BPRM.v6(1).2026.18 Research Feature



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A PROPOSED SUSTAINABLE ATMOSPHERIC WATER HARVESTING PRODUCT FOR RURAL SRI LANKA: AN EXPLORATORY STUDY USING PELTIER MODULE TECHNOLOGY

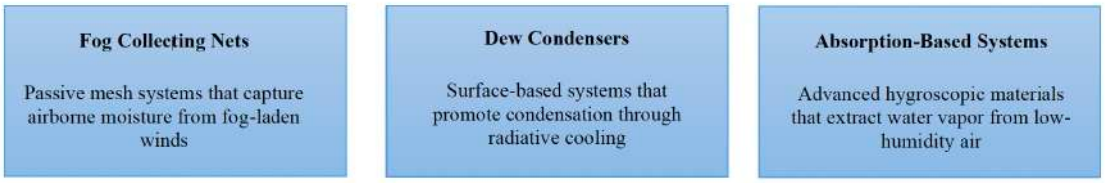
> "Sustainable water harvesting is not a technological solution, but a lifeline for rural communities empowering resilience, preserving natural resources, and securing water for future generations in Sri Lanka"

Introduction

Atmospheric Water Harvesting (AWH) technology has emerged as a sustainable, innovative design solution to address drinking water scarcity in rural arid regions of developing countries, where traditional water harvesting solutions are often irregular and insufficient. This technology involves extracting water vapor from ambient air and converting it to liquid form through several active and passive technological implementations including fog collecting nets, dew formation condensers, and advanced absorption-based design solutions emphasizing feasibility as an alternative water harvesting solution for communities with severe water scarcity.

The World Bank has identified continued water-access challenges and vulnerability to climate-related hazards in Sri Lanka (World Bank, 2021). Atmospheric Water Harvesting (AWH) provides an alternative research pathway because it extracts moisture directly from ambient air. Existing approaches include fog collection, dew/radiative condensation, sorption and active condensation. Condensation-based systems can be particularly relevant under humid conditions, although their performance depends strongly on climate and energy availability (Tu & Hwang, 2020; Tashtoush & Alshobaki, 2023).

Among Sri Lankan rural regions, water scarcity remains a major challenge due to unpredictable rainfall patterns, prolonged drought periods, long-distance accessibility issues toward water resources, and insufficient available water harvesting design solutions. Most of these communities fulfill water demand from wells, small reservoirs, and seasonal rainwater sources that have become increasingly unreliable as climate variability intensifies.



Research Approach- Mixed-Method and Design-Based Research

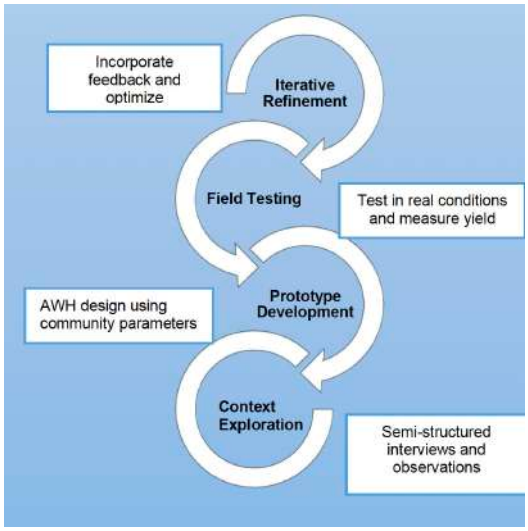


Figure 1 – Research Approach

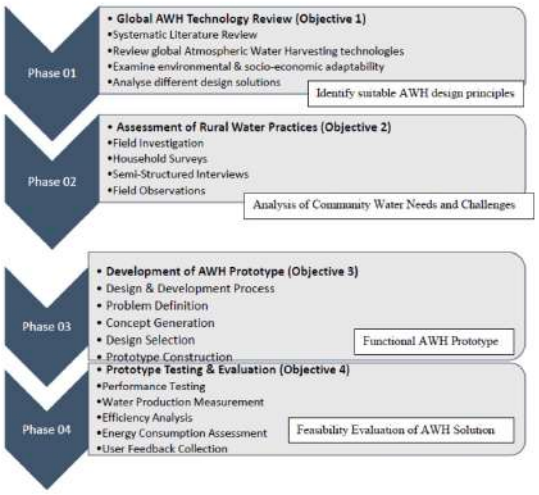


Figure 2 – Research Methodology

The research will move through four connected stages - context exploration, prototype development, field/laboratory testing, and iterative refinement. This approach connects a practical design problem with measurable technical evidence and community feedback (Wang & Hannafin, 2005).

The research begins with understanding context parameters and environmental constraints through a mixed-method exploration phase. Semi-structured interviews with sample groups, field observations, and survey data collections will be conducted in parallel with environmental parameter measurements such as humidity and temperature to understand the adaptation feasibility of AWH technology integration. The developed prototype will then be tested under real environmental conditions within a selected community to investigate water harvesting feasibility and efficiency.

