50th Anniversary Lecture:

Dissecting the biology/materials interface for innovative antifouling solutions

by Professor James Callow, Emeritus Professor of Plant Science, School of Biosciences, University of Birmingham, UK.

Abstract:

Biofouling in the marine environment involves a complex interaction between living organisms exhibiting specific selective attachment behaviours and adhesion properties, and the physico-chemical properties presented by the coating, which are in turn modified by biotic and abiotic factors (biofilms, grazing, conditioning layers etc). If we are to understand this complexity, and use the resulting information in predictive models to facilitate rational design of non-biocidal coatings, quantitative, reproducible and carefully controlled, hypothesis-driven experimentation is required. This is most readily achieved through laboratory-scale experimentation that enables clear structure/property/performance correlations to be established through the use of well-defined settlement/adhesion bioassays and, for example, sophisticated approaches to imaging. It is often argued that laboratory-scale experimentation/bioassays do not take account of variables associated with the ‘real world’. Whilst this is obviously true, informed investigators see laboratory assays as a necessary part of a continuum of investigations at different levels of scale and complexity, rather than providing a solution per se. The purpose of this presentation, is to consider some examples of interdisciplinary investigations that have attempted to study, in a systematic way, the influence of specific surface properties on the settlement behaviour and adhesion properties of certain fouling organisms. The examples will be drawn mostly from collaborative, interdisciplinary programmes supported by The US Office of Naval Research (ONR) and the European Commission, and will focus on the green macroalga Ulva linza and slime-forming diatoms. Examples of the successful translation of laboratory investigations into practical coating development and ‘real-world’ evaluation will be considered.

About the Speaker:

Professor Jim Callow has worked on marine algae for over 40 years. Initial focus was on cell-cell recognition processes (for example, how do male gametes recognise their female
counterparts?). Latterly the focus, in partnership with Dr Maureen Callow, has been on bioadhesion in the context of marine biofouling with a particular emphasis on interdisciplinary investigations into the interactions between algal cells and micro/nanostructured materials, including those with ‘biomimetic’ implications. Professor Callow has lead two major European programmes in the area of nanomaterials for antifouling applications. For 19 years the laboratory provided biological expertise to the programme on marine biofouling run by the US Office of Naval Research. Professor Callow has authored/co-authored over 300 scientific publications and is currently Emeritus Professor of Plant Science in the University of Birmingham.

Plenary Lectures:

Microbial biofilms – biology and control
By Professor Staffan Kjelleberg, Director, Singapore Centre on Environmental Life Sciences Engineering, Nanyang Technological University, Singapore; Co-Director, the Centre for Marine Bio-Innovation, University of New South Wales, Australia

Abstract:
Recent years have witnessed a rapid development in our understanding of biofilm biology. These are derived from both mechanistic studies of genetic development programs and biofilm structure and function, as well as whole biofilm community meta-omics and systems biology approaches. Unravelling the fundamentals of biofilm biology is essential for targeting and controlling biofilm processes across a range of natural and engineered systems.

This talk will address the identification of specific stages of the biofilm lifecycle as targets for control. These include, for example, intra and extracellular signaling and molecular components and interactions that define the structure and function of the matrix in which the biofilm cells are embedded. Specifically, interactions between extracellular signals and polymeric components, matrix structural and developmental features, and the intracellular nitric oxide mediated signaling cascade for biofilm cell dispersal will be discussed.

Unexpectedly, the extracellular matrix domain greatly contributes to the activity of the biofilm. The matrix displays extensive electroconductivity, employing several soluble electron shuttles. Further, bioelectrochemical matrix systems provide conduits for likely attachment and transfer of small signalling and/or electrogenic compounds. These functions mediate biofilm-based bioconversion, including those with detrimental outcomes such as microbially induced corrosion.

The recent advances in next generation sequencing and systems biology have enabled a detailed assessment of the structure and function of complex communities. Metagenomics and
metatranscriptomics approaches have elucidated unexpected diversity and function of natural biofilms. This has opened up opportunities for biofilm management and control. For example, combined metagenomics and analytical chemistry informs on the elaborate communal extracellular signaling engaged by a large number of different species for specific outcomes by the community. Furthermore, combining metatranscriptomics and metagenomics has mapped the intricacies of communal co-metabolism, suggesting a mechanism by which the community attains stability.

