

Rheology, nano/microFluidics and bioFouling in the Oceans (RheFFO) Working Group

Newsletter #3 (29 June, 2016)

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INTRODUCTION

Since the last newsletter, *RheFFO*-02, in November 2014, *RheFFO* has welcomed 12 new members and it has held four International Workshops. We applied in 2014 to the Scientific Committee for Ocean Research (SCOR) for endorsement, but this was not retained. We made a more detailed application in 2015, but this was again not retained at the SCOR's Annual Meeting in December 2015. I have thus decided not to apply in 2016. It may be that we need to reconsider the best way forward for the *RheFFO* working group (WG). After the four WGs in the last 12 months, two more opportunities may exist, one during the World Rheology Conference in Kyoto, Japan in August 2016, and another during the International Conference on Harmful Algae, to be held in Florianopolis, Brazil in October. I encourage and implore members to come forward with their ideas for collaboration between ocean and lake scientists, rheologists, and surface scientists, so that we can educate each other, and each others' students, to apply *RheFFO* interdisciplinary ideas to solving pressing problems in natural waters, where

possible with economic innovative applications.

HONOUR

Congratulations are due to *RheFFO* member



Elisa Berdalet! She has become **Chair of GlobalHAB** the Unesco-IOC (Intergovernmental Oceanographic Council) Harmful Algae Bloom Programme. Dr Berdalet is

also Vice-Director of the Marine Biology and Oceanography Department, Consejo de Investigaciones Científicas, Barcelona, Catalunya, Spain.

NEW MEMBERS

New members having joined *RheFFO* since Newsletter-02 on 2014-11-08 are:

Dr Myriam BORMANS

Dr Bormans is Research Director at the



National Centre for Scientific Research and at the Université de Rennes I, France. Among her specialisms are; the role of turbulence in phytoplankton dynamics,

colony formation and EPS production, and morphological traits-based ecology. She provides experimental grid stirred tank, and NanoSIMS (Secondary Ion Mass Spectrometry) expertise

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<http://acro.pagespro-orange.fr/RheFFO>

Dr Jinju (Vicky) CHEN

Lecturer in NanoBiomechanics, in the Dept. of



Mechanical and Systems Engineering, Newcastle University, England. Her specialisms include modelling and experimental characterisation of rheology of biofilms,

biofilm formation, and biofilm attachment as well as microfluidics for biofilm characterisation

Dr Mariachiara CHIANTORE

Dr Chiantore is Associate Professor in

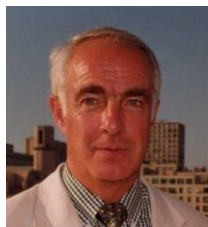


Ecology at DiSTAV, Dept. of Earth, Environmental and Life Sciences at the Università di Genova, Italy. Her specialisms include modeling and mitigation of benthic harmful algal

blooms. Ecology of *Ostreopsis* spp., especially environmental triggers and toxic effects.

Dr Michel DENIS

Dr Denis is Research Director (“emeritus active”) at the French



National Centre for Scientific Research, now based at the Mediterranean Institute of Oceanology, Marseille, France. Dr Denis is very experienced

in plankton ecology, and is a pioneer of applying flow cytometry (FC) to plankton studies. In recent work he has been using FC in studies of picoplankton vertical migration, possibly modulated by mucus or TEP.

Ms Valentina GIUSSANI

Valentina is a doctorant at Dept of Earth and



Environmental Science, University of Genoa, Italy. She specialises in Ecotoxicology and management of benthic harmful algal blooms, especially in relation to their mucilaginous matrix.

Dr Rodrigo J. GONÇALVES

Researcher at the National Council of



Scientific and Technological Research of Argentina (Consejo Nacional de Investigaciones Científicas y Técnicas -CONICET). Workplace: Estación de Fotobiología Playa Unión

Chubut, Argentina. Vice-Director (ad honorem) Estación de Fotobiología Playa Unión. Head of Animal Ecology research area (ad honorem) Estación de Fotobiología Playa Unión. Research on: responses and adaptation of zooplankton to combined physical and biological environmental factors; Ecological study of plankton motility

Dr Moshe HAREL

Dr Harel is CEO of Sha'ked Microbial



Solutions Ltd., Tel Aviv, Israel. His work includes mutual relationships between the freshwater cyanobacterium *Microcystis* sp. and dynamics of EPS.

