Mapping the micro-scale distribution of metal-potentially harmful elements (PHEs) and their mobility in contaminated soils (Ref IAP2-18-192)

University of Stirling, Biological and Environmental Sciences (BES)
In partnership with Durham University and BGS.

Supervisory Team
- Clare Wilson, University of Stirling
- Karen Johnson, University of Durham
- Jo Wragg, BGS
- Christian Schroeder, University of Stirling

Key Words
1. Soil structure, 2. intra-aggregate distribution, 3. metal-PHEs, 4. in-situ microanalysis, 5. bioavailability

Overview

Understanding the dynamics of potentially harmful elements (PHEs) within soils is important if we are to accurately assess the risk PHEs pose to human health and the environment. There has been significant research, for example, into the role of soil biology on bioavailability and into the way in which PHEs are adsorbed to soil surfaces. It has also long been known that the mobility of heavy metals in structurally undisturbed soils is very different to that in homogenised soils where the structural aggregates have been destroyed and more recently it has been recognised that the distribution of PHEs between aggregate size fractions influences the release characteristics of heavy metals from soil. However, virtually nothing is known about the micro-scale distribution of PHEs within soil aggregates and micro-aggregates, and what this may mean for their mobility within the soil and ultimately their bioavailability.

The formation of soil aggregates is controlled by a range of biotic and abiotic factors in a cycle of physical turnover as aggregates from, develop and degrade.

Well-structured soils are characterised by micro-spatial heterogeneity in biological, physical and chemical conditions that could affect the nature of surface sorption sites and the adsorption and retention of PHEs from solution. For example, redox conditions vary spatially within aggregates as a result of intra-aggregate patterns of porosity, SOM and microbial distributions, influencing oxidation states.

SEM-EDS of Pb-bearing grains (pink) within a soil micro-aggregate, Leadhills, Scotland.
and Fe (hydr)oxide forms that may influence the adsorption of PHEs and hence their mobility. The aims of this project are 1) to map the intra-aggregate distribution of metal-PHEs within soil in order to better understand the physical dynamics of PHEs in the soil environment and 2) to determine the effects of intra-aggregate PHE distribution on their mobility in the soil as it affects bioavailability.

Methodology

Sampling sites in northern England and Scotland with contrasting structural properties will be selected to represent a range of contamination scenarios. Soils will be analysed to characterise their structural, as well as chemical and biological, properties. The distribution of PHEs such as Pb and Cu within soil aggregates and in relation to soil pores, Fe hydr(oxides) and soil organic matter will be established using micromorphology, SEM-EDS and image analysis of polished soil thin sections and freeze-fractured soil aggregates. Chemical extractions and before and after micro-analysis of soil thin sections will look for differential contributions linked to intra-aggregate distribution. We will also apply to UK Diamond Light Source for access to XANES and EXAFS to determine the form of metal-PHEs and sorption processes linked to intra-aggregate distribution. Wet chemical extractions of aggregates and aggregate fractions derived from aggregate sieving and soil peeling will establish the influence of soil aggregation on PHE mobility. Mössbauer spectroscopy will determine the relationships between PHEs and Fe (hydr)oxides in soil aggregates.

Timeline

0-12 months: Will be spent training in the techniques, management and policy, and with the principles of environmental pollution and soil science / analysis. Project planning, experimental design, laboratory training and field sample collection will be the focus of year 1. A draft introductory chapter, methodological framework and a robust project plan will be expected by the 9 months point.

12-24 months: The second year will be spent largely undertaking experimental and analytical work, alongside this training in analytical skills and statistical analysis, project management, and communication of results will be provided. An application for analytical beam time to use Synchrotron facilities will also need to be submitted. By the end of year 2, methodology chapters should be completed together with a clear publication plan and a draft of at least one results chapter.

24-36 months: Will be spent finishing the experimental and analytical phases alongside data analysis, data modelling and the writing up of results chapters. Training will be given in publication and employability. Presentation of the results at an international meeting will be expected as will the drafting of key results as papers.

36-42 months: In the final 6 months you will be focussing on the final submission of the thesis, journal publication of results and their wider dissemination of your research via conferences and workshops as well as appropriate social media.

Training & Skills

The student will benefit from a range of specialist and generic training skills that will be provided during placements within the partner institutions and through membership of the NERC IAPETUS DTP consortia. Many of NERC’s top 15 ‘most wanted skills’ will be developed through this project.

The specialist skills and expertise that will be developed during this project include:

- Awareness of contaminated land assessment frameworks and procedures.
- Multidisciplinary research.
- Environmental sampling.
- Experimental design and operation.
- Soil micro-analysis including: micromorphology, image analysis, SEM-EDS.
- Bulk soil chemical analysis (dependent on PHE choice)
- Mössbauer spectroscopy.
- Data analysis and modelling.

The student will also benefit from the generic training offered by the University of Stirling and the IAPETUS NERC DTP including research skills, project management, statistics, scientific writing and employability skills. The student will be expected to present the results of their research annually at the BES student symposium and for at least one national and one international conference.

References & Further Reading


Further Information

Dr Clare Wilson  c.a.wilson@stir.ac.uk  tel: 01786 467817.