Integrated Hydrometallurgical Strategies for the Selective Recovery of Critical Metals from Industrial Waste Streams

Summary

The urgent demand for waste-free and carbon-neutral technologies continues to grow, especially in light of global resource security challenges. In this context, historical landfills must be reimagined as valuable resource reservoirs for the future. This project aims to achieve the comprehensive valorisation of mineral waste streams by: • Recovering critical raw materials, and • Reducing the carbon footprint through advanced carbonation technologies. The expected outcomes include both fundamental and applied knowledge in integration of optimized extraction processes for low-magnesium (4–6% MgO) raw materials into a scalable, potentially zero-waste valorisation model for ash deposits, contributing to the sustainable supply of critical raw materials.

Research field:	Chemical, materials and energy technology
Supervisors:	Dr. Mai Uibu Dr. Can Rüstü Yörük
Availability:	This position is available.
Offered by:	School of Engineering Department of Materials and Environmental Technology
Application deadline:	Applications are accepted between June 01, 2025 00:00 and June 30, 2025 23:59 (Europe/Zurich)

Description

The research

The aim of the proposed research project is the comprehensive valorization of mineral waste streams through the development of critical raw material resources, as well as the reduction of carbon footprint using carbonation technologies. Waste is inherently heterogeneous and varies over time in terms of properties and quantities, which requires highly flexible solutions.

The proposed research direction involves the valorization of mineral waste deposits such as deposited oil shale ash (approx. 600 million tons) through hydrometallurgical methods. One pilot-stage solution is the carbonation-based valorization of Ca-rich deposited oil shale ash to produce precipitated CaCO#, offering the first large-scale use case for this waste. The next challenge would be the valorization of secondary products from selective Ca extraction using hydrometallurgical methods to recover critical raw materials (Mg), as well as Al, S, and ultra-pure nano-SiO#. The choice of extraction agents must consider not only efficiency and selectivity but also regenerability, cost, and environmental safety. The valorization model developed for deposited oil shale ash could also be applied to other waste deposits.

Expected outcomes include both fundamental and applied knowledge for integrating optimized extraction solutions for low-Mg content (4–6% MgO) raw materials into a potentially zero-waste ash deposit valorization complex in the context of critical raw materials. The experimental study is supported by thermodynamic and process models, including energy and material balances and CO# binding efficiency calculations.

Responsibilities and (foreseen) tasks

We are looking for a highly motivated and dedicated PhD candidate with a strong background in chemical and materials engineering, and a keen interest in sustainable resource recovery and hydrometallurgical processes.

The successful candidate will:

- Conduct both experimental and theoretical research focused on the development of integrated hydrometallurgical strategies for the selective extraction of critical metals from industrial waste streams.
- Investigate and optimize process parameters for metal recovery, purification, and valorization.
- Present research findings at national and international scientific conferences.
- Publish results in peer-reviewed scientific journals.
- Participate in doctoral-level coursework.

- Prepare and submit a yearly research plan to demonstrate independent research capabilities.

Candidate Profile – Required Qualifications and Skills

Applicants should meet the following criteria:

- A master`s degree in Chemical and Materials Engineering or a closely related field.
- A clear interest in the topic of the position.
- Working knowledge of thermodynamic and process (Aspen plus, HSC) modelling is an asset.
- Possess strong communication skills for presenting research and writing scientific publications.
- Demonstrate excellent teamwork and analytical problem-solving abilities, with a creative, critical, and open-minded approach.
- Have a solid understanding of inorganic material characterization and environmental chemistry.
- Be capable of working independently and proactively in a research environment.

The candidate should submit a research plan for the topic, including the overall research and data collection strategy. The candidate can expand on the listed research questions and tasks, and propose theoretical lenses to be used.

We offer:

- A fully funded 4-year PhD position at one of Estonia's largest and most internationalized engineering research centers, offering a multidisciplinary environment that includes engineers, chemists, economists, and IT specialists.
- Employment as an "Early Stage Researcher" at the university, with full salary support for the nominal duration of the doctoral program.
- Integration into the Laboratory of Inorganic Materials within the Department of Materials and Environmental Technology.
- Opportunities for international collaboration, including conference participation, research visits, and networking with leading global universities and research institutions.

About the department

The Laboratory of Inorganic Materials at TalTech focuses on both fundamental and applied research in inorganic multicomponent systems, aiming to develop innovative materials and explore new applications for Estonia's abundant mineral resources. Key research areas include mineral carbonation, production of precipitated calcium carbonate (PCC), reuse of alkaline industrial residues, and strategies to mitigate the environmental and health impacts of waste. The lab also investigates ways to reduce the reliance on natural raw materials in the construction sector by promoting sustainable, efficient, and environmentally responsible material solutions. These efforts combine experimental research with advanced mathematical modeling to optimize outcomes.

Tallinn University of Technology (TalTech) is Estonia's only technology-focused university, offering comprehensive degree programs at the Bachelor's, Master's, and Doctoral levels in engineering, applied sciences, IT, business, and maritime studies. As the most international university in Estonia, TalTech is known for its dynamic development, global outlook, and strong emphasis on innovation. Its green and compact campus is among the most modern in Europe, fostering a vibrant academic and research environment.

(Additional information)

For further information, please contact dr. Mai Uibu (mai.uibu@taltech.ee).

To get more information or to apply online, visit https://taltech.glowbase.com/positions/1015 or scan the the code on the left with your smartphone.