About the Speaker:

Prof. Staffan Kjelleberg is Director of the Singapore Centre on Environmental Life Sciences Engineering, NTU Singapore, and Co-Director, the Centre for Marine Bio-Innovation UNSW Australia. His research interests include bacterial biofilm biology, chemically mediated interactions used by bacteria and higher organisms, and harnessing/controlling biofilms for engineering and public health applications. His research incorporates a meta-‘omics approach to explore microbial communities and processes in complex systems, with translational outcomes in biotechnology and environmental/public health domains. Prof. Kjelleberg employs a multidisciplinary approach for advancements in microbial ecology, as well as for the merger of the previously disparate fields of environmental microbiology, eukaryote ecology and environmental engineering. His work on bacterial adaptive responses and biofilm biology has provided insights into the predominant modes of life of bacteria in the environment. Discoveries of interactions at different scales, ranging from within the biofilm, between biofilms and their surrounding environment, to those with higher organisms, have contributed to ecological theory and biofilm control outcomes.

Designing Small Structures to Control Marine Corrosion

By Dr. Harvey Hack, President of NACE International; Senior Advisory Engineer, Northrop Grumman Corporation, Undersea Systems, USA

Abstract:
This paper describes the important considerations for designing structures, especially small objects and mechanisms, which will be employed underwater for extended periods of time. Methods of corrosion control for underwater systems are described, including specific details for those that are of most use underwater. These include maintenance and operation, materials selection, corrosion allowance, design considerations, environmental modification, cathodic protection, and coatings. The underwater performance of the major metal types and the major types of hardware are also described, as are brief descriptions of performance of specific non-metals. Finally, a series of underwater design rules of thumb are presented.

About the Speaker:
Dr. Hack is a Senior Advisory Engineer at Northrop Grumman Corporation, Undersea Systems. He received his PhD in Metallurgy from The Pennsylvania State University. He is a NACE Certified Corrosion Specialist, Cathodic Protection Specialist, and Level III Coating Inspector, a Registered Professional Engineer in Maryland, and a Fellow of NACE International, ASTM International, the Institute of Corrosion, and the Washington Academy of Sciences. He has received the NACE T. J. Hull and Distinguished Service Awards, the ASTM Frank W. Reinhart and Committee G1 Francis L. LaQue Memorial Awards, the ASM/Penn State McFarland Award, and the Sea Horse Institute Francis LaQue Award. He is a former Chairman of the ASTM Board of Directors and former President of the Council of Engineering and Scientific Specialty Boards. Dr. Hack is the 2014-2015 President of NACE International. He has authored many papers and books, primarily in the area of Marine Corrosion.

**Keynote Lectures:**

**The Biology of Fouling Organisms: A Field Perspective**

By Professor Geoffrey Swain, Director, Centre for Corrosion and Biofouling Control, Florida Institute of Technology, USA

Abstract:

Understanding the biology of fouling organisms is fundamental to the management and development of strategies and methods for the control of biofouling. There is a wealth of knowledge on the subject. This talk will review past and present research in terms of what, where, when and how fouling becomes established. Fouling is initiated from propagules present in the water column, whose presence is determined by spatial and temporal variation. Their choice of substrate, however, is controlled by sensory receptors that can respond to both environmental and substrate conditions. Once settled, growth rates, competition and predation will play a role in determining the final community structure. From a management perspective this knowledge can help optimize ship and structure cleaning schedules; locate the placement of seawater intakes and other critical components; understand the potential for introducing non-indigenous species; and identify the locations and times of year when biofouling control is required. The development of novel methods to prevent fouling will benefit from a detailed knowledge of the morphology, physiology and behavior of the propagules. Finally, this knowledge may also be used to re-establish benthic communities in areas that have been impacted by anthropogenic activities.