Dr Xavier MARI

Researcher, Institute of Research for



Development, Marseille, France. His research includes: characterisation of marine transparent exopolymeric particles (TEP), measuring sinking and rising, cohesive properties, aggregation dynamics in oceans and estuaries.

Prof Dr Javeed Shaikh MOHAMMED

Head, Faculty of Innovative Design and



Technology, Universiti Sultan Zainal Abidin, Kuala Terengganu, Malaysia. His research includes: biological microelectromechanical systems (BioMEMS), nanotechnology, microfluidics, hydrogels.

Dr Michael ORCHARD

Postdoctoral Researcher at the School of Life



Sciences, University of Lincoln, Joseph Banks Laboratories, Lincoln, England. His research includes high-speed videomicroscopy of predation in marine protists, adhesion, rheology and

surface science

Dr Massimo VASSALLI

Dr Vassalli is a researcher at CNR, the



National Research Council, Biophysics Institute, Genoa, Italy. He uses physical tools such as atomic force microscopy and optical tweezers to measure physical

properties of biological systems (mainly mechanics and rheology of cells, gels and proteins).

Prof Dr Tracy A. VILLAREAL

Dr Villreal is professor at the Marine Science



Institute and Dept. of Marine Science, University of Texas at Austin, USA. His research includes: phytoplankton ecology, notably the ecology of oceanic phytoplankton, vertical migration, growth

and nitrogen fixation in diatom symbioses. His lab uses both field and laboratory studies to understand phytoplankton responses.

Prof Dr Dun ZHANG

Prof. Zhang is Head of the State Key

Laboratory for Marine Corrosion and Biofouling, Institute of Oceanology Chinese Academy of Sciences, Qingdao, P.R. China. Among other topics, she specializes in biofouling and corrosion of surfaces, notably in relation to "green" (non-toxic) anti-biofouling, modulated by the sculpturing and other physico-chemical properties of surfaces, including biomimicry.

PROPOSAL TO SCOR

For *RheFFO* members who have not already heard, our second proposal to SCOR, the Scientific Committee on Ocean Research, for endorsement as a SCOR working group was not retained at the [SCOR Annual Meeting in Goa, India, 7-9 December 2015](#). This was despite having improved the WG and the proposal since the first submission in 2014. We have not submitted a new proposal for 2016. While this eliminates the possibility to receive SCOR funding for meetings and workshops, with the accompanying prestige, it does give the *RheFFO* WG more freedom of structure, membership and action. We need to discuss how to structure our WG activities in the new situation.

IRJ

**International Workshops on Rheology macro/
nanoFluidics and bioFouling in the Ocean and other
natural waters – Reports.**

**First International *RheFFO* Workshop, held at Qingdao,
P.R. China, 8th October 2015.**



Time and place:

The First International Workshop on *Rheology nano/microFluidics and bioFouling in the Oceans and other natural waters (RheFFO)* was held on 8th October 2015 in the meeting room of the *Chinese Journal of Oceanology and Limnology*, at the Institute of Oceanology Chinese Academy of Sciences (IOCAS), Qingdao, People's Republic of China.

Programme

Thursday 8 October (Meeting room 514, 5th Floor, Bldg 7)

0815 Arrival, tea/coffee

0830 **Posters:**

L. Seuront, J.G. Mitchell & L. Schapira

On a possible contribution of microbial and phytoplankton communities to seawater viscosity in Antarctic waters.

L. Seuront, I. Kesaulya, D. Vincent & J.G. Mitchell

Phytoplankton viscosity and phytoplankton biomass during a spring bloom of *Phaeocystis globosa* in the eastern English Channel.

Discussion document.

T. Wyatt

“Cardiovascular” phytoplankton.

0900 **Ian Jenkinson**

Opening, Welcome, Practical information.

0930 Round-table introductions and personal biographies.

10.00 **Jim Mitchell & Annie Taylor**

The Sino-Australian COLOMBO plan including exchange of graduate students.

10.20 **Jim Mitchell**

Chemotaxis in *Vibrio corallyticus* coral mucus

10.50 **Zhuo Li**

The use of microfluidics in rheology

11.20 **Ian Jenkinson**

Thoughts on thalassorheology

11.50 **Group photograph**

12.00 **Working lunch** (Wu Sheng Guan Holiday Hotel)

14.10 **Michel Denis**

Evidence for pulsed exportation in the water column of the north-western Mediterranean Sea.

