SERVICES & FACILITIES ANNUAL REPORT - FY April 2014 to March 2015

SERVICE	FUNDING	AGREEMENT	ESTABLISHED as S&F	Term 2yrs extended by 6 yrs
FENAC	BLOCK	PR120021	2009	

TYPE OF SERVICE PROVIDED:

The Facility for Environmental Nanoscience Analysis and Characterisation (FENAC) provides a unique service meeting the needs of the 'environmental nanoscience' community. Originally envisaged as a service supporting the (eco)toxicological community investigating the biological impact of manufactured nanomaterials*, FENAC also underpins the wider environmental community looking at manufactured nanoparticle chemistry and transport, along with incidental (combustion, industry etc) and natural (microbial, weathering etc.) nanomaterials and research work into potential applications of nanomaterials in, for example, environmental remediation or alternative energy. FENAC provides access and analysis for relevant samples, helping FENAC users through the whole process from experimental design to data analysis, in a fully collaborative manner. For doctoral and postdoctoral researchers carrying out measurement and data analysis, the discussions during training have provided a sound basis for future work. In some years, FENAC has also trained researchers more formally through 2 day summer schools, also leveraging NERC Knowledge Exchange programmes and University of Birmingham support.

Professor Eugenia Valsami-Jones was director of FENAC during 2014-2015, Dr. Iseult Lynch was Deputy Facility Director, Dr. Christine Elgy was facility manager and Dr. Maria Thompson and Eimear Orgill provided technical support (5% FTE) within FENAC. The facility offers a unique combination of experimental, analytical and metrological methodologies and the expertise to deploy such methods appropriately. There is competitive access to FENAC, with submissions due every 6 months.

*Nanomaterials, defined as having at least one dimension between 1 and 100 nm, are of three types: manufactured (deliberately produced), incidental (accidentally produced) and natural (produced by natural sources). FENAC offers a unique, proven ability to characterise and interpret the physico-chemical properties of nanoparticles from all sources, including complex environmental matrices (e.g. organisms), for properties including size, aggregation properties, surface behaviour, dissolution and morphology. Using a multi-method approach, FENAC incorporates a number of methods grouped as:

Microscopy (atomic force microscopy (AFM), confocal laser scanning microscopy (CLSM) and electron microscopy, including scanning, environmental scanning, scanning tunnelling and transmission electron microscopy (SEM, ESEM, STEM and TEM));

Spectroscopy (electron energy loss spectroscopy (EELS), x-ray energy dispersive spectroscopy (X-EDS), x-ray photoelectron spectroscopy (XPS), fluorescence correlation spectroscopy (FCS), and inductively-coupled plasma – mass spectrometry (ICP-MS));

Separation (including field–flow fractionation (FFF), ultrafiltration (UF), analytical ultracentrifugation, (AUC), disc ultracentrifugation and dialysis);

Other techniques, including dynamic light scattering (DLS), nanoparticle tracking analysis (NTA), differential centrifugal sedimentation (DCS), x-ray diffraction for crystal structure and surface area measurements by BET.

ANNUAL TARGETS AND PROGRESS TOWARDS THEM

FENAC has provided support for 14 projects during the 2014-2015 year. Of these, five are completed and nine on-going. The projects cover diverse topics: the protein corona around nanoparticles, Xenopus embryo nanoparticle uptake, nanoparticles in aluminium mine wastes, and marine colloids. Method development for probing the surface hydrophobicity of nanoparticles by AFM has been carried out. Presentations have been made at conferences and meetings, to promote the work of FENAC. Demand for work at FENAC has remained strong throughout 2014, with 15 applications to FENAC and 7 projects funded.

SCORES AT LAST REVIEW (each out of 5)		Date of Last Review:		
Need	Uniqueness	Quality of Service	Quality of Science & Training	Average
5	4.5	4.5	5	4.75

CAPACITY of HOST ENTITY FUNDED by S&F	Staff & Status	Next Review (March)	Contract Ends (31 March)
20%	Professor Eugenia Valsami-Jones (3 hrs/wk); Dr. Christine Elgy (100% FTE); Eimear Orgill and Dr Maria Thompson (5% FTE combined)	2017	2017

FINANCIAL DETAILS: CURRENT FY						
Total Resource Allocation	Unit Cost £k			Capital Expend £k	Income £k	Full Cash Cost
£128.605k	£0.503k per day	£0.04k per hour electron microscopy	£0.06k per 10 icp-ms samples			£137.61k