About the Speaker:

He frequently consults fundamentals of offshore engineering with industry, state and federal agencies in the fields of corrosion and biofouling control. Prior to joining Florida Tech, he worked in the North Sea oil industry conducting corrosion and biofouling surveys on offshore structures. He also has extensive experience with designing and implementing hydrographic and marine resources studies. Memberships include the Institute of Corrosion Science and Technology, Marine Biological Association U.K., National Association of Corrosion Engineers and the Society of Naval Architects and Marine Engineers.

**Understanding the Fundamental Mechanisms of Microbial Adhesion and Colonization – Assaying Methods to Assist in the Future Design of Fouling Resistant Coatings**

By Dr Paul Molino, Research Fellow, Intelligent Polymer Research Institute, University of Wollongong, Australia

Abstract:
Critical to the design of efficient fouling resistant materials is a basic understanding of the nature of microbial adhesion and colonization, as well as the ability to rapidly assay surfaces of different chemistry and morphology. In recent years a number of innovative techniques have been developed, or adapted from other fields, in order to investigate the mechanisms through which microbial cells, such as bacteria and diatoms, interact and colonize coatings and structures. Herein I present a suite of techniques that have provided significant insight into microbial cell attachment and growth, including turbulent flow channels, atomic force microscopy and optical and fluorescence microscopy, as well as emerging techniques such as quartz crystal microgravimetry (QCM) and scanning ion conductance microscopy (SICM) that promise to advance our understanding of microbial fouling processes.

About the Speaker:
Dr Paul Molino is a Research Fellow at the Intelligent Polymer Research Institute, embedded within the Australian Institute for Innovative Materials at the University of Wollongong. He has worked on developing methods to characterize diatom and bacterial fouling of coatings in the field, as well as laboratory based methods that are aimed at giving further insight into the nature of microbial interactions directly at the cell – material interface. Current work includes the development of nanostructured ultra-low fouling materials.
Quantifying Cyprids’ Bioresponse as a Performance-Relevant Measurement of Engineered Surfaces

By Dr William Birch, Senior Scientist, A* Institute of Materials Research & Engineering, Singapore

Abstract:
Cyprid settlement has been used as a targeted single-species assay, designed to measure the fouling-resistance performance of engineered surface properties. This single-parameter measurement offers a quantifiable measure of the cyprids’ bioresponse that is less complex than surface colonization by multiple organisms, as generated by a marine field-test assay. The present talk will describe quantifying the cyprids’ exploration walk, which is regulated by cyprid/surface interactions and thus offers insights into the evolution of a process that putatively determines their settlement. Anchoring points, formed by cyprids exploring engineered surfaces, can be imaged in a controlled environment, either under static conditions or in the controlled shear provided by a microfluidic channel. On model surface chemistries, significant variations in quantifiable step parameters correlate with the cyprids’ surface affinity. Cyprids exhibit distinct preferences for the location of their anchoring points when exploring patterned microstructures, consisting of pillars with tuneable dimensions. The exposure of cyprids to ultrasound, a fouling deterrent, has been shown to significantly alter their exploration behaviour. A recent adaptation of the assay configuration for planar substrates enables the observation of cyprids exploring surfaces of widely differing wettability, either within the bulk water phase of whilst confined to the air/water interface by wetting forces. These methods quantify several performance-relevant parameters, thus facilitating a multi-faceted evaluation, to discern the engineering criteria for fouling-resistant surfaces.

About the Speaker:
William Birch received his PhD from Carnegie Mellon University (1994). Prior to joining A*IMRE, he worked in Corning Inc. and Genewave & Lovalite. Dr Birch’s group works on innovating laboratory-scale assays, which are designed for performance-relevant measurements of marine organisms interacting with engineered surfaces. Current efforts focus on assay configurations suitable for quantifying the exploratory behaviour of barnacle (Amphibalanus amphitrite) cypris larvae (cyprids) interacting with centimeter-scale planar surfaces, bearing high added value motifs and surface chemistries. They are expanding these activities to probe the interaction of cyprids with characterized marine biofilms, deposited in a controlled manner on the same engineered substrates.
**Mussel adhesion in a warmer, high-CO2 world: an ecomaterial approach**