15.00 Institute Director Song Sun welcomes the Australian delegates.

16.00 **Elisa Berdalet & Magda Vila** (via video link)

The rheological characteristics of the *Ostreopsis* sp. blooms. Open questions

16.30 **Sophie Leterme**

Biofilms, biofouling and extracellular polymeric substances.

17.00 **Peng Wang**

Slippery liquid porous surfaces for inhibition of microbiologically influenced corrosion.

17.30 **Jim Mitchell & 10 al.**

Diatom frustule nanostructures improve nutrient uptake.

18.00 **Ian Jenkinson**

Nano/microfluidics around phyto- and zooplankton.

1830 **Discussions**

2000 **Closed Workshop.**



Participants present at the First International *RheFFO* workshop, Qingdao, 8th October 2015. From left to right: Peng Wang, Ian Jenkinson, Michel Denis, Sophie Leterme, Jim Mitchell, Zhuo Li, Annie Taylor. Participants at a distance were Elisa Berdalet, Laurent Seuront and Tim Wyatt.

Sponsorship by the following organizations is gratefully acknowledged.

- [IOCAS](#) and the **Chinese Society of Oceanology and Limnology**, through the [Chinese Journal of Oceanology and Limnology](#), provided sponsorship in kind for the workshop by hosting it in CJOL's rooms within IOCAS.
- **IOCAS** and **ACRO (Agence de Conseil et de Recherche Océanographiques)**, France jointly sponsored the meeting through the participation of Ian Jenkinson.
- **IOCAS** sponsored the participation of Peng Wang.
- **Flinders University**, Adelaide, S. Australia provided sponsorship by sending three delegates, Jim Mitchell, Sophie Leterme and Annie Taylor to participate in the workshop.
- CSIC, Barcelona, Catalunya, Spain.
- CSIC, Vigo, Galicia, Spain.
- University of Science and Technology, Lille, France
- Tongji University, Shanghai, China.
- Mediterranean Institute of Oceanography, Marseille, France.

Report

0900. Ian Jenkinson gave a welcoming talk, introducing the ideas behind the *RheFFO* working group (WG). *RheFFO* WG has been submitted to SCOR for consideration for endorsement and funding, but this has not been obtained yet. The decision will be made and announced at the SCOR executive meeting to be held in Goa, India on 9-10th December 2015. Ian drew attention to the [RheFFO web site](#). The WG is limited to 20 members in its core section, and there are two more members in the extended WG. WG members are strongly encouraged to submit their publications related to *RheFFO* topics to Ian, who will list them on the *RheFFO* website with a *RheFFO* number as *RheFFO*-endorsed publications. It is hoped that this will encourage members to read (or at least have a look at) each other's publications to understand the scope of the *RheFFO* set of disciplines.

0930. Round-table introduction by the members present to their background.

1000. Presentation 1. Annie Taylor presented the COLOMBO program that will pay Australian students to go to China for 3 months during their Honours Degree to do research. Qingdao City government and National JRC with Qingdao/Flinders Uni. There is a need to find placements for the Australian students in China, particularly in Qingdao. This was followed by a discussion.

1020. Presentation 2. Jim Mitchell gave a talk about coral mucus and motility and chemotaxis in the bacterium *Vibrio corallyticus*, which occurs in association with this mucus. At high speeds the mechanical traction between the bacterial flagellum and the mucus collapses so misguides and turns (flick). Higher viscosity results in slower speed and less turning, thus efficiency.- Dimethylsulphoniopropionate (DMSP) is produced by symbionts in coral. It is a source of energy for bacteria but also impacts cloud cover. DMSP also impacts gene copies in bacteria. Energy requirement increases with viscosity but diffusivity decreases. He also mentioned work in his group about human mucus and associated bacteria (sphingosines).

In the discussion about vibrios and mucus, it was noted that biofilms limit bacterial movement across membranes. Vibrios can burrow as well as move along a surface. Their flagella rotate at 1.7 k-revolutions per second max speed.

Studies already made on polymers in others fields can provide much inspiration for the study of marine polymers and associated organisms. This is important as part of the *RheFFO* rationale.

