

Decoding Lithium Transformation Mechanisms in Biological Systems for Green Extraction and Waste Remediation

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Project Highlights:

- Multidisciplinary research integrating fieldwork, advanced molecular analysis, microscopy, and spectroscopy techniques to study biological lithium interactions.
- Aims to unravel biochemical pathways of lithium transformations and geochemical cycling in microorganisms and hyperaccumulating plants.
- Findings will drive the development of eco-friendly lithium biomining strategies, with global applications for lithium recovery and environmental remediation.

Overview:

Lithium (Li), the lightest metal element, has become an essential resource in the 21st century, critical for achieving sustainability goals and reducing greenhouse gas emissions. Its prominent role in lithium-ion batteries for electric vehicles and renewable energy storage has amplified demand (Ambrose and Kendall, 2020, Speirs et al., 2014). With global lithium needs projected to surpass \$50 billion by 2030, developing efficient and environmentally sustainable extraction methods is crucial (Graham et al., 2021). Traditional extraction methods, such as hard rock mining and brine evaporation, are not only resource-intensive but also contribute significantly to environmental degradation (Mousavinezhad et al., 2024).

While newer technologies, like direct lithium extraction (DLE) — as utilised by Cornish Lithium in the UK to extract lithium from geothermal brine — show promise, they still raise considerable environmental concerns (Rentier et al., 2024, Farahbakhsh et al., 2024). Therefore, alternative approaches are needed that minimise ecological impact while meeting growing demand.

Biological processes, particularly those involving microorganisms and plants, offer a promising, eco-friendly solution for lithium recovery and waste remediation (Brune and Bayer, 2012). Certain microorganisms can bioleach lithium from mineral matrices (Zhao et al., 2023), while some plants show potential for hyperaccumulating lithium from contaminated soils (Miletić et al., 2024). These biologically based methods could lead to more sustainable lithium mining and environmental cleanup, with lower energy requirements and greater cost efficiency. **However, despite their promise, the underlying mechanisms driving lithium transformation and uptake in these systems remain poorly understood.**

(a)

Chemical speciation characterisation

Sorption-desorption? Extracellular secretion? Organic acids?

Lithium-bearing minerals (e.g. LiAl(SiO₃)₂)

Sorption-desorption? Extracellular secretion? Organic acids?

Biomining?

Li⁺, ?, ?.

Bio recovery?

Rhizo-stabilisation?

Hyper-uptake?

Li⁺, ?, ?.

Chemical speciation characterisation

seawater and brines
acidic
alkaline
neutral
organic acids?
minerals
microbes
plants
animals
humans
...
etc.

(b)

Lepidolite, K(Li,Al)₃(Al,Si,Rb)₄O₁₀(F,OH)₂

Petalite, LiAl(Si₂O₆)₂

Spodumene, LiAl(SiO₃)₂

Lithium carbonate, Li₂CO₃

Lithium nitrate, LiNO₃

Lithium Phosphate, Li₃PO₄

Potential changes in Li speciation by Biochemical transformations

Year 1: Conduct a comprehensive review of lithium geochemistry and biomining. Refine research questions and experimental design. Select field sites and prepare sampling protocols. Collect lithium-

rich samples from rocks, brine, and waste sites. Sequence microbial communities and identify lithium-related genes and pathways.

Year 2: Conduct experiments on lithium uptake in hyperaccumulating plants. Perform ionomics to analyse lithium in plant tissues. Track lithium in microbial systems using isotope tracing analysis. Develop a novel micro-spectroscopic approach to study lithium transformations in microbial and plant systems.

Year 3: Integrate findings into mechanistic models of lithium biogeochemistry. Test engineered biological systems for enhanced lithium recovery and remediation. Complete thesis writing and submit for examination. Finalise and submit manuscripts for peer-reviewed publication.

Training and skills:

TARGET researchers will participate in a minimum of 40 days training over the 3.5 years of study composed of:

- an annual one-week workshop dedicated to their year group, and tailored to that cohort's needs in terms of skills development – *for the first three years of their study*;
- an annual all-TARGET workshop with cross-year interactions, advanced training and opportunities to specialise in particular areas – *all years of study*;
- a number of one-day workshops;
- additional online events and in-person workshops attached to relevant conferences.

The student will receive specialized training in field sampling and experimental design, as well as in plant and microbial culturing. They will also learn advanced molecular biology techniques, mass spectrometry, and morphological-chemical characterization techniques using electron microscopy, including Electron Energy Loss Spectroscopy (EELS) and Energy Dispersive X-ray Spectroscopy (EDX). Additionally, training will encompass Raman and Fourier Transform Infrared (FTIR) spectroscopy.

Partners and collaboration (including CASE):

The student will be based at the School of Earth and Environment, University of Leeds, and will spend time at the Camborne School of Mines, University of Exeter. There, they will engage in mining education and collaborate with ongoing research on lithium geochemistry, gaining access to geological lithium samples from the UK and Canada.

Further details:

Please visit <https://target.le.ac.uk/> for additional details on how to apply.

For more information about this project, please contact G.A.Adediran@leeds.ac.uk

Further reading:

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