By Professor Emily Carrington, Professor of Biology, University of Washington, USA

Abstract:
Mussels are key aquaculture species and often dominate temperate rocky shores worldwide, forming dense aggregations firmly tethered by byssal threads, extracellular fibers molded by the mussel foot. Field studies with Mytilus spp. have shown byssus strength, or tenacity, follows a strong seasonal cycle, rendering both wild and farmed populations prone to “fall-off” in late summer/early fall when increased storm activity coincides with weak attachment. Seasonal weakening is due primarily to environmentally-induced changes in the material properties of individual byssal threads. Using custom laboratory mesocosms, we quantified the effects of two common environmental stressors, elevated temperature and pCO2 (= ocean acidification), on the mechanical performance of byssal threads in M. trossulus. Both stressors caused thread weakening and loss of extensibility, but targeted different regions of a thread. These results suggest multiple environmental stressors, including ocean acidification and warming, can combine to critically compromise the structural integrity of mussel adhesion.

About the Speaker:
Emily Carrington is Professor of Biology at the University of Washington. Her research is based at the Friday Harbor Laboratories in the San Juan Islands, where she leads a marine biomechanics research group and directs the Ocean Acidification Environmental Laboratory. For over two decades, she has focused on the mechanical design of marine invertebrates and macroalgae, especially those that thrive in one of the most physically challenging habitats on earth, wave-swept rocky shore. Her work on mussels and their byssal adhesion links materials science, fluid mechanics, organismal biology and environmental science to develop a mechanistic understanding of how coastal organisms will fare in changing ocean climates.

**Microbial fouling of membranes and strategies for control**

By Associate Professor Scott Rice, University of New South Wales, Australia; Visiting Assistant Professor, School of Biological Sciences and the Singapore Centre on Environmental Life Sciences Engineering (SECLSE), Nanyang Technological University, Singapore

Abstract:
Bacteria form biofilms on almost all surfaces, ranging from ship hulls to cooling towers, to indwelling biomedical devices. Biofilms also play positive roles, for example,
floc and granule formation for the biological remediation of contaminated water. Therefore, there is strong drive to understand the processes of biofilm formation, to either eliminate biofilm formation in some industrial processes and human health, or to encourage their formation, for processes such as remediation. To develop innovative, environmentally friendly, biofilm control technologies, it is essential to understand the process of biofilm formation and to evaluate natural systems that prevent or reduce biofilm formation. For example, we have discovered that the endogenous production of small molecules within the biofilm, both reactive oxygen species (ROS) and cell-cell signalling molecules, can induce biofilm dispersal. Thus, by understanding biofilm formation from both the bacterial and environmental perspective, it is possible to manipulate the biofilm, to encourage or discourage formation, to benefit specific needs.

About the Speaker:
Associate Professor Scott A. Rice has a joint appointment in the Singapore Centre on Environmental Life Science Engineering (SCELSE) at Nanyang Technological University and the Centre for Marine Bio-Innovation at the University of New South Wales. He obtained his PhD in Microbiology from the University of Tennessee, USA in 1996 and has, for the past 18 years studied the microbial cell-cell interactions and the development of surface associated communities, called biofilms. The research is a mixture of applied and fundamental science aimed at elucidating the genetic mechanisms that drive interactions between bacteria as well as between bacteria and higher organisms. One goal is to identify key regulatory switches in the biofilm lifecycle that can be exploited to subsequently control the formation and dissolution of biofilms. The outcomes of this work are captured in 80 publications and patents for the application of biofilm control strategies.