1050. Presentation 3. Zhuo Li presented the use of microfluidics in Rheology. It included:

- Flow and deformation effects exhibited by complex systems
- Use and design of quantitative analytical tools that correctly capture rheological effects using a rheometer; development of a new rheometer to focus on micro- and nano- scale measurements
- Applying qualitative rheological knowledge to diagnostic, design and optimization problems to develop quantitative models; need for validation data.
- Viscoelastic properties of polymers
- Stagnation flow in cross-slot microfluidics with rheological measurements – use of velocity maps to measure the viscosity
- Many applications for industry, biological and physical processes
- Specific interest into treatment of sludge, which is EPS (exopolymeric polymeric substances), rather like EPS in the ocean, but generally more concentrated.

<http://cep.tongji.edu.cn>

1150. Group photo and working lunch.

1410. Presentation 4. Michel Denis presented pulsed mineralization in the NW Mediterranean Sea. It is associated with: pulsed exportation; Respiration in the water column; Abundance and viability of heterotrophic prokaryotes (flow cytometry) and respiratory activity. Important facets described were the heterotrophic prokaryote community structure; depth dependence – SYBR Green; viability propidium iodine (red); fluorescence and energy transfer cause decrease in fluorescence of SYBR

Green, decrease in fluorescence is also caused by decrease in binding sites for the two stains. Investigation was made of short-term viability. Bacterial communities can be sustained by the microzooplankton – so they can also be very abundant at 500m where the zooplankton remains during the phytoplankton diurnal migrations. There was investigation of the periodicity in the production of transparent exopolymeric particles (TEP) with regard to future modelling of pulsed export.

1445. **Institute Director Song Sun** received the visiting Australian members of the meeting in the context of promoting present and future Sino-Australian scientific collaboration.

1600. Presentation 5. Elisa Berdalet gave a ppt presentation by video link from Catalunya, Spain. Title: The rheological characteristics of the dinoflagellate *Ostreopsis* sp. blooms. The dinoflagellate *Ostreopsis* forms planktonic and benthic HABs, causing respiratory and cutaneous irritations. They grow on macroalgae but when in high quantities (bloom) they aggregate at the surface. Paradoxically, sometimes *Ostreopsis* is present but there are no irritations. There is Interest in characterizing the chemical properties of the mucus. What is the role of the mucus in the impact of *Ostreopsis* blooms in the surrounding organisms? How is gas and nutrient diffusion at the microscale of *Ostreopsis* cells? Can we characterize the rheological properties of the seawater affected by the *Ostreopsis* mucus?

Discussion: Blooms occur every year. *Ostreopsis* is found in Nice, Villefranche, Genoa, Blanes (Mediterranean) – no specific environment. She talked of the **OstreoRisk** project. Some preliminary information on the chemical composition of the mucus is available. Mucus looks different when in attached or floating form.

1630. Presentation 6. Sophie Leterme gave a ppt talk on the roles of extracellular polymeric substances (EPS), which include transparent exopolymeric polymers (TEP), in the twin themes: 1) biofilm formation and maintenance, and 2) biofouling. She stressed that EPS, which are of microbial origin, are a complex mixture of biopolymers comprising polysaccharides, proteins, nucleic acids, uronic acids, humic substances, lipids, and so on. They derive from bacterial and algal secretions, shedding of cell-surface materials, cell lysates and adsorption of organic constituents from the environment. EPS is both produced by, and comprises a physical substrate for, a wide variety of free-living and bound bacteria-based ecosystems, including biofilms, bioflocs and biogranules. Discussion continued on the importance of EPS in biofilm formation and maintenance, particularly in desalination plants, and as a precursor to biofouling.

1700. Presentation 7. Peng Wang provided a recorded PowerPoint presentation that was played and projected at the workshop. It was entitled “Slippery liquid porous surfaces (SLIPS) for inhibition of microbiologically influenced corrosion.” Superhydrophobic (SH) surfaces are sculptured surfaces with a hydrophobic coating. SLIPS repel materials such as water and dirt. SLIPS fabrication was explained. SH surfaces are used commercially for aeroplanes anti-icing surfaces, green anti-biofouling and anti-corrosion applications, as well in self-cleaning materials. As it is important to phase out toxin-based anti-fouling coatings on ships and other marine structures and replace them with green alternatives. Techniques are being improved for mass-production of nano-structured surfaces resistant to both bacteria-mediated corrosion and biofouling

1730. Presentation 8. Jim Mitchell gave us a presentation on how diatom nanostructures improve nutrient uptake. After reminding us of the varied and detailed nano structure of diatom valves (which is partly why they are so beautiful), he presented the model of how these micro/nano-structures has been modelled to interact with nano-structure of nutrient concentration in the water.

