Atmospheric water harvesting

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Capturing water from air in an economical and stable way

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An atmospheric water harvesting device comprising a super-stable hygroscopic hydrogel origami panel and a window-like glass chamber operates efficiently at a wide range of relative humidities, providing an economic and safe water solution for decentralized regions.

Freshwater scarcity is an increasing global challenge, projected to threaten more than half of the world's population within the next two decades[1,2]. Sorption-based passive atmospheric water harvesting (AWH) devices are one of the potential solutions to water-related challenges. Such devices use hygroscopic sorbents capable of capturing moisture from air. The moisture is then desorbed through solar energy to yield drinking water[3]. Although promising, current passive AWH devices still suffer from sorbent-related limitations associated with low sorption capacity, reduced desorption efficiency, and water impurity, as well as device-related limitations involving long-term durability and large-scale demonstrations. For example, nanoporous sorbents such as metal-organic frameworks can capture water at relative humidity as low as 20% (ref. 4), but their non-swelling framework leads to reduced water uptake at high humidity levels. Hydrogel-based sorbents, on the other hand, offer broad chemical tunability and substantial swelling capacity[5,6]. However, their intrinsically limited water uptake[7] often necessitates the incorporation of hygroscopic salts to enhance performance, which introduces stability concerns arising from crystallization and leakage of salts.

Now, writing in Nature Water, Chang Liu and colleagues report an economically scalable atmospheric water harvesting window (AWHW) designed for year-round use and capable of collecting safe drinking water across a broad range of relative humidity levels[8]. In the extreme aridity of California's Death Valley, where nighttime humidity drops to just 18%, the AWHW produced approximately 0.36 litre per square metre per day of water, achieving a thermal efficiency of 9.3%. In contrast, in the humid urban setting of Cambridge, Massachusetts, the AWHW demonstrated a significantly higher areal water production of 1.26 liters per square metre per day. Beyond its remarkable water collection performance, the AWHW is highly cost-effective and capable of recovering its cost within 9 days in high-humidity regions and 25 days in arid regions, when compared to the cost of commercial bottled water. The economic advantage makes it a potentially off-grid solution for communities facing persistent water scarcity.

The economically scalable AWHW incorporates a multiscale design that integrates innovations at both the device and material levels. At the device level, the AWHW, operating on a day–night cycle, features a vertically oriented, dual-sided, and origami-shaped hydrogel panel, enclosed within a transparent window coated with a passive radiative cooling layer (Fig. 1a). During the nighttime, the hydrogel panel captures moisture from ambient air; while in the daytime, the hydrogel panel absorbs heat from solar energy, releasing the absorbed water as vapour. The vapour condenses on the transparent window, which maintains high solar transmittance while emitting thermal radiation in the 8–13 μm wavelength range. This radiative cooling effect lowers the window surface temperature by approximately 0.5 to 1 °C, thereby enhancing condensation and improving overall water yield. Structurally, the hydrogel panel is shaped into a dome-like origami array (Fig. 1b,d), which increases the effective surface area by a factor of 3.1 compared to a flat panel, maximizing its swelling capacity. Moreover, the geometric design of the origami array creates warm valleys and cool apexes during desorption, reducing thermal losses and enhancing evaporation efficiency.

At the molecular level, the team designed a super-stable non-porous hygroscopic hydrogel (Fig. 1c,e), which is composed of poly(vinyl alcohol) (PVA) as a flexible polymer network to facilitate water transport, lithium chloride (LiCl) as a hygroscopic agent to capture moisture from ambient air, and glycerol as a phase stabilizer to prevent salt crystallization during repeated sorption–desorption cycles. A major limitation of conventional salt-loaded hygroscopic hydrogels is the progressive decline in performance due to salt crystallization and leakage. To address this, the team introduced glycerol to uniformly encapsulate LiCl salts, effectively inhibiting crystallization and minimizing aggregation. Another critical issue is the potential contamination of collected water, as evaporating water from porous hydrogels can form water clusters that carry small quantities of salts. To ensure high water purity, the team employed a non-porous hydrogel matrix that inhibits lithium ion migration into the vapour phase. Experimental validation showed the PVA–LiCl–glycerol hydrogel retained 90% of its original performance after 340 sorption–desorption cycles, equivalent to nearly one year of daily operation, demonstrating excellent long-term durability. In addition, all water samples collected from both laboratory and field tests contained lithium-ion concentrations well below the US safety threshold of 0.06 ppm, confirming the AWHW's effectiveness in producing safe drinking water.

