

**Final report for the ESF-funded FIMIN workshop on
“Environmental Iron Microbiology”**University of Manchester and University of Bangor
16th-20th January 2012

Organised by Professors Jon Lloyd (Manchester) and Barrie Johnson (Bangor)

1) Summary

Iron is the 5th most abundant element in the Earth's crust. It occurs naturally as either ferrous or ferric iron and forms a wide variety of minerals, some of which are highly reactive in the environment. Iron tends to coordinate with a large number of organic and inorganic ligands, and this in turn exerts a strong impact on its redox properties. Our understanding of the chemical and biological fundamentals of surface processes and iron mineral transformation reactions is, however, still surprisingly incomplete. Improvement of our knowledge on the function of this abundant element in biogeochemical cycles is therefore a goal in many scientific disciplines. Moreover, it will significantly contribute to obtaining a better understanding of processes that are crucial to human and societal development such as the supply of clean water, remediation of contaminated sites or the regulation of CO₂ emissions.

The FIMIN Research Networking Programme supports a cross-disciplinary approach to understanding the role of iron in the environment, aiming to make the ensuing knowledge, expertise and relevant instrumentation available to researchers throughout Europe. This Research Networking Programme addresses this need through an intensive training and education programme. The ultimate goal of the FIMIN project is to elucidate the functionality of iron minerals through understanding cycling of electrons and matter through iron minerals, encompassing contrasting disciplines in the environmental sciences, including geochemistry, biogeochemistry, microbiology, soil and hydrological sciences, and biotechnology.

As part of these activities, the Steering Committee of FIMIN approached Professor Lloyd to organize a residential workshop covering the latest advances in the microbiology of iron transformations in the environment. With Professor Barrie Johnson (Bangor) a 5-day residential course was organised, split between two university groups with longstanding interests in the geomicrobiology of iron. The first half of the course was spent at the University of Manchester, based in the Williamson Research Centre for Molecular Environmental Science, focusing on redox cycling of Fe in neutral/alkali pH environments, covering Fe(III) reduction and Fe(II) oxidation and also Fe uptake and cellular metabolism in microbial systems. The second half of the course was based in the University of Bangor and hosted by the Bangor Acidophile Research Team (BART) and focused on redox cycling of Fe at acidic pH, covering both Fe(II) oxidation and Fe(III) reduction, with an emphasis on acid mine drainage environments (a major concern worldwide, including in Europe). The Manchester and Bangor teams, with the support of other invited internationally recognized experts in Fe geomicrobiology, delivered a series of lectures, practical exercises and demonstrations, supported by fieldwork to cover the following; culturing techniques, molecular ecology techniques, genomic and post-genomic approaches, mineralogical and geochemical techniques, environmental impact and biotechnological applications. The course was aimed at researchers working on all aspects of the microbial Fe cycle, and attracted 30 applicants, from which 16 exceptional early stage researchers were selected for attendance. The meeting was delivered on budget, and from course feedback was judged an overwhelming success by the attendees.

2) Description of the scientific content and discussion at the event

The meeting was hosted by two groups (in Manchester and Bangor) with highly complementary interests in the microbial cycling of iron. Most attendees arrived in Manchester on the evening of Sunday 15th January, and the course started formally on the morning of Monday the 16th, with a transfer to Bangor on Wednesday 18th.



The FIMIN “Environmental Iron Microbiology” workshop attendees plus organisers

Part 1: The University of Manchester

Based in the Williamson Research Centre for Molecular Environmental Science (WRC), within the School of Earth, Atmospheric and Environmental Sciences at the University of Manchester, the first two days of the meeting focused on redox cycling of Fe in neutral/alkali pH environments, covering Fe(III) reduction and Fe(II) oxidation and also Fe uptake and cellular metabolism in microbial systems. After an initial introductory lecture, the course co-director Prof Jon Lloyd delivered two lectures giving first an introduction to the microbial iron cycle followed by an overview of microbiological tools that can be used to dissect complex biochemical processes coupled to the Fe cycle. This lecture focused on neutral pH systems, especially Fe(III)-reducing systems, and included traditional culturing-based approaches and complementary DNA/RNA-based molecular techniques. Prof David Vaughan, an eminent environmental mineralogist also based at the University of Manchester, then gave an overview of mineralogical techniques that can be used to study microbial transformations of iron, including XRD, electron microscopy, STM, AFM as well as Mossbauer and synchrotron spectroscopy techniques. A short lunch was then followed by a three hour practical session, located in the state of the art geomicrobiology laboratories of the WRC. A series of workstations were set up and manned by research staff in the centre covering; cultivation of Fe(III)-reducing bacteria such as *Geobacter* and *Shewanella* species, DNA extraction/amplification and bioinformatics analyses. These afternoon laboratory sessions were based on information delivered in the lectures earlier in the day, and equipped the attendees with a good practical knowledge of key techniques required to work on Fe-microbe interactions.