Discussion: : Some phytoplankton, including diatoms and dinoflagellates, may be able to constantly replace the polymeric liquid through pores between their structures and might thus be able to inhibit fouling and increase manage (or “engineer”) near-field shear and diffusion of nutrients, toxins and pheromones through that process. This needs investigation. The nano structures in Wang’s and Mitchell’s presentation are at similar (1 nm to 1µm) scales. This suggests that biomimicry in this field

could be a fruitful source of industrial/commercial innovation, and spur collaboration between entrepreneurs and ocean scientists.

1800. Presentation 9. Ian Jenkinson gave a talk on Nano/microfluidics around phyto- and zooplankton. It included parts on measured drag reduction and drag increase associated with phytoplankton, as well as possible effects at biological surfaces, such as zooplankton appendages. and the potential for SLIPS phenomena in phytoplankton, as well as properties of vicinal water close to surfaces, at scales including those of the nanosculpturing dealt with in the two preceding talks by Wang and Mitchell

Submitted documents

Presentation 10. Tim Wyatt provided a discussion document entitled, Cardiovascular phytoplankton. He argues that the EPS surrounding phytoplankton has many of the properties and functions of a semi-liquid organ, such as vertebrate blood. As such, it has been developed through evolution, and, as increasing research is showing, it serves a complex set of roles in biomodulating ocean structure and function.

Presentation 11. Laurent Seuront sent a first electronic poster on seawater viscosity in relation to occurrence and bloom stage of the phytoplankton *Phaeocystis globosa* as well as foam production in the English Channel. Seuront used a robust and relatively cheap commercially produced viscometer for this work. Measured viscosity was increased up to 40% compared to non-bloom seawater, due to phytoplankton EPS.

Presentation 12. Laurent Seuront sent a second electronic poster on the measured contribution by phytoplankton and bacteria to seawater viscosity in Antarctic waters. He used a viscometer similar to that in the preceding talk, and found viscosity increase up to about 80% associated with increased phytoplankton and bacterial abundance.

1830. General discussion.

Discussions ranged around several themes, including: Polymers; Surfaces; Density; Turbulence; The Ocean as a polymer matrix.

It was felt that to move forward, there is a need for one to three common foci, that can benefit from the WG's interdisciplinary composition and the professional networks of each of the members. Ideas to move forward are discussed further in the Annex.

2000. The workshop was closed.

Workshop annex – Moving forward.

The need for a programme for moving *RheFFO* forward was agreed at *RheFFO-01*.

Preamble

Practically all the bounding surfaces of the ocean, whether living or non-living are biopolymeric. These include biofilms and organisms on sediments, rocks, and glycocalyxes around bacteria and protists. The higher organisms, crustaceans, fish, whales, may be special cases. From the industrial-innovation point of view, the hulls and surfaces of ships and other structure also generally bear biofilms. Desalination membranes depollution-adsorption materials and other filters also accumulate polymer layers and biofilms, that generally seriously impede their function. Different combinations of these categories can be studied together by small, interdisciplinary representing subsets of the disciplines in this WG.

Foci

Focus 1. Making a global rheology map for the Ocean:

- a) Looking at maximum viscosity in one location of the ocean

- b) Taking into account the vertical distribution of viscosity as well as the importance of surface processes
- c) Impact of viscosity on the circulation of vessels
- d) Automated system to measure viscosity on SOOP and Argo floats
- e) Measuring viscosity using the density of the Argo float and its buoyancy?
- f) Could gliders be used? Cooperation with marine engineers
- g) Drop viscometer?
- h) Availability of IOCAS and other national fleets?
- i) Collaboration should be sought with harmful algal bloom programmes such as GEOHAB/GlobalHAB

After the meeting, we have added two more foci:

Focus 2. Intercalibration of viscometers and rheometers:

- a) Mettler/Contraves/LS30 and LS40 (used by phytoplankton cultures and seawater by Jenkinson & co-workers)
- b) ichthyoviscometers; (used for phytoplankton cultures and intertidal organic “fluff” by Jenkinson & co-workers, 2007a, 2007b)
- c) low-shear capillary viscometers (used for phytoplankton and bacterial cultures by Jenkinson & Sun, 2014)
- d) Cambridge Instruments *Viscolab* (used by Seuront & co-workers for seawater, several publications),
- e) fluorescence depolarization (used by Carlson et al. for seawater including surface slicks, but see modern characterization of scales for FD (Holyst et al, 2009, Phys. Chem. chem. Phys.))
- f) at smaller scales and for both pelagic and benthic EPS, including sediments, atomic force microscopy (AFM) is likely to be very useful, using both the imaging and the force measuring tools of AFM to complement each other.
- g) calibration with modern low-shear imposed-stress rheometers such as *Malvern*.
- h) Need to calibrate in the 3 dimensions, strain-rate, stress, length-scale, and across different deformation geometries (shearing, elongation...)