The Effect of Biotic Components on Corrosion: Current Advances and Future Perspectives
By Professor Iwona Beech, Biocorrosion Centre, Department of Botany and Microbiology, University of Oklahoma

Abstract:
Significant progress has been made in understanding the effect biological component exerts on marine corrosion of metallic materials. With unprecedented developments in mass spectrometry, as well as imaging and surface analytical techniques, direct in-situ observations of structures and chemical functions at micron and sub-micron resolutions are now within grasp. However, demonstrating spatial and temporal relationship between biological activity and electrochemical events on surface of bio-fouled materials still presents a major challenge. Current developments in the fields of nucleic acid-based technologies, in particular the rapid expansion of affordable techniques facilitating metagenomic and meta-transcriptomic analysis, allows simultaneous characterization of taxonomic composition, metabolic content and, more importantly, gene expression within biofilm communities. The above techniques, when coupled with proteomics and metabolomics,
including metabolomic imaging, offer great promise in understanding the role biotic components play in corrosion. Examples are presented to demonstrate progress made in elucidating biodeterioration of iron and ferrous alloys in marine environments under oxygenated and anoxic conditions. Emphasis is placed on discussing aspects of corrosion that require additional investigations, e.g. biotically-mediated electron transfer processes, and the effect of organic compounds on the rate of cathodic (reduction) reactions.

About the Speaker:
Dr. Iwona Beech is an internationally recognized expert in the field of biofilm-influenced corrosion and biofouling. She has over 24 years of research experience in studying fundamental and applied aspects of biocorrosion of metallic and biodeterioration of non-metallic materials in both freshwater and marine environments and an extensive history of collaborations with Academia and Industry worldwide, including oil, gas and shipping industries and the navy. Dr. Beech is an authority on a variety of advanced microscopy, including atomic force microscopy, and surface science techniques for characterizing biofilm/substratum interactions. Her current research focuses on the use of immuno and molecular biology techniques and advanced mass spectrometry methods to understand the importance of biofilm community structure and involvement of bacterial metabolites, including extracellular polymeric substances, in microbiially-influenced corrosion (MIC). In addition to funding received through the OU Biocorrosion Center, current research efforts are sponsored by ONR Global/ONR, the European Union Marie Curie Network, Saudi-Aramco Oil Company and the Royal Navy through QinetiQ Ltd.

Potential Ennoblement of Stainless Steel in Natural Seawater

By Dr Dominique Thierry, Director, French Corrosion Institute, Brest, France

Abstract:
Stainless steels are widely used for different applications in seawater in the oil and gas and desalination industry. It is well known that the corrosion potential of stainless steel shifts to the noble direction (ennoblement) when exposed to natural seawater. The other significant effect of the biofilm on metallic surfaces is a dramatic increase of the cathodic efficiency (e.g. cathodic reduction of dissolved oxygen), promoting the corrosion reactions and increasing the rate of corrosion propagation. Although, this has been widely studied in natural seawater at temperature ranging from 15°C to 40°C, very little is known on the effect of temperature (in a wider temperature range), dissolved oxygen content and chlorination level on the corrosion potential and the cathodic efficiency of stainless steel in natural seawater. In this paper we will report corrosion potential and cathodic efficiency of stainless steel as a function of temperature (e.g. from 5°C to 70°C), dissolved oxygen content (e.g. from 20 ppb to saturation) and chlorination level (from 0 to 10 ppm). The results will be discussed in terms of risk for crevice corrosion and bi-metallic corrosion when coupling to other
materials. In addition results from exposure in tropical sea will be presented and compared to that of temperate seawater heated at the same temperature. The results will be discussed in terms of risk for crevice corrosion.

About the Speaker:

Dr Thierry obtained his PhD in corrosion science from the Pierre and Marie Curie University, and taught at the Royal Institute of Technology, Stockholm, Sweden. Currently, he is the managing director of the French Corrosion Institute located in Brest, France. He has authored more than 200 scientific papers in peer review journals and of several book chapters.

**Metals and their Corrosion Behaviour in Seawater - An Engineers Overview**

By Mrs Carol Powell, Consultant, Copper Development Association and Nickel Institute, UK

Abstract:
There are many different alloys available to engineers for structures, systems and components for use in sea water. These include steels, stainless steel and alloys of copper, nickel, aluminium and titanium. Good performance relies on an understanding of their corrosion behaviour and a requirement that they are selected and designed to their strengths and not their weaknesses. Many systems are mixed metals and knowledge of the compatibility of alloys in contact with each other is also crucial. Different alloy groups have different methods of corroding depending on the sea conditions. Flow, temperature, stagnation, pollution, applied stresses and aeration can all produce a different response. Some alloys can show uniform thinning while others may show localized corrosion which can include corrosion at crevices, pitting, stress corrosion and corrosion of preferential phases. This Keynote presentation provides a brief overview of the world of metals and their response to one of the most corrosive environments there is, giving examples of the types of corrosion which can occur and how to avoid them.