Having given a basic introduction to microbial iron cycling at neutral pH, the second day focused on new cutting edge “post-genomic” tools that are becoming important in the area, and also other emerging related topics. An experienced senior postdoc from the Manchester Geomicrobiology

group (Dr Thanos Rizoulis), who had delivered the bioinformatics training on day 1, gave an overview of genome sequencing technologies, applied to metal-reducing systems and then Dr Mike Wilkins (Pacific Northwest National Lab, Richland USA) discussed the use of proteomic tools to monitor Fe(III)- and U(VI)-reducing aquifer microbial communities. After the morning coffee break, Prof Roy Goodacre (Manchester Interdisciplinary Biocentre) gave a lecture on the application of complementary metabolomics techniques for studying microbial systems, including Fe(III)-reducing systems. Prof Lloyd then gave an overview of the biotechnological exploitation of Fe(III)-reducing bacteria, covering bioremediation, catalysis, biomedical and energy-related applications. Prof John Coates (University of California, Berkeley) then covered Fe(II) oxidation at neutral pH, and Prof Yeala Shaked (Hebrew University) gave a lecture on the importance of iron cycling in marine planktonic systems, including a discussion of microbial iron uptake systems.

Part 2: Bangor University

The group transferred to North Wales on the morning of Wednesday Jan 18th. After a brief introduction to Bangor University, the course co-director Prof Barrie Johnson discussed the specialised techniques required for the isolation, cultivation and identification of iron-oxidizing/reducing acidophiles, which have been the longstanding focus of the Bangor group's interests. After a coffee break, Dr Kevin Hallberg, also from Bangor, gave the first of two lectures on DNA-based methods for characterizing acidophilic microbial communities, including PCR-based profiling techniques such as T-RFLP, that have been developed extensively by the group. The second follow-up lecture on this topic was delivered on the morning of Thursday 19th by Dr Hallberg, and then recent advances in acidophile "environmental genomics" were described by Bangor academics Professor Dr. Peter Golyshin and Dr. Olga Golyshina. The application of complementary proteomics approaches to the study of Fe(II)-oxidising acidophiles was covered by Dr Mark Dopson (Linnaeus University, Sweden). Subsequent lectures covered environmental aspects of these extremophilic organisms (two lectures by Professor Axel Schippers, BGR Hannover; Germany). The second of these was delivered on the Friday morning, followed by a lecture by Prof Barrie Johnson on biotechnological applications of acidophilic Fe(II)-oxidisers, principally in the mining sector, for bioleaching of various ore types. New work on the application of acidophilic Fe(III)-reducing bacteria was also described.



Laboratory classes; Bangor University

In the afternoon of the final day, the attendees were taken to Parys Mountain, an abandoned copper mine, that has been the focus of much acidophile research, most notably by the Bangor group. Upon return, the final session allowed the teaching staff and attendees to discuss the key themes covered during the course, and explore synergies across the two sides of the Fe redox side covered, while drawing important parallels between acidic and near neutral systems. Feedback was also collected (see section 3).



Parys Mine field trip

Attendee participation. There was plenty of opportunity throughout the workshop for the early-stage researchers to interact with the teaching staff. On each day, there were coffee and lunch and dinner breaks attended by the staff at Manchester and Bangor, with considerable mixing at each opportunity. The lectures were also informal, with attendees (and members of the teaching team) encouraged to ask questions throughout. Finally, on the Monday, Tues and Wednesday evenings, there were short presentations by the attendees, on their own research interests.

3) Assessment of the results and impact of the event on the future direction of the field

The following template was used to obtain feedback on the course. The overwhelming response was exceptionally positive, with a cumulative total against each question shown in the table below. There was little negative feedback, although one respondent did note that it would have been better if we could have provided nicer weather for the workshop! Several attendees praised the breadth of information provided, the quality of lectures and the usefulness of the practical sessions.

An obvious quantifiable outcome of the meeting is the number of attendees who expressed a strong interest in applying for upcoming FIMIN travel grants to develop their microbiological skills further. The organizers are working with several PhD students from the workshop on follow-up applications.

Evaluation Fe Geomicrobiology Course Manchester/Bangor 16-20th March 2012

Attending the course was useful for performing my PhD project.	agree 16	-	-	-	disagree -
The content of the course fulfilled my expectations.	agree 12	4	-	-	disagree -
I learnt about new concepts / techniques / and other aspects of iron geomicrobiology	agree 15	1	-	-	disagree -
Diversity of subjects presented during the course	too high 3	3	10	-	too low -
Scientific level of the lectures	too high 3	3	10	-	too low -
The field trip was relevant and of value for me.	agree 12	4	-	-	disagree -
The course gave me the opportunity to discuss my research questions with other PhD students/researchers.	agree 12	3	1	-	disagree -
The course gave me the opportunity to discuss my research questions with the invited speakers.	agree 12	3	1	-	disagree -
Attending the course was useful for expanding my professional network.	agree 13	3	-	-	disagree -
The course was well organized.	agree 15	1	-	-	disagree -
The course has encouraged me to apply for a travel grant within FIMIN in the future.	Yes 7	2	7	-	maybe no -
I would like to attend the final FIMIN conference	Yes 11	5	-	-	maybe no -
I plan to apply for upcoming FIMIN training activities (workshops)	Yes 6	2	8	-	maybe no -
The most useful aspect of the course for me was...					
The course could have been more useful if....					