Focus 3. Surfaces

- a) Changes of water properties
 - i. $\leq 1\text{nm}$ from surface
 - ii. $\leq 1\mu\text{m}$ from surface
 - iii. $\leq 1\text{mm}$ from surface
 - iv. $\leq 1\text{m}$ from surface: Grading into turbulent regime.
- b) Adhesion and repulsion of organisms and substances (nm – cm)
 - i. Positive and negative ions
 - ii. Non-polar materials
 - iii. Organisms, incl. bacteria (s.l.), protists, zoospores and gametes
 - iv. Larvae of fouling organisms
 - v. Biofilms
 - vi. Hydrophilic vs hydrophobic surfaces, contact angle...
- c) Corrosion, electric fields and electrochemical techniques. (Wang Peng as inspiration?)
- d) Effects of nano/microgeometry
 - i. Non-living materials
 - ii. Diatoms

- iii. Dinoflagellates
 - iv. Copepods and other zooplankton, incl. filter-feeding animals
 - v. Fishes, especially their gills.
 - vi. Fishes, especially their outer surfaces, scales, slime and swimming
 - vii. Other living organisms
- e) Effects of slime on surfaces
- i. Turbulent drag reduction
 - ii. Sloughing off of foulers (interaction with item 2).

[Qingdao and La Roche Canillac, 2016-06-18, compiled by Ian Jenkinson, with the help of the *RheFFO*-01 participants.]

Second International *RheFFO* Workshop, held in Shanghai, P.R. China, 25th December 2015.

On 2015-12-25 the **Second International *RheFFO* Workshop** was held at Tongji University, Shanghai, China. The workshop was hosted by *RheFFO* member Dr LI Zhuo, Tongji University, College of Environmental Science & Engineering, Shanghai, China.

Present were **Li Zhuo, Chen Jinju, Ian Jenkinson**, and about **12-15 postdocs and graduate students** from Tongji University

Morning - Presentations

0915 Welcome and Introduction by Li Zhuo.

0930 *RheFFO* member Dr CHEN Jinju gave several talks on work in her lab in England.

The subjects covered included a considerable amount on surface-surface interactions. Further material was based on her recent paper in *Interface Focus* (Royal Society) entitled, “Nanomechanics of living cells: a review”

Dr Chen also talked about her lab’s work on nanoindentation as a measurement of mechanical properties. Living cells are much more fragile than metals, for example, to nanoindentation must use low-stress techniques such as Atomic Force Microscopy (AFM). Stiffness ranges from that of blood <1mPa to cartilaginous bone >1kPa. AFM-derived force statistic can also provide μ -scale roughness properties.

Adhesion may be considered as a nanoscale property, while bulk mechanical properties of substrates represent higher length scales

Dr Chen also presented work on bacteria and biofilms; she has funding of around 5GBP for this project from the UK.

She talked about modelling bacterial adhesion, and the pros and cons of DVLO models.

Got μ m-scale roughness from AFM force statistics.

Funding from the Engineering and Physical Sciences Research Council (EPSRC).

Ian Jenkinson gave a talk on Thalassorheology (see *RheFFO*-01)

LI Zhuo presented work done by her research group ‘see *RheFFO*-01).

1200-1330 Working lunch.

1400 - Afternoon – Visit to the lab and demonstration of the research facilities, followed by discussions

Ways to move the research forward were discussed. Conclusions were that we should try to write collectively 2-3 papers. Amongst different journals though suitable was *Water Research*.

1700 – The workshop was closed.

Third International *RheFFO* Workshop, held in Qingdao, P.R. China, 30th-31st December 2015.

On 2015-12-30 (Wed.), the **Third International Workshop on *RheFFO*** took place, again in the Chinese Academy of Sciences Institute of Oceanology, Qingdao, China, but this time hosted by Professor DUAN Jizhou in the State Key Laboratory of Marine Biofouling and Protection.

