

From air to safe water

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Atmospheric water harvesting promises decentralized water supplies but has largely prioritized yield over safety. A multifunctional material demonstrates how water harvesting and microbial control can be combined within a single platform.

Producing clean water is becoming challenging as climate variability, pollution, and infrastructure gaps place growing pressure on existing supplies. These challenges are most severe in regions where centralized water treatment is difficult to maintain and power supply is unreliable. Atmospheric water harvesting (AWH) has therefore gained attention as a decentralized approach to extract water directly from the air¹. In most implementations, AWH systems are designed as modular processes, in which moisture capture and water treatment are treated as distinct and sequential functions. Previous studies have examined sorbent materials design², thermal management³, and heat-exchanger modules⁴ to improve freshwater yield.

Ambient air is nonsterile and contains bioaerosols, particles and droplets that can transport microorganisms, such as bacteria and viruses. These contaminants can enter harvested water during condensation or be introduced during subsequent handling and storage. Most AWH systems, however, are designed primarily to maximize water yield, with limited consideration of water quality during the harvesting process. Consequently, microbial control is typically addressed only as a downstream step, often requiring additional energy, consumables, or operator intervention. As a result, the microbiological safety of harvested water under realistic operating conditions remains poorly understood⁵.

Now writing in *Nature Water*, Cheng and colleagues⁶ propose a promising strategy that addresses this challenge by integrating microbial inactivation directly into the moisture-capturing sorbent, enabling simultaneous water harvesting and disinfection to occur within a single material platform (Fig. 1). This platform is built around a mussel-inspired hygroscopic aerogel, where polydopamine-like interfacial interactions stabilize hygroscopic salt, LiCl, and anchor a photothermal component, such as carbon black, within a porous polymer network. The salt drives moisture uptake from humid air, while the photothermal additive converts absorbed sunlight into localized heat. This heating releases the captured water as vapour for downstream condensation and simultaneously inactivates microorganisms at the sorbent surface, under operating conditions (1 sun irradiation at 24 °C and varied relative humidity of ~30–90%). In this design, disinfection is an intrinsic function of the harvesting medium rather than an auxiliary unit appended to the device.

A notable aspect of this strategy is its emphasis on biosafety evaluation based on biocompatibility rather than inference from appearance or basic water chemistry alone. Beyond standard antibacterial assays, Cheng et al. assess the harvested water using in vitro cytotoxicity tests

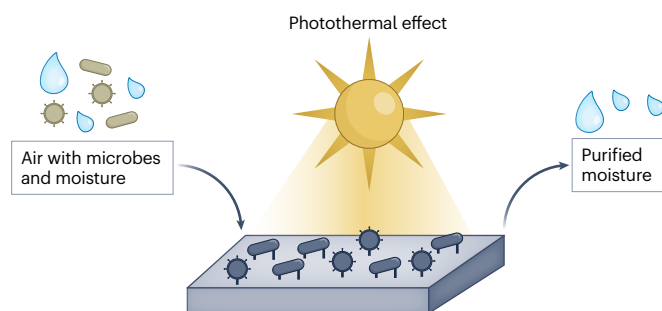


Fig. 1 | Atmospheric water harvesting with integrated disinfection. Ambient air containing moisture and microorganisms contacts a hygroscopic, photothermal aerogel. Solar heating promotes pathogen inactivation on the sorbent while driving water release as vapour, which is then condensed to produce biologically safer water.

and a 14-day in vivo feeding study in rats, reporting no observable tissue damage or toxicity within the experimental scope. This level of validation is particularly relevant for AWH research, where water quality is often judged primarily by physicochemical metrics. By linking a water-from-air platform to biological compatibility testing, this work strengthens the framework for defining water quality in decentralized water production.

Importantly, integrating this safety mechanism has a negligible impact on water harvesting efficiency. The aerogel maintains high moisture uptake across a wide range of relative humidity conditions. In addition, a simulated airflow and condensation setup demonstrates the daily cycles of water capture and release of the device. These results show that microbial control at the sorbent level can be compatible with competitive AWH productivity rather than inevitably reducing yield. Furthermore, the sorbent functions as a multifunctional water module, combining moisture uptake, light-driven water release, and microbial suppression in a single material. Such functional integration may benefit field deployment, as fewer external components can reduce failure points and lower maintenance demands.

Looking ahead, a key priority is to report productivity and microbiological quality together using standardized safety metrics. A system-level design perspective could further extend the device performance, particularly under sub-optimal solar conditions. For example, self-powered actuation and sensing could complement solar-driven disinfection without substantially increasing system complexity. Ambient energy harvesters, such as triboelectric nanogenerators, could intermittently power low-energy fans or control electronics to stabilize airflow and condensation when sunlight is limited^{7–9}. Harvested energy could also be stored and released as high-voltage pulses to trigger electroporation-based disinfection¹⁰, in which transient electric fields permeate microbial membranes without chemical additives. Coupled with an integrated sensor that monitors water quality parameters (conductivity, turbidity, and related operational indicators), such a system could

activate pulsed disinfection only when contamination risk exceeds defined thresholds.

Translating these materials from lab-scale demonstrations to large-scale outdoor technologies will require further technical advances to address challenges such as dust accumulation, biofilm growth, and potential salt loss. These factors can progressively alter pore accessibility, sorption kinetics, and photothermal heating, directly affecting both water yield and microbial suppression. Robust validation across diverse climates and operating conditions will therefore be essential, incorporating realistic maintenance intervals and user practices. Correspondingly, certification frameworks should evolve to define standards that assess both productivity and microbiological safety over sustained operation, rather than relying on isolated, short-term tests.

In conclusion, this study shifts the trajectory of AWH technology from a singular focus on water yield towards the reliability and safety of water delivery under realistic conditions. It demonstrates that microbial control can be intrinsically engineered into the harvesting material, eliminating the need for separate downstream treatment. As the field advances, such multifunctional sorbents that integrate capture, release, and microbial suppression may play a central role in realizing autonomous, point-of-use systems that deliver biologically safe water access wherever sunlight and humidity are available. Such intrinsically safe AWH platforms hold strong promise for deployment in regions facing water scarcity and lacking access to conventional

water treatment infrastructure. Such conditions are increasingly widespread due to mounting environmental pollution and the rising costs of water treatment.

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Competing interests

The authors declare no competing interests.