FINANCIAL COMMITMENT (by year until end of current agreement) £k				
2014-15 128.605	2015-16 127.00			

STEERING COMMITTEE	Independent Members	Meetings per annum	Other S&F Overseen
FENAC	8	2	0

APPLICATIONS: DISTRIBUTION OF GRADES (current FY — 2014/15)													
	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**R***	**Pilot**
NERC Grant projects*													
Other academic			2	1									
Students			3			2	2		1		2	1	1
TOTAL			5	1		2	2		1		2	1	1

APPLICATIONS: DISTRIBUTION OF GRADES (per annum average previous 3 financial years —2011/2012, 2012/2013 & 2013/2014)													
	10	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	**R***	**Pilot**
NERC Grant projects*				0.67			0.33					0.67	
Other academic			1.00	1.33		0.67	0.67		0.33		0.33	0.33	1.00
Students			1.33	1.67		0.67					0.33	0.33	1.00
TOTAL			2.33	3.67		1.33	1.00		0.33		0.67	1.33	2.00

PROJECTS COMPLETED (current FY – 2014/15)												
	10 (α5)	**9**	**8 (α4)**	**7**	**6 (α3)**	**5 (α2)**	**4**	**3 (α1)**	**2**	**1 (β)**	**0 (Reject)**	**Pilot**
NERC Grant projects*				1								
Other Academic												1
Students			2	1								

For Projects worked on

Project Funding Type (current FY – 2014/15) (select one category for each project)										
Grand Total	**Infrastructure**					**PAYG**				
	Supplement to NERC Grant *	**PhD Students NERC**	**PhD Students Other**	**NERC Centre**	**Other**	**NERC Grant***	**PhD Students NERC**	**PhD Students Other**	**NERC Centre**	**Other**
14	2	1	4		7					

Project Funding Type (per annum average previous 3 financial years - 2011/2012, 2012/2013 & 2013/2014)										
Grand Total	**Infrastructure**					**PAYG**				
	Supplement to NERC Grant *	**PhD Students NERC**	**PhD Students Other**	**NERC Centre**	**Other**	**NERC Grant***	**PhD Student NERC**	**PhD Student Other**	**NERC Centre**	**Other**
12	0	3.33	4	0		4.67				

For projects worked on

User type (current FY – 2014/15) (include each person named on application form)				
Academic	**NERC Centre**	**NERC Fellows**	**PhD Students**	**Commercial**
28	**0**	**2**	**6**	**1**

User type (per annum average previous 3 financial years - 2011/2012, 2012/2013 & 2013/2014)				
Academic	**NERC Centre**	**NERC Fellows**	**PhD Students**	**Commercial**
12.00	**0.00**	**0.33**	**4.67**	**0.00**

For projects worked on

OUTPUT & PERFORMANCE MEASURES (current year)										
Publications (by science area & type) (calendar year 2014)										
SBA	**ES**	**MS**	**AS**	**TFS**	**EO**	**Polar**	**Grand Total**	**Refereed**	**Non-Ref/ Conf Proc**	**PhD Theses**
	2	**2.5**	**1**	**7.5**			**13**	**7**	**5**	**1**

Distribution of Projects (by science areas) (FY 2014/15)							
Grand Total	**SBA**	**ES**	**MS**	**AS**	**TFS**	**EO**	**Polar**
14	**0.33**	**4.33**	**1.83**		**7.5**		

OUTPUT & PERFORMANCE MEASURES (per annum average previous 3 years)										
Publications (by science area & type) (Calendar years 2011, 2012 & 2013)										
SBA	**ES**	**MS**	**AS**	**TFS**	**EO**	**Polar**	**Grand Total**	**Refereed**	**Non-Ref/ Conf Proc**	**PhD Theses**
	1.00	**4.00**		**9.67**			**14.67**	**7.33**	**7.33**	

Distribution of Projects (by science areas) (FY 2011/2012, 2012/2013 & 2013/2014)							
Grand Total	**SBA**	**ES**	**MS**	**AS**	**TFS**	**EO**	**Polar**
10.67	0.11	0.78	4.28	**0.33**	5.17	0	**0**

For projects worked on

Distribution of Projects by NERC strategic priority (current FY 2014/15)							
Grand Total	**Climate System**	**Biodiversity**	**Earth System Science**	**Sustainable Use of Natural Resources**	**Natural Hazards**	**Environment, Pollution & Human Health**	**Technologies**
14	**0**	**0**	**2.5**	**0.33**	**0.83**	**9.83**	**0.5**

**Either Discovery Science (Responsive Mode) or Strategic Science (Directed Programme) grants*

OVERVIEW & ACTIVITIES IN FINANCIAL YEAR (2014/15)

In the past year, work at FENAC has supported a range of projects seeking better characterisation of nanoscale materials and processes. We present a short selection of highlights from these projects in the relevant section below.

