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Biomining of high-value metals from electrical battery waste

"Testing the capacity for *Azolla* to grow and function as a biomining bioagent helped us determine if the plant can be used directly or whether semi-synthetic bioengineering approaches will be required."

PROJECT AIMS: The first aim was to assess the viability of the nitrogen-fixing water fern *Azolla filiculoides* as a bioremediation agent within contaminated aquatic ecosystems and waste disposal sites. To this end, the tolerance of *Azolla* towards a range of commonly occurring heavy metal contaminants, including lithium, was investigated.

Second, whether lithium is actively removed from solution by the plant, or merely tolerated via other mechanisms was investigated.

Third, the scale-up potential for the biomining of lithium from battery waste was investigated via the creation of a prototype growth chamber.

RESULTS: The viability of *Azolla* was assessed by several metrics, including root density, leaf coverage, red:green ratio, and senescence rate. The tolerance rates for *Azolla* towards lithium differed greatly between batches, affected by conditions such as plant prior health, media composition and lighting. For most batches of *Azolla*, detrimental changes occurred at a minimum lithium concentration of ~100 mg/L. However, some batches could tolerate up 180 mg/L, indicating that lithium tolerance can be increased with optimisation and plant conditioning.

Tolerance levels could be optimised via the addition of artificial sea water, at the expense of growth rate. However, tolerance of *Azolla* towards several other heavy metal contaminants was much lower than would be commercially viable; this result highlights the necessity for pure lithium in solution and limits the use of *Azolla* in battery recycling.

Preliminary results from inductively coupled plasma mass spectrometry experiments indicated that *Azolla* can remove lithium from solution. Experiments to investigate where lithium is stored within the plant are ongoing.

The scale-up potential for lithium biomining in a vertical farm was investigated using multi-tiered, heat- and light-controlled incubators, and research is ongoing to replicate this in a low-cost, automated manner.

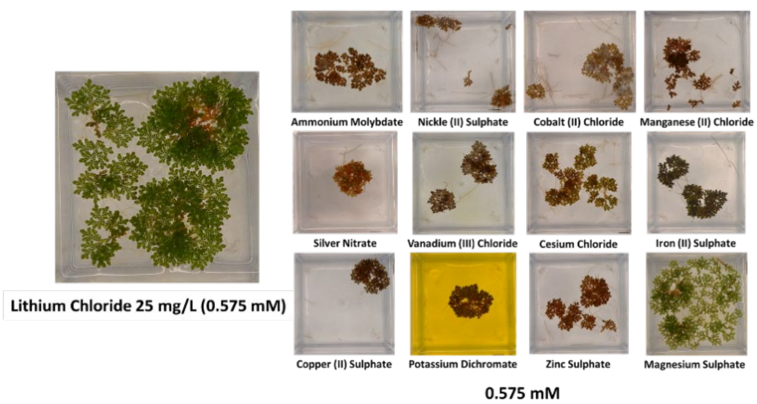
Change in technology readiness level: 2 to 4

OUTCOMES & NEXT STEPS:

Experiments are underway to further increase the lithium tolerance and bioremediation capacity of *Azolla*, including:

- Testing additional sub-species of *Azolla* for increased natural lithium tolerance.
- Plant conditioning of *Azolla filiculoides.*
- Addition of additives such as artificial seawater.
- A bio-materials approach to dissect the biochemistry behind the lithium bioremediation capabilities of *Azolla*; this approach could identify artificial materials capable of removing lithium from solution at much higher concentrations than the plant could otherwise tolerate.

A paper, patent and research proposal are being written.



Azolla tolerance for a range of metals after 3 weeks.