# Selective metal extraction from geological materials using electrokinetic leaching

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**Project Highlights:**

- ‘keyhole surgery’ mining
- Metal mining but with lower environmental impact
- Unlocking stranded metal resources to support the energy transition

**Overview:**

Currently most metals are extracted from ores that are blasted, excavated, pulverised and then processed on the surface. This requires a large energy input (at a time when we need to be decarbonising), generates large volumes of waste and is damaging to the environment. This PhD project will seek to deliver a new approach which would comprise the use of an electric field to facilitate the movement of a solvent into an ore body for the selective *in situ* extraction of a target metal. This new approach to mining, if successful, would enable metals to be extracted from subsurface ores (and waste repositories) whilst imparting minimal damage to the surface environment and avoiding the generation of environmentally hazardous mine tailings.

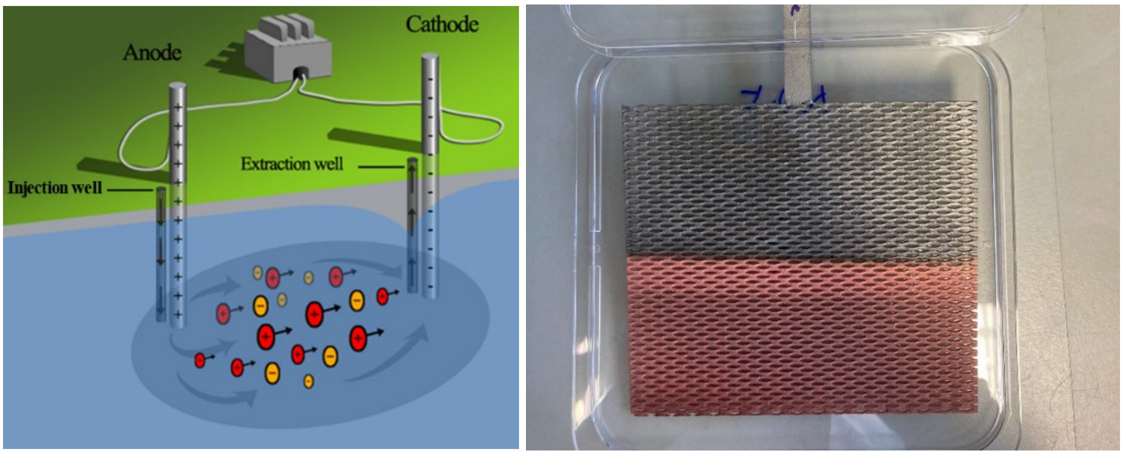


*Figure 1. LHS: Schematic diagram of the movement of leached metal ions under a superimposed direct current electric field. RHS: Photograph of copper which has been leached and then deposited onto a cathode.*

**Methodology:**

The student will first determine the mineralogical composition, target metal deportment and speciation within candidate geological materials using a range of analytical methods, including: XRD, Raman spectroscopy, FTIR, SEM-EDS and EPMA and by undertaking sequential extractions. A series of leaching tests will then confirm a suitable solvent formulation. Electrokinetic experiments will then be constructed and leachates analysed using ICP-OES/MS. Results from these measurements will be used to modify and further refine the electrokinetic apparatus design (membrane composition, electrode composition, DC current voltage gradient, etc.).

**Possible Timeline**

Year 1: Undertake literature review to determine a suitable candidate geological material to focus the study on. Undertake an experimental campaign to determine the samples mineralogical composition, target metal deportment and speciation. Complete a first round of electrokinetic experiments. Presentation of results at a UK meeting. Consideration of training needs.

Year 2: Refine the electrokinetic approach via systematic change of electrokinetic variables. Undertake research placements at the BGS (hydrogeochemical characterisation of the geological samples) and the University of Leicester (solvent design). Presentation of results at an international meeting; preparation of a manuscript. Re-evaluation of training needs.

Year 3: Completion of laboratory study and potentially an upscaled trial in the field. Finalisation and publication of manuscripts. Laison with industry and consideration of career options.

**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.

**Partners and collaboration:**

Dr Rich Crane (Exeter) will support the student for sample collection, laboratory analyses, and electrokinetic apparatus design. The student will join a thriving research community at the Camborne School of Mines, Department of Earth and Environmental Sciences, University of Exeter, and benefit from accessing world-class analytical facilities, including a multi-million pound mineralogy analytical characterisation suite and mineral processing laboratories. Further research support will also be provided from Prof Jon Chambers (BGS) and Prof Gawen Jenkins (University of Leicester) for hydrogeochemical analyses and solvent design respectively. We will draw on our wide network of UK and international industrial collaborators for sample acquisition. The student will also benefit from the opportunity to apply for BGS University Funding Initiative (BUFI) funding to further support their research. The maximum funds that can be applied for from BUFI are £7000, and will be used to contribute to expenses incurred by the student undertaking their research with BGS (T&S, fieldwork support, consumables).

This PhD project is ambitious and cross-disciplinary. It will equip the student with a wide range of skills – including: hydrometallurgy, geochemistry, mineralogical analysis, hydrogeology and electronics. These skills are highly attractive to both industrial and academic employers, particularly those engaged in critical mineral processing and green chemistry.

It will most suit a student who has a background in environmental engineering, electrochemistry, geochemistry and who already has experience in the design and application of electrokinetics.

**Further reading:**

Yan, Y., Ling, Z., Shu, W., Huang, T. and Crane, R., 2023. Chromium removal from contaminated soil using a novel FeOx/granular activated carbon-based three-dimensional electrokinetic system. *Chemical Engineering Journal*, *455*, p.140613.

Martens, E., Prommer, H., Sprocati, R., Sun, J., Dai, X., Crane, R., Jamieson, J., Tong, P.O., Rolle, M. and Fourie, A., 2021. Toward a more sustainable mining future with electrokinetic in situ leaching. *Science Advances*, *7*(18), p.eabf9971.

**Further details:**

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