Traditional freshwater sources, such as rivers, lakes, and groundwater, are progressively degraded by man-made pollution, limiting their ability to meet growing water demands. Consequently, atmospheric water harvesting has gathered significant attention, as the atmosphere contains nearly six times more freshwater than all rivers combined[3]. Looking ahead, the economically scalable AWHW developed by Liu et al. offers a practical and deployable solution for providing affordable family-scale drinking water, independent of geographic constraints. Beyond its application potential, the findings by Liu et al. are fundamentally compelling. This work demonstrates a multi-disciplinary engineering approach that integrates molecular

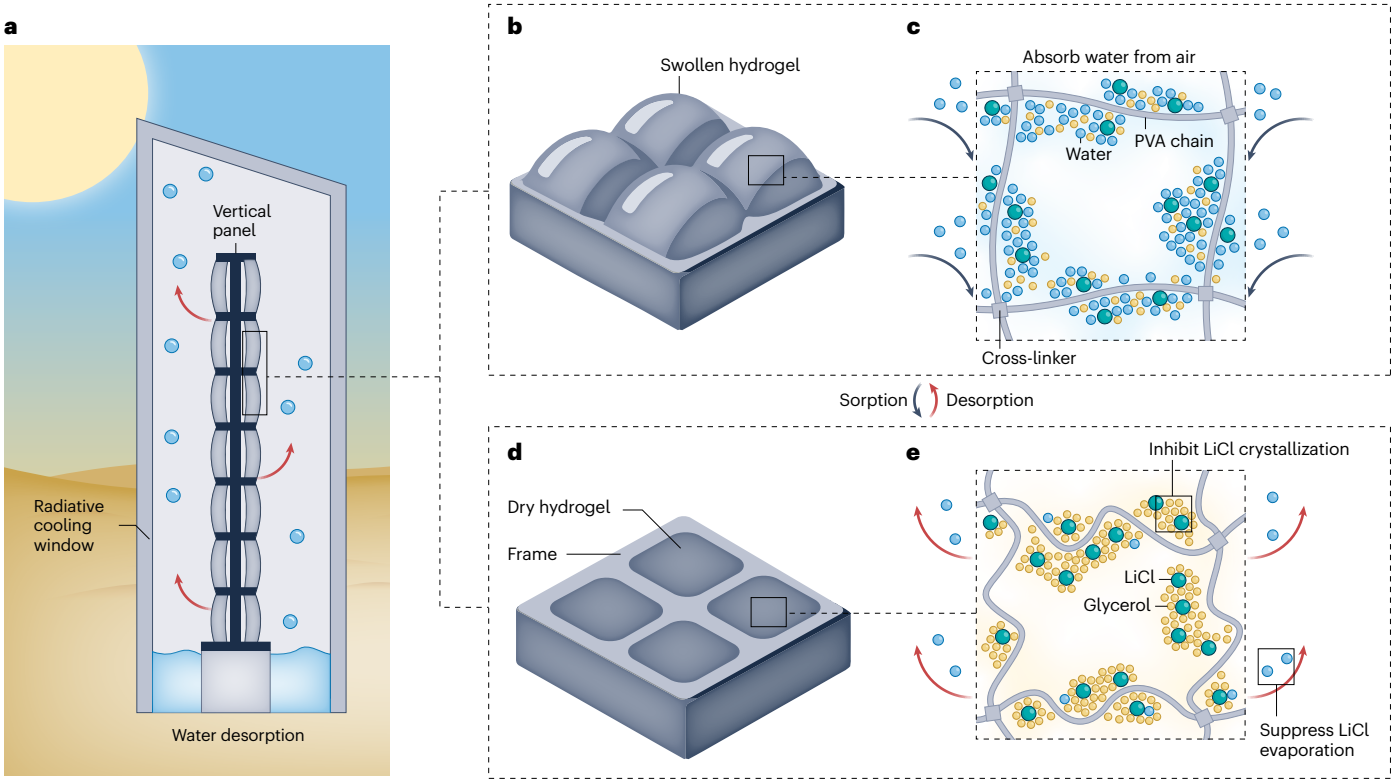


Fig. 1 | Design of the economically stable atmospheric water harvesting window (AWHW). a, Schematic of the AWHW featuring a vertical hydrogel panel and a transparent window for water desorption. **b**, Dome-shaped origami hydrogel array after water sorption. **c**, Molecular schematic showing that the PVA–LiCl–glycerol hydrogel absorbs water vapour from air. **d**, Origami hydrogel array after water desorption under sunlight. **e**, Molecular illustration of the role of glycerol in inhibiting LiCl crystallization and suppressing LiCl evaporation.

design of a super-stable and non-porous hydrogel, structural design of an origami-shaped hydrogel panel, and thermophotonic design of a radiative cooling condenser. This integrated approach paves a new path for manipulating water transport between hydrogels and surrounding environments.

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Competing interests

The authors declare no competing interests.