

Biogeochemistry of contaminants in extreme environments

Supervisors: Doug Stewart, Rob Mortimer and Ian Burke



Highly alkaline chromate contaminated ditch water at a legacy chromium ore processing residue disposal site in the North of England

over the past decade into the fundamental basis of this technology. The vast majority of this research, however, has used laboratory models with very benign conditions (i.e. in pH 6-8 freshwater media and using low contaminant loadings) compared with those observed at real industrially contaminated sites. Recent insights into microbially mediated geochemical transformations under more realistic conditions of elevated pH and ionic strength have shown that behaviour at extremes is often fundamentally different with respect to both the biogeochemistry observed and their ultimate geo-microbiological controls. This project will use a series of novel laboratory models from both natural and contaminated sites to determine the fundamental bio-geochemical processes that are supported at extremes of pH, ionic strength and contaminant concentrations within heterogeneous soil-water systems. A new understanding of bio-geochemical processes occurring under extreme conditions will enable a determination of the key thresholds and limits to existing bioremediation technologies when they are applied at contaminated sites. Also fundamental questions about the genetic potential for microbiology metabolism and replication at extremes will itself be explored.

Methodology: Field sampling will be undertaken at a number of industrially contaminated sites. Samples



Sub-soil sampling at a contaminated site

Background: Industrial activity over many decades, and in some cases centuries, has left a large and sometimes troublesome legacy of industrially contaminated land. It is therefore vitally important to understand the factors that control the transport and fate of industrial contaminants in the geo-sphere if these sites are to be managed to ensure the long-term protection of potentially potable groundwater.

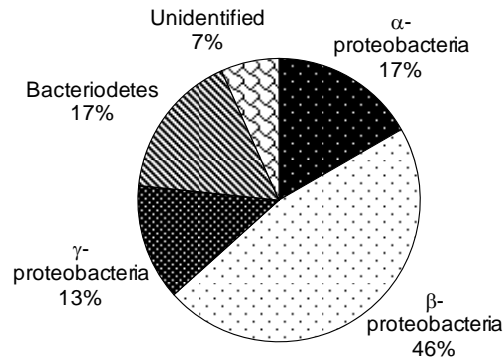
Aim: To understand the role of soil micro-organisms in determining the geochemistry of groundwater contaminants in the extreme environments found at industrially contaminated sites.

The project: The use of biological ground treatments has been proposed for the *in situ* immobilisation of contaminant metals and radionuclides, thereby reducing their associated environmental risk. There has been a great deal of laboratory investigation



Calcite precipitation where water leaching highly alkaline lime production waste emerges to atmosphere at a site in the Peak district

will be geochemically and microbiologically characterised. Soil micro-organisms that have evolved or adapted to survive in the extreme environments at industrially contaminated sites will be cultured, isolated and studied. Bio-geochemical transformations typical of these environments will be studied in laboratory batch and column tests. Advanced geochemical methods such as electron microscopy, X-ray photoelectron spectroscopy and X-ray absorption spectroscopy will be used to understand the key underlying geochemical transformations that occur. State of the art microbial community analysis involving PCR based DNA extraction methods and 16S rRNA gene sequencing will be used to evaluate changes in the microbial ecology that result. The anticipated outcome of the project is a



Microbial community of soil taken from a highly alkaline chromate contaminated site after incubation under anaerobic conditions for 68 days (based on phylogenetic affiliation of the 16S rRNA gene sequences)

better mechanistic understanding of the role of soil micro-organisms in mediating the geochemical changes observed, and particularly their role in determining the fate of any contaminants. Successful delivery of this project will identify whether bio-transformation of contaminants is an appropriate treatment method for real industrial legacy sites.

In summary, this is an interdisciplinary project aimed at developing core underpinning knowledge that will aid development of novel engineering solutions to the contaminated land legacy of the industrial revolution. Success in this project will require a multidisciplinary approach involving classic civil engineering site investigation techniques allied to state of the art biogeochemical, molecular and geo-microbiology methodologies.

The Applicant: This project will suit either an engineer willing to acquire skills in geochemistry and microbiology, or a geochemist or microbiologist wishing to tackle applied environmental problems. The successful applicant will join an interdisciplinary team with expertise in all the necessary areas, so training and support will be readily available.

Recent Publications:

D.I. Stewart, I.T. Burke, D.V. Hughes-Berry and R.A. Whittleston (2009). Microbially mediated chromate reduction in soil contaminated by highly alkaline leachate from chromium containing waste. *Ecological Engineering*, doi:10.1016/j.ecoleng.2008.12.028.

D.I. Stewart, I.T. Burke and R.J.G. Mortimer (2007). Stimulation of microbially-mediated chromate reduction in alkaline soil-water systems. *Geomicrobiology Journal*, 24 (7-8), 655-669.