PROJECT TITLE: Developing bioinspired magnetic nanoparticles for the recovery of critical metals from environmental and anthropogenic waste

DTP Research Theme(s): Dynamic Earth, Changing Planet

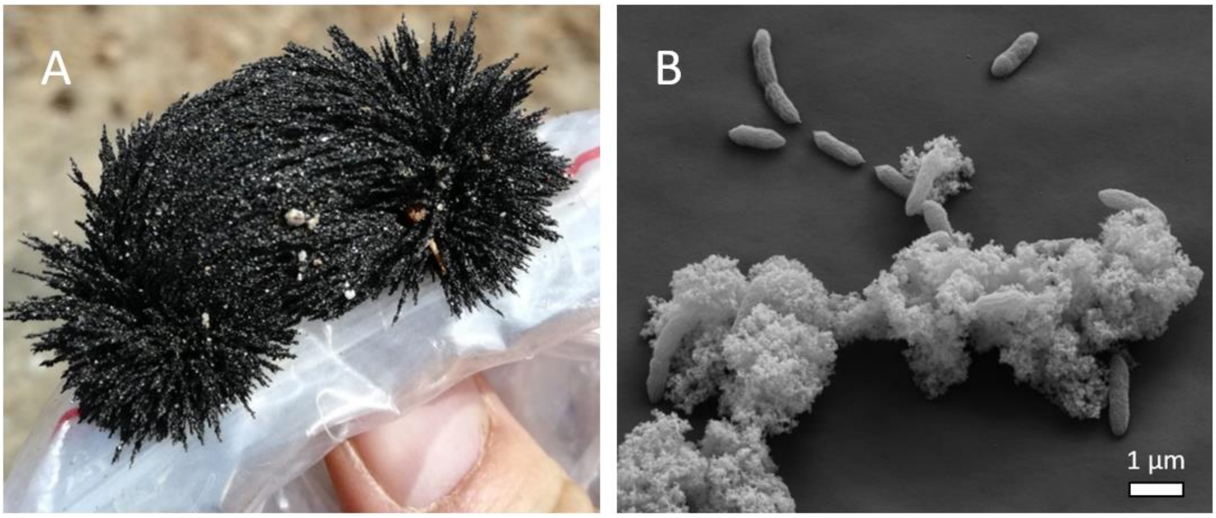
Lead Institution: University of Bristol

Lead Supervisor: James Byrne, University of Bristol, School of Earth Sciences

Co-Supervisor: Rich Crane, University of Exeter, Camborne School of Mines

Project Enquiries: james.byrne@uni-tuebingen.de

Project keywords: Environmental mineralogy, magnetism, metal recovery, microbial reduction and oxidation, Rare earth elements (REEs).



Magnetic nanoparticles from microbial or geogenic processes can be found in almost every environment on earth. A) Magnetite will strongly respond to a magnet and can act as a sink for different metals. B) Magnetite formed in association with bacteria observed by Scanning Electron Microscopy.

Project Background

The availability and recovery of critical metals (CMs) such as cobalt, silver and rare earth elements (REEs) is coming under increasing scrutiny as global demand for electronics dependent upon CMs continues to grow. Long term global supplies of CMs are under strain, with extremely low global rates of recycling. Therefore, more sustainable methods for CM recovery need to be developed in order to meet future challenges associated with diminishing supply. Such sustainable methods include the use of reactive, magnetic nanoparticles such as nanoscale zerovalent iron (nZVI) which can bind CMs and be magnetically recovered. nZVIs typically have a core shell structure with Fe(0) surrounded by iron oxides such as magnetite, which is an essential component of the nZVI reactivity. Magnetite is a naturally occurring mineral phase which is extremely reactive towards a number of metals and metalloids including cobalt, zinc, chromium and REEs, and can be produced *via* both abiogenic and biogenic approaches. These biogenic approaches, typically through microbial iron reduction, are a low cost and sustainable alternative to harsher chemical extraction methods and can potentially be designed to selectively target specific metals thereby decreasing the requirement for downstream separation of CMs. This project will investigate how both biogenic minerals such as magnetite and nZVI can be used to selectively extract different metals and CMs from different sources in the environment such as mine tailings or waste water supplies.

Project Aims and Methods

The aim of this project is to develop new materials for the extraction of CMs through bioinspired processes. More specifically, the student will:

- Synthesize magnetic nanoparticles (biogenic magnetite and abiogenic nZVI) under controlled laboratory conditions through microbial Fe(III) reduction and chemical precipitation.
- Compare reactivates of both magnetite and nZVI towards CMs such as cobalt and REE.
- Use advanced analytical methods including spectroscopy, electron microscopy, synchrotron techniques and x-ray diffraction to build a mechanistic understanding of how CMs bind to reactive nanoparticles
- Develop methods for selectively targeting specific CMs.
- Collect samples from several field sites where CMs have been identified as present in waste waters, biosolids and mine tailings in the South West of England (including Wheal Maid, Cornwall; the County Adit, Cornwall; Poldice, Cornwall)
- Develop new strategies to promote magnetite formation in situ for targeted CM recovery.

This interdisciplinary project covers a broad range of disciplines including geology, chemistry, biology and physics in an emerging field of bioinspired metal recovery. The project will look at how we can use bacteria as natural factories to for metal recovery in order to improve sustainability and reduce environmental impact associated with our technologically driven world. The project will provide the student with the opportunity to develop as an independent researcher with the opportunity to shape their project with their own ideas from the beginning. Ultimately the student will develop skills that will provide a competitive edge for a future career in academia, industry or the private sector.

Candidate Requirements

We foresee this project would be best suited for a student who has a strong background in biogeochemistry, mineralogy and chemistry (preferably MSc-level). The work will include the planning, setup and running of all experiments under the supervision of the supervisors including data analysis, presentations in group seminars and at conferences, as well as writing of publications together with supervisors. The PhD student will be sent on relevant training workshops to learn advanced analytical techniques where appropriate.

Training

The student will be trained in a range of laboratory based techniques including mineral synthesis, microbial cultivation, geochemical measurements and analytical methods including synchrotron based tools, electron microscopy and QEMSCAN. They will be encouraged to participate in NERC GW4+ DTP training courses and be able to access training opportunities from UoB and UoE such as lectures within BSc/MSc courses: Geomicrobiology; Soil and Water Contamination; Mine Waste Characterisation, Prediction and Treatment. Funding is provided for the student to present their research at a high profile international conference and will be encouraged to apply for grants that support further travel opportunities.

References / Background reading list

- Byrne, J. M., N. Klueglein, C. Pearce, et al. (2015). "Redox cycling of Fe(II) and Fe(III) in magnetite by Fe-metabolizing bacteria." Science 347(6229): 1473-1476.
- Byrne, J. M., V. S. Coker, S. Moise, et al. (2013). "Controlled cobalt doping in biogenic magnetite nanoparticles." Journal of The Royal Society Interface 10(83): 20130134.
- Crane, R. A. and D. J. Sapsford (2018). "Sorption and fractionation of rare earth element ions onto nanoscale zerovalent iron particles." Chemical Engineering Journal 345: 126-137.

School URL: http://www.bristol.ac.uk/earthsciences/courses/postgraduate/

Bristol NERC GW4+ DTP Prospectus:
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The application deadline is 1600 hours GMT Monday 6 January 2020 and interviews will take place between 10 and 21 February 2020

General Enquiries:
Bristol NERC GW4+ DTP Administrator: Email: bristol-nercgw4plusdtp-admin@bristol.ac.uk