About the Speaker:

Ms Carol Powell has been a consultant metallurgist to both the Copper Development Association and Nickel Institute in the UK for 20 over years with particular specializations in marine corrosion and applications for copper-nickels, stainless steels and high nickel alloys. She has been a member of the UK Marine Corrosion Forum and Copper-Nickel Task Group since their inception and is currently deputy chair of the European Federation of Corrosion Marine Working Party. She is a graduate of Birmingham University, a member of the Institute of Marine Engineering, Science and Technology and a Fellow of the Institute of Materials, Minerals and Mining. She has written over 40 papers and publications.
Seawater Nutrient Pollution and the Long Term Immersion Corrosion of Steels

By Professor Robert Melchers, School of Engineering, University of Newcastle, Australia

Abstract:
Structural steel is used widely for major infrastructure in or around seawater harbours, for shipping and for offshore structures. Protection using coatings or cathodic protection systems or both can be effective if properly maintained. However, some infrastructure is unsuited to such protective measures and reliance is then placed on a sacrificial corrosion allowance. A variety of data show that corrosion loss for steel in marine exposure conditions is not a simple linear function of time and that it is influenced by many factors, principally seawater temperature and microbiologically influenced corrosion (MIC). Recent studies have shown that in seawater MIC mainly is the result of elevated concentration of dissolved inorganic nitrogen (DIN). Two developments are reviewed in this paper. The first is the construction of model for the long-term corrosion of steel in DIN nutrient-polluted seawater using data from a variety of field exposure programs. The simplified model is shown to asymptote the long-term part of the previously proposed bi-model model for marine corrosion. The second considers the phenomenon of accelerated low water corrosion and that this also is correlated with DIN nutrient concentration. The results allow for average seawater temperature and also for the variability in observed corrosion losses. The models permit prediction of long-term corrosion loss in waters polluted with DIN and of known average temperature. The results of example applications suggest that anthropological pollution of seawater potentially is a major hazard for corrosion of steel infrastructure.

About the Speaker:
Robert E Melchers is Professor of Civil Engineering at The University of Newcastle, Australia. He holds a BE and MEngSc from Monash University and a PhD from the University of Cambridge, UK. He is a Fellow of the Australian Academy of Technological Sciences and Engineering. From 2004 to 2008 and again 2009-2013 he was also an Australian Research Council Professorial Fellow and currently holds a Outstanding Researcher Award also from the Australian Research Council. He was one of two Visiting Scientists, European Economic Community Marie Curie BIOCOR research program (2010-13). His most recent awards include the 2009 Corrosion Medal (Australasian Corrosion Association), the 2012 Jin S Chung Award (International Society of Offshore and Polar Engineers) and the 2013 John Connell Gold Medal (Institution of Engineers, Australia). For 2014 he is Eminent Speaker for the Institution of Engineers Australia. His research interests include structural reliability and marine corrosion and in particular the long-term effect of biological influences on marine corrosion of steel. He has published several books and more than 500 peer-reviewed journal and conference papers.
Hydrogel-based fouling control coatings
By Dr Stefan M. Olsen, Research engineer, Hempel A/S, Copenhagen Area, Denmark

