Emulsion-Templated Composite Biogels for Scalable Solar-Driven Atmospheric Water Generation

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Freshwater is becoming a depleting resource globally due to climate change, urbanization, and pollution. Thus, there is an urgent need for decentralized and energy-efficient freshwater generation technologies. Sorbent-based atmospheric water harvesting (SAWH) is a promising technique for extracting water vapor directly from air, yet it suffers from limited water uptake at low relative humidity, sluggish cycling kinetics, and requires high energy inputs for desorption. Herein, a solar-driven SAWH system is proposed, inspired by the hierarchical porosity of bone. A sodium alginate-based polymerized high internal phase emulsion (PolyHIPE) biogel, was utilized to improve water transport kinetics. Lithium chloride (LiCl) was crosslinked throughout the PolyHIPE structure to improve water vapor capture and condensation. A photothermal additive, carbon ink, was incorporated to enable efficient solar-thermal energy conversion, allowing passive water release without external energy input. The performance of these materials was evaluated with gravimetric water uptake measurements under varying relative humidities (RH), with the PolyHIPE biogel system harvesting 1.1 g g?¹ of water at low RH and up to 3.55 g g?¹ at high RH ($p<0.05$). Over five absorption/desorption cycles, the PolyHIPE structures exhibited negligible uptake decline compared to non-templated controls ($p<0.05$). Infrared imaging under simulated sunlight demonstrated rapid heating, reaching approximately 70 °C within one hour. Following optimization, the system achieved approximately 1.19 g g?¹ water uptake under outdoor conditions with excellent cyclicity. These results demonstrate the potential for biomimetic PolyHIPE based photothermal sorbents as accessible SAWH systems to combat the world water crisis.

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