Present:

Prof Dr DUAN Jizhou, Dr WANG Peng, Dr CHEN Jinju, Prof Dr Ian JENKINSON, about 6 postdocs and graduate students from the State Key Lab on Marine Biofouling and Protection host institute.

This workshop took place principally in the form of an invited seminar by Dr Chen Jinju, followed by discussions, particularly for future collaboration.

2015-12-30. Prof Duan Jizhou welcomed the participants and introduced **Dr Chen Jinju** (School of Mechanical and Systems Engineering, University of Newcastle-upon-Tyne, England).

Presentations

Dr Chen then gave presentations of the work of her laboratory.

Biofilm formation

Important to know mechanical properties of biofilm, as then you know what forces are needed to remove it. Her laboratory has five teams, working on topics including:

- Biological modeling
- Flow and mechanics
- Ab initio parameters
- Validation
- "Seeking new biology " (incl. genomics)

In a water treatment plant there can be 10^{18} bacteria of 3000 species. They bear considerably more genes than in human genome

Some of the laboratory's work is targeted towards:

- Scaling up and integrating with flow
- Modelling floc movement relative to flow
- Using and improving OpenFOAM app. LAMMPS app. OpenFOAM app.
- Modeling effects of wall and EPS forces on bacterial growth
- Surface roughness and bacterial adhesion. Typical biofilm adhesion forces are around $\sim 0-70$ J/m². AFM is used for measurement of such forces (and can be used also for imagery of sub- μ m-scale fibrils and macromolecules – IRJ).
- MicroPIV (on slide under microscope) is also available and used in Chen Jinju's lab.
- Rheometry viscous and elastic components of biofilms is also carried out.

12.00 Working lunch

1500-1700 Discussions

Discussions had two main focuses:

- Development of collaboration on *RheFFO* topics, particularly fouling by biofilms and their formation and adhesion, as well as development of methods to eliminate biofilms., and the roles of biofilms in secondary biofouling and corrosion;

- Development of collaboration between IOCAS and the University of Newcastle. In particular, there may be finds available to recruit students to carry out doctorates in Dr Chen's lab in England.

2015-12-31

0900-1200 Continuation of discussions

1200 Working lunch

1500-1700 Continuation of discussions

1700 The workshop was closed.

Fourth International *RheFFO* Workshop, held in Newcastle-upon-Tyne, England, U.K., 14th April 2016.

On 2016-04-14 (Thur), the Fourth International Workshop on *RheFFO* took place at the University of Newcastle-upon-Tyne, England, in the School of Mechanical and Systems Engineering, hosted by **Dr CHEN Jinju**, who is a **lecturer in nano-biomechanics**. .

1030-1230

Prof. Dr. Ian Jenkinson was introduced by Dr Chen's to members of her research team, including **Dr Saikat JANA, Yunyi CAO, Samuel Geage Vere CHARLTON and Nehir KANDEMIR**, and he gave a lecture entitled, entitled **Rheometry of Natural Waters**.

1230-1420 Working lunch.

14.20 1500 Visit to the research laboratories, including the nano-PIV facility.

1600-1700. Seminar by **Ian Jenkinson**, entitled, **Rheology of Natural Waters**, to the School of Mechanical and Systems Engineering, attended by the School head, Prof. John Appleby, who asked various pointed questions, and other members of the School.

1730-2000 Working dinner, followed by visit to central, historic Newcastle and Gateshead.

2000 The meeting was closed.

Opportunities for new workshops

Before, after or during the 17th International Conference on Rheology, 8-13 August, Kyoto, Japan. *RheFFO* member LI Zhuo and Ian Jenkinson plus a grad student of Li Zhuo are already scheduled to be present at the conference. Other interested scientists please make contact!

Before after or during the 17th International Conference on Harmful Algae, 9-14 October, Florianopolis, Brazil. *RheFFO* member Elisa Berdalet and Ian Jenkinson are already scheduled to be present at the conference. Other interested scientists please make contact!

JOB OPPORTUNITY

Dr Jinju (Vicky) CHEN is recruiting a EU /UK student for a fully funded PhD project on Biofilm mechanics at the University of Newcastle-upon-Tyne, England. The student is expected to start by the end of Sept. 2016. Please reply to Dr Chen jinju.chen@newcastle.ac.uk