4) Final Meeting Programme □

Monday, January 16th

- Tea/coffee and registration in the Williamson Research Centre for Molecular Environmental Science, within the School of Earth, Atmospheric and Environmental Sciences, University of Manchester 10.00-10.20
- Introduction to course and welcome to the University of Manchester: JRL 10.20-10.30
- Introduction to the microbial iron cycle: JRL 10.30-11.00
- Cultivation of Fe(III)-reducing microorganisms (lecture): JRL 11.00-12.00
- The Fe mineral-microbe interface: DJV 12.00-13.00
- Lunch 13.00-14.00
- Cultivation and molecular ecology of Fe(III)-reducing bacteria including demonstrations/practicals in the Geomicrobiology Laboratories: JRL, CB, AR and VC 14.00-17.00
- Student presentations: 17.00-18.00
- Dinner 19.00

Tuesday, January 17th

- Genomics and Fe(III)-reducing systems: AR/JRL 9.00 – 10.00
- Proteomics: MJW 10.00-10.45
- Coffee: 10.45-11.00
- Metabolomics: RG 11.00-12.00
- Applications of Fe(III)-reducing bacteria: JRL 12.00-13.00
- Lunch 13.00-14.00
- Fe(II) oxidation at neutral pH: JC 14.00-15.30
- Tea/Coffee: 15.30-15.45
- Fe inputs and availability: YS 15.45-17.00
- Student presentations 17.00-18.00
- Dinner (Manchester curry house)

Wednesday, January 18th

- Transfer from Manchester; leave 10.00 arrival at Bangor 13.00
- Lunch (at the Management Centre) 13.00-14.00
- Welcome and introduction to Bangor University; DBJ, 14.00 – 14.15
- Isolation, cultivation and identification of iron-oxidizing/reducing acidophiles: DBJ, 14.15 – 16.15
- Coffee, 16.15 - 16.30
- DNA-based methods for characterizing acidophilic microbial communities (part 1): KBH, 16.30 – 18.00
- Student presentations 18.00-19.00
- Return to the Management Centre and evening meal.

Thursday, January 19th

- DNA-based methods for characterizing acidophilic microbial communities (part 2): KBH, 9.00 – 10.00
- Coffee 10.00 - 10.15
- Environmental Genomics: PG/OG, 10.15 -12.30
- Lunch (Management Centre) 12.30-13.30
- Proteomics applied to acidophilic microorganisms: MD, 13.30 – 16.00
- Coffee 16.00 - 16.15
- Environmental Aspects, part 1: AS, 16.15 – 18.00
- Return to the Management centre. Workshop dinner 18.00

Friday, January 20th

- Environmental Aspects, part 2: AS, 9.00-10.00

- Coffee, 10.00 – 10.15
- Current and Emerging Biotechnologies that Utilize Iron—metabolizing Acidophiles: DBJ 10.15 – 11.45
- Lunch (Management Centre) 12.00- 13.00
- Depart for Parys Mountain visit, 13.00
- Return to Bangor University, 16.00
- Resume, final discussions and feedback; Jon Lloyd and Barrie Johnson to lead, 16.00-18.00

Saturday, January 21th
Departure from Bangor

List of speakers

Instructors (Manchester)

Professor Dr Jon Lloyd (JRL; University of Manchester)
 Professor Dr David Vaughan (DJV; University of Manchester)
 Mr Christopher Boothman (CB; Geomicrobiology Experimental Officer, University of Manchester)
 Dr Thanos Rizoulis (AR; University of Manchester)
 Dr Vicky Coker (VC; University of Manchester)
 Professor Dr Roy Goodacre (RG; University of Manchester)
 Dr Mike Wilkins (MJW; PNNL, USA)
 Professor Dr John Coates (JD; University of California, Berkeley)
 Professor Dr. Yeala Shaked (YS; Hebrew University)

Instructors (Bangor)

Professor Dr. Barrie Johnson (DBJ; Bangor University)
 Dr. Kevin Hallberg (KBH; Bangor University)
 Dr. Sabrina Hedrich (SH; Bangor University)
 Professor Dr. Peter Golyshin (PG; Bangor University)
 Dr. Olga Golyshina (OG; Bangor University)
 Dr. Mark Dopson (MD; Linnaeus University, Sweden)
 Professor Dr. Axel Schippers (AS; BGR Hannover; Germany)