Significance of the Study

This research provides a feasible and sustainable product design solution for the water scarcity challenge among rural regions in the Sri Lankan local context, where communities rely on traditional design solutions that remain inadequate. The study bridges the existing design solution gap by investigating AWH technology aligned with socio-cultural and environmental factors.

Research Approach – Design-Based Research

Stage	Proposed activities	Evidence
1. Context exploration	Select rural community recruit ~35 households questionnaire, 8–12 semi-structured interviews, observation.	Water sources, seasonal constraints, user needs, space, energy access.
2. Environmental study	Record temperature, RH and relevant environmental conditions at standardized morning, afternoon and evening periods continuously logging where possible.	Climate operating range and relationship with condensation potential.
3. Prototype development	Peltier modules, aluminium condensation surface, heat sinks, fans, collection/storage unit future solar-battery integration.	Design specifications, BOM, thermal/electrical measurements.
4. Iterative testing	Controlled testing followed by representative field-testing record yield, power, temperature, RH and operational problems.	L/day, Wh/L or kWh/L, reliability and design-change log.
5. Validation	Integrate quantitative measurements, user feedback and laboratory water-quality results.	Feasibility matrix and refined design recommendations.

Table 1 – Design Based Research Approach

Proposed AWH Prototype

The proposed device will use thermoelectric/Peltier cooling to lower a condensation surface below the atmospheric dew point. A preliminary configuration will use 12-V DC thermoelectric modules, aluminium heat sinks, forced-air fans, a thermally managed condensation chamber and a food-contact-compatible collection/storage pathway. A grid-powered supply will support prototype development, while solar photovoltaic generation and battery storage will be investigated as a later off-grid option. The number of modules, surface area, insulation and fan capacity will be finalized through measured prototype performance rather than treated as fixed assumptions.

Design parameter	Initial proposal	Planned measure
Cooling	Peltier thermoelectric cooling	Cold/hot-side temperature yield
Power	12-V DC	V, A, W, kWh/day, Wh/L
Condensation	Aluminium, cleanable surface	Surface temperature; drainage
Heat rejection	Heat sinks + fans	Hot-side temperature; airflow
Water handling	Closed, food-contact-compatible pathway	Microbiological/chemical quality
Maintenance	Accessible cleaning and service points	Time/frequency of maintenance

Table 2 – Design Parameters

Planned Data Collection and Analysis

Quantitative measures will include ambient temperature, relative humidity, water yield, voltage, current, power consumption and operating duration. Yield will be reported as L/day and mL/hour, while energy performance will be reported as Wh/L or kWh/L. Repeated measurements will be used to examine variation across environmental conditions. Qualitative data will be coded thematically around water access, usability, maintenance, affordability, safety, trust and acceptance. Quantitative and qualitative findings will be triangulated during each DBR iteration.

Feasibility Criteria – Planned Measures

Criterion	Measure	Purpose
Water yield	L/day mL/hour	Determine useful supplementary output
Energy efficiency	Wh/L or kWh/L	Quantify electrical burden
Cost	LKR capital cost LKR/L	Assess economic implications
Reliability	Repeated-operation success and yield variation	Assess consistency
Water safety	Microbiological + chemical laboratory tests	Assess compliance before consumption
Maintenance	Cleaning/service time and frequency	Assess household practicality
Acceptance	Survey ratings + interview themes	Inform design refinement

Table 3 – Design Criterion

Ethics and Community Engagement

Participation will be voluntary and based on informed consent. Household information will be coded to protect confidentiality. Participants will receive clear information that the device is an experimental research prototype and that its water is not automatically safe for drinking. Prototype testing will initially be supervised, with electrical, thermal, structural and hygiene risks assessed before household exposure. Vulnerable households will receive additional safeguards, and institutional ethics/research approval and relevant community permissions will be obtained before recruitment.

Expected Outcomes

- A context-specific set of climatic and household design requirements.
- An iteratively refined Peltier-based AWH prototype and documented design decisions.
- Measured evidence linking environmental conditions, water yield and energy consumption.
- Water-quality evidence against applicable drinking-water requirements.
- A feasibility framework covering yield, energy, cost, reliability, safety, maintenance and acceptance.
- Design recommendations for future field testing and renewable-energy integration.

Scope and Limitation

The study will initially examine one selected rural community and therefore will not automatically represent all Sri Lankan climatic or socio-economic conditions. Prototype performance will depend on module efficiency, heat rejection, airflow, condensation-surface design, environmental conditions and electricity availability. Seasonal variation and long-term durability may require subsequent studies.

Conclusion

This study proposes an exploratory, context-sensitive investigation of Peltier-based atmospheric water harvesting for rural Sri Lanka. Its contribution will be determined through community research, environmental monitoring, prototype iteration and laboratory validation. The research does not assume that AWH is already a feasible or sustainable drinking-water solution. Instead, it will establish whether defined technical, water-quality, economic, maintenance and community-acceptance conditions can be met and will use the resulting evidence to guide future product development.

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