

Metal and Sulphur Dynamics in a Unique Compost Bioreactor System for Treatment of Metal-Polluted Waters (Ref IAP-17-78)

Newcastle University, School of Engineering

In partnership with University of Stirling and

CASE partners: Coal Authority and Environment Agency

Supervisory Team

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Key Words

Metals, sulphur, treatment, geochemical cycling

Overview

Discharges from abandoned base metal mines are by far the single biggest source of toxic metals such as zinc and cadmium to the aquatic environment of England and Wales¹, and mining is a globally important source of aquatic pollution. The pervasive nature of mine water pollution is a key reason why low cost, low carbon solutions are sought to alleviate the problem (known as passive treatment). Based on research conducted at Newcastle University, in 2014 Europe's first large-scale 'compost bioreactor' was commissioned at the abandoned Force Crag mine site, in the Lake District National Park (Figure 1). The system relies on bacterial sulphate reduction (BSR) to immobilise metals, especially the primary pollutant zinc, as their sulphides. The process design of the treatment scheme was a partnership project involving the Coal Authority, Environment Agency, National Trust, and Newcastle University, and was funded by Defra. Newcastle University continues to lead on the detailed monitoring of the performance of the system.

Although cycling of sulphur and zinc are important from the perspective of the effectiveness of the treatment system, research on a pilot-scale compost bioreactor (also known as a vertical flow pond; VFP) indicated that iron cycling may play an important indirect role in the overall biogeochemical dynamics of the reactor². Specifically, over time iron appeared to be transformed from oxidized iron phases in the compost substrate into iron sulphide. The role of competition of iron and zinc for *in-situ* sulphide, as well

as displacement reactions in solid sulphides in the immobilisation of the main pollutant, zinc, is not well understood but critical for the sustainable implementation of this remediation system.



Figure 1. The Force Crag compost bioreactor treatment system, comprising duplicate vertical flow ponds (VFPs) (Photo courtesy of John Malley, National Trust)

This research project will thus investigate the cycling of sulphur, iron and zinc in the Force Crag VFP treatment system. The results of the research will directly inform the functioning of such passive treatment systems, and will also provide important insights into the cycling of metals and sulphur in the natural environment. Of particular importance to the Environment Agency and Coal Authority, the project will deliver insights on the possible longevity of such systems. This is a key question for system owners, and is one that is fundamentally controlled by nutrient dynamics. In addition, this research will inform possible approaches

to limiting release of hydrogen sulphide from treatment units such as this, which can otherwise result in nuisance odours.

Methodology

The student will be based in the School of Engineering at Newcastle University, with visits to Stirling University to monitor iron mineral transformation, as and when required. The project will involve routine fieldwork at the Force Crag treatment system, which is a 2.5 hour drive from Newcastle. Sampling will include both treatment system water and solid samples, with subsequent detailed analysis of both undertaken at Newcastle and Stirling Universities.

Activities at Force Crag will be supplemented with laboratory-based batch and column experiments to investigate the extent to which S, Zn and Fe dynamics under carefully-controlled lab conditions represent those that occur at larger scale under ambient environmental conditions.

Field and laboratory techniques will include on-site water quality measurements, ICP-OES and ICP-MS analysis for metals concentrations, sequential extraction procedures to investigate the mobility of metals, and Mössbauer spectroscopy to determine and monitor solid iron phase composition and transformation.

Timeline

Year 1: Detailed literature review work; training in field and laboratory techniques.

Year 2: Commencement of field and laboratory based work, focusing on the Force Crag treatment system and then with lab-scale investigations; possible conference attendance / presentation towards end of year.

Year 3: Continuation of field and laboratory work, to conclude by end of second quarter at latest; thesis write up and preparation of journal article(s) as appropriate.

Funding ceases after 3.5 years

Training & Skills

In addition to the IAPETUS doctoral training process, the student will receive training in all aspects of field and laboratory techniques by the very experienced technical staff at Newcastle University, with equivalent training at Stirling for specific techniques. The student will therefore gain key skills in both routine and advanced sampling and analysis techniques for inorganic constituents of water and solids. The student will be actively encouraged to attend relevant taught MSc modules on the wide range of programmes delivered both within the School of Engineering and elsewhere, thus widening their knowledge base. Courses in relevant data analysis techniques will be followed by the student (e.g. statistical analysis), and the supervisory team will lead on guiding the student on how to go about preparation of international peer-reviewed journal papers and delivery of conference presentations; key skills for a successful researcher.

References & Further Reading

¹Mayes, W.M., Potter, H.A.B. and Jarvis, A.P. (2013) Riverine flux of metals from historically mine orefields of England and Wales. *Water Air & Soil Pollution*, **224**:1425.

²Environment Agency (2014) *Mitigation of pollution from abandoned metal mines: Investigation of passive compost bioreactor systems for treatment of abandoned metal mine discharges*. Environment Agency Science Report SC090024/1. Environment Agency, Bristol, UK.

Further Information

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