FENAC has undertaken a programme of centralisation of laboratory equipment, which will continue into 2015/2016. A new clean area has been built within the FENAC laboratory which now houses the single particle inductively coupled plasma-mass spectrometer instrument (SP ICP-MS) with the capability of determining the size and concentration of nanoparticles and the level of dissolved ions from the nanoparticles at the same time, making it ideal for dissolution studies. The inductively coupled plasma-optical emission spectrometer (ICP-OES) has been installed within the main FENAC laboratory. This instrument covers a broader range of elements with higher sensitivity than originally envisaged, and will be particularly useful for elements which cannot be analysed by atomic absorption spectroscopy. The atomic force microscope has also been re-located to the FENAC laboratory. There are a number of advantages from the centralisation: the time saved in journeys across campus the use equipment; the efficient use of cancelled time slots on heavily booked equipment; the opportunity to run more than one experiment at a time when the equipment is in the same laboratory.

Environmental science research could be more strongly represented in applications to ISIS, the pulsed neutron and muon source at the Rutherford Appleton Laboratory, and Diamond Light Source, the UK's national synchrotron science facilities. The FENAC manager visited ISIS or Diamond in early 2015 to develop an understanding of the way in which work at the facilities could benefit environmental nanoscience research. This will enable FENAC to provide advice to our users about the opportunities for work at these facilities.

Presentations have been made at conferences and meetings, to promote the work of FENAC. These are listed in Appendix 1.6.

The potential to expand the activities of FENAC by improving interactions with industry has been discussed and preliminary work to this end has commenced, with support from NERC, the University of Birmingham and the FENAC steering committee (see Annex 1.4).

SCIENCE HIGHLIGHTS. *To focus on economic and societal impacts and benefits where possible*

Are iron nanoparticles in wet deposition a potential source of bioavailable Fe to marine algae?
Zongbo Shi, University of Birmingham

The iron (Fe) biogeochemical cycle has a critical influence on primary production in large areas of the oceans, and consequently has the potential to impact on climatic change through the fixation of atmospheric carbon by phytoplankton, with the potential for significant benefits to the environment. Iron nanoparticles (FeNPs) are known to occur in rainwater (Shi et al., 2009) as a result of atmospheric processing of mineral dusts, and thus are a potential source of bioavailable Fe in high nitrogen, low carbon (HNLC) areas of the ocean through wet-deposition. The extent to which Fe (ferrihydrite) nanoparticles are bioavailable to a model marine diatom *Thalassiosira pseudonana* was investigated, with nanoparticle characterisation carried out at FENAC. The study has produced significant data and a paper is in preparation from this work.

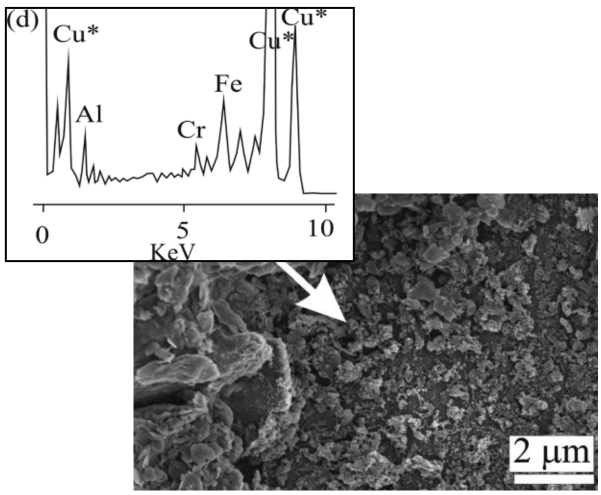

Figure 1. SEM and XRD data for ferrihydrite nanoparticles

Characterising silver nanoparticle stability in suboxic waters. Dan Lapworth, British Geological Survey
This study has characterised the changes in physical and chemical characteristics of capped and uncapped AgNP within synthetic sub-oxic aqueous matrices following exposure to S2-, and in the presence/absence of humic-like material. The stability of AgNPs due to the formation of Ag-sulphide and Ag- organic matter interactions was evaluated and tested. This work is important to understand the forms of silver found in the suboxic regions of lakes where the solubility and stability of the nanoparticles will influence the bioavailability and so the toxicity of the AgNPs to organisms in that environment.

