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Comment

Comment on: *A Mangrove-Inspired Off-Grid System Integrating Electrodialysis and Photothermal Evaporation for Direct Lithium Salt Extraction from Brine*

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An artificial mangrove for the lithium age

Every electric car, every grid battery, every phone in every pocket runs on lithium. The trouble is that demand is climbing faster than the supply, and much of what counts as "supply" still comes from a process that would look oddly familiar to a salt-maker two thousand years ago: pump salty water out of the ground, spread it across vast, shallow desert ponds, and wait for the sun. Then there is the long wait of one to two years. The ponds sprawl across tens of square kilometers, visible from space. They drink groundwater in some of the driest parts of the planet, require chemicals at several stages, and even then, about half the lithium is discarded with the leftover brine. What emerges is not a finished product at all. It must be filtered, precipitated, and purified through yet more steps—each one consuming energy and shedding more of the metal along the way. The bottleneck is separation. Lithium has to be prised away from other metal salts dissolved in seawater. In brine, lithium is outnumbered by sodium, and, worse, by magnesium. Lithium and magnesium sit next to each other diagonally in the periodic table and behave so similarly in water that telling them apart is like trying to sort two nearly identical grains of sand by hand, several million times over.

Nature has been grappling with a version of the problem for ages. Mangroves live with their roots submerged in seawater, and they succeed by splitting the job between different parts of the tree. The roots let water in while blocking most of the salt. The trunk carries the enriched sap upward. Then the leaves, warmed by sunlight, do the extracting: they evaporate the water and leave behind visible crystals of salt on the surface. It all runs on sunshine, with no human supervision required.

Now, Kian-Ping Loh[1] and colleagues of the Department of Chemistry, National University of Singapore, have tried to recreate that division of labour in machinery. Their system uses a lithium-selective ceramic membrane, made of LLTO, as the "root." The ceramic is threaded with channels set up so precisely that lithium slips through while magnesium is turned back. A circulating channel plays the "trunk," keeping the enriched liquid moving so it doesn't clog. And a black, leaf-shaped fabric acts as the "leaf," soaking up 97% of the light that falls on it, warming to 54 °C within six minutes, and evaporating 2.1 litres of water per square metre each hour—leaving solid lithium salt to be collected.

The shape of the "leaf" turns out to matter more than you might expect. A plain, round absorber encourages salt to crystallise directly on the evaporating surface, clogging the pores and choking the device. By cutting the absorber into radiating arms, they draw the liquid outward so crystals form at the tips rather than in the centre—an approach that echoes the way mangroves shed salt through glands at their edges. The result was a jump in salt recovery from 0.35 g to 0.52 g, and, just as importantly, the system stayed alive, continuing to work instead of failing. The numbers deserve to be stated without fuss. With the ceramic membrane in place, the system moved lithium at 9.6 mg per square metre per hour while rejecting magnesium by a factor of 648, improving to 812 as the run continued. It delivered that performance for 72 hours straight, without interruption. All the while, sunlight did the concentrating and crystallising that usually requires both evaporation ponds and a year's patience.

Why this matters beyond the membrane community

This is more than an incremental tweak to an already busy field. Three things lift it into a category of its own.

First, it turns four steps into one. Most conventional lithium recovery chops the task into separate operations of separation, filtration, evaporation and precipitation, each demanding its own kit, its own energy bill, and its own round of unavoidable losses. Here, selection, concentration and crystallisation are built into a single, continuous device. Brine goes in; lithium salt comes out.

Second, it tackles a genuine engineering constraint rather than merely describing a neat idea. The authors explicitly grapple with a key tension: the flow of ions through the membrane must be matched to the rate of evaporation at the surface. If lithium moves through too quickly, salts form inside the membrane. If evaporation is too aggressive, the surface dries out. Designing around that balance is what welds two familiar technologies, membrane separation and solar evaporation, into something that actually works.

Third, it isn't really "about lithium" at all. Nothing in the concept depends on lithium specifically. Change the membrane, and the same root–trunk–leaf logic could be used to extract other strategic materials from seawater, geothermal fluids, or industrial waste—the very feedstocks whose supply increasingly resembles a national-security question.

Challenges ahead in making it a practical process

A demonstration and a practical process are separated by numbers this paper does not yet provide. For the rate to matter at scale, it likely needs to rise by ten to a hundred times above the reported 706 mg per square metre in three days, while keeping selectivity intact, otherwise the land area required simply becomes the old pond footprint wearing a new label. Energy use, too, must be expressed in kilowatt-hours per kilogram of lithium, including both the electrical drive and the pumping. Running off-grid may describe how the system is built; it does not tell you whether it is cheap.

Then there is product quality. The crystals must be analysed. For battery-grade lithium, purity must exceed 99.5%, and simple evaporation tends to drag sodium and potassium along for the ride.

Most decisive is lifetime. A run of 72 hours proves little about a year in a real salt environment, where a brittle ceramic membrane faces fouling, and day-after-day heating and cooling. And finally, often the overlooked detail, what happens at the anode. Chlorine gas is produced in the process and must be captured or engineered away.

Notwithstanding the challenges above, the authors have shown that a solar-driven, single-step brine-to-salt route is physically possible. The next phase, showing it can be affordable, durable, and scalable, is where the real difficulty now lies. Plainly, though, this is work worth doing.

Conflicts of Interest

The author declares no conflicts of interest.

References

1. Liu, H.T.; Zhang, K.; Lu, C.; Liu, J.; Loh, K.P. A Mangrove-Inspired Off-Grid System Integrating Electrodialysis and Photothermal Evaporation for Direct Lithium Salt Extraction from Brine. *Sustain. Sci. Innov.* **2026**, *1*, 103130. [CrossRef]

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