Endocytic pathways of iron absorption from iron nano-iron compounds using an in-vitro

digestion/Caco-2 cell model system: Susan Fairweather-Tait

Iron deficiency is the most prevalent nutritional deficiency in the world. Iron fortification of staple foods or condiments directed to the whole population is a sustainable and an effective low-cost approach. Currently, strategies are being developed to synthesize novel nano-sized iron supplements and fortificants that are safe and bioavailable. This work could have an impact on human health and nutrition throughout the world. Uptake mechanisms of iron nano-compounds are under examination, and it is essential to characterise the nanoparticle dispersion in the reaction medium for this work. The media under study was extremely complex and was found to contain various types of nanoparticles. Dynamic light scattering proved unsuitable for examining the changes in the iron containing nanoparticles under these conditions. Although the disc centrifuge is not generally considered suitable for mixtures of different nanoparticles, as the particle size can only be determined if the density of the material is known, for this project FENAC used the disc centrifuge to characterise the media under the various experimental conditions, and the iron containing nanoparticles in water, and obtain 'fingerprints' for the material. This enabled us to identify changes occurring to the nanoparticles when they were introduced into the media, and to follow changes occurring throughout the reaction process. The insight from FENAC, and development work carried out there has benefitted the project.

Isotopically modified silver nanoparticles to assess nanosilver bioavailability and toxicity at environmentally relevant exposures. FENAC development work

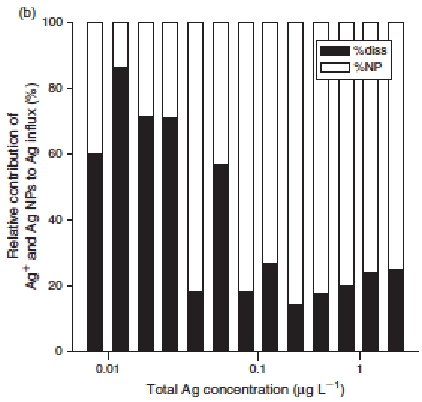

Figure 2: Relative contribution of Ag^+ and AgNPs to the overall Ag influx in the snail *Lymnaea stagnalis*.

Development work took place at FENAC to assess the advantages of silver nanoparticle (AgNP) stable isotope labelling as a tracing technique. A study published last year (Croteau et al, 2014) demonstrated that the pattern of Ag influx into the body of a snail, when exposed to AgNPs, changes as a function of concentration and a considerable amount of uptake from nanoparticulate (vs dissolved) Ag occurs at lower exposure concentrations (see Figure 2). These lower exposures were only possible due to the stable isotope tracer, thus demonstrating the applicability and importance of this technique developed at FENAC.

1. Handley-Sidhu et al. (2014) Bacterially produced calcium phosphate nanobiominerals: sorption capacity, site preferences, and stability of captured radionuclides. Environ Sci Technol. Jun 17;48(12):6891-8. **Impact Factor 5.481**
2. Beddow et al. (2014). Effects of engineered silver nanoparticles on the growth and activity of ecologically important microbes Environmental Microbiology Reports, 6, 448-458. **Impact Factor 3.264**
3. Kadar et al. (2014) Chemical interaction of atmospheric mineral dust-derived nanoparticles with natural seawater - EPS and sunlight-mediated changes. Science of the Total Environment, 468-469, 265-271. **Impact Factor 3.163**
4. Kadar et al. (2014) Colloidal stability of nanoparticles derived from simulated cloud-processed mineral dusts. Science of the Total Environment 466-467, 864-870. **Impact Factor 3.163**

FUTURE DEVELOPMENTS/STRATEGIC FORWARD LOOK

FENAC will continue to support the research of NERC's nanoscience community and enable access to a great diversity of users who require a better understanding of nanoscale properties to solve problems ranging from atmospheric pollution to nuclear waste disposal and from nano-bio interactions to artefact characterisation.

FENAC has begun to investigate new approaches to maximising the facility's impact; one such approach is to support more interactions with industry by providing a modest amount of advice and/or training.

Another aspect of interest for the forthcoming year to explore, pending funding applications, is the development of automated systems of nanoparticle synthesis and processing (e.g. suspension and characterisation), so as to maximise experimental reproducibility.

Non-Mandatory Facility-specific OPMs: utilisation, allocation of capacity etc