Abstract:
Due to their very low surface energy and high elasticity, Fouling Release coatings have, historically, been based on polydimethylsiloxane binders. Additives of low surface energy polymers, such as phenyl modified polysiloxane oils were implemented to sustain the low surface-energy of the coatings and prolong the fouling release performance. However, these early Fouling Release coatings came out short against biofouling when seawater exposure exceeded one year [Yebra et al. 2004 and Yebra and Catalá 2011]. In 2008, Hempel A/S launched a hydrogel-based Fouling Release coating inspired by biomedical research. To increase biofouling resistance, these coatings contain a hydrophilic modified silicone polymer that migrates to the surface upon immersion and creates a hydrogel layer at the outermost surface of the coating. The hydrated layer of the hydrogel-polymers can be considered similar to the co-existence of water and ice at low temperature [Yebra and Catalá 2011]. Water trapped in this layer exhibits a gradient from liquid water to more gel-like, trapped water. The antifouling performance of such a surface has been proved to overperform conventional and alternative technologies significantly [e.g. Zhang et al. 2013, Zargiel and Swain 2012, Scardino et al. 2012, Zargiel et al. 2011].

Clean Fouling Release coatings are known to have improved fuel-efficiency over conventional antifouling coatings [Schultz 2007]. This is due to the smoothness and lower friction coefficient generally associated with silicone coatings [Yebra and Catalá 2010]. However, all Fouling Release systems to date tend to decline in performance over a five-year operational period to a higher or lower degree. This diminishes the overall fuel-efficiency of the silicone coatings over extended immersion periods. Further improvement of the performance has therefore been needed to prolong the fuel-efficiency.

Biocide-release from Fouling Release coatings has, until recently, not been possible because only low amounts of biocides can be used in a silicone coating in order to maintain surface smoothness, and biocides release rapidly from the silicone matrix. With the introduction of the ActiGuard ® technology, it has become possible to exploit biocides in silicone-based coatings and thereby extend the fouling-free period of these types of coatings. This results in a significantly prolonged fuel-efficiency of the silicone based coatings with a minimum amount of biocide.

This presentation will give an introduction to the hydrogel-based fouling release technologies, introduced in X3 and leading up to the ActiGuard® technology. The unique features of combining hydrogels and biocides in a silicon-based coating will be disclosed together with a description of the working mechanism and performance of the technology.
Seawater abundant copper ions - Selective and efficient copper uptake and release as a new antifouling mechanism

By Professor Magnus Nyden, Director, The Ian Wark Research Institute, University of South Australia, Adelaide, Australia

Abstract:
The average copper concentration in seawater is around 3 ppb and up to 10 and even 114 ppb have been reported in a yacht basin in San Diego Bay and coastal water of India, respectively. Thus, metal contamination from antifouling coatings in marinas and harbours is of major concern. Extraction of metals, especially uranium, from oceans has attracted scientific interest over the last century. Although the concentration of valuable metals in the oceans is typically very low, the vast abundance of water makes the total amount significant compared to minerals-based metals.

Based on recent studies of copper selectivity and efficiency of polymer based coating materials we propose that natural abundant copper could also be the basis for a new antifouling mechanism. It is based on adsorption and release of naturally abundant copper ions. The technique comprises a coating that selectively adsorbs the naturally abundant copper and an on-demand electrochemical trigger that makes the copper release at extreme concentrations, and thereby acts as a biocide. Our results show that the concept holds significant promise, not only for marine biofouling prevention but also for water purification and sensing applications as well as extraction of copper from oceans.

About the Speaker:
Magnus Nyden is a physical chemist and received his PhD from Lund University, after which he worked as a Professor at Chalmers University of Technology. In 2003 he was involved in the large cross-disciplinary program, Marine Paint, where he led the research and development group responsible for developing concepts for controlling release of marine biocides for the paint industry. He was the inventor of a technology for controlling release of fungicides and algicides from house coatings, from which the start-up company Capeco AB was established. He was also the Director of SuMo Biomaterials, a cross-disciplinary program based on industrial needs and scientific excellence. He is currently the Director and Research Professor at the Ian Wark Institute of the University of South Australia. His research is focused on colloid and interface science with a particular emphasis on particles and polymers at interfaces, in solutions and in gels.
Conventional and innovative antifouling technologies in industrial cooling water systems

By Dr Sanjeevi Rajagopal, Department of Animal Ecology and Ecophysiology, Radboud University Nijmegen; Senior Scientist in IMARES, Wageningen University, The Netherlands

Abstract:
Chlorination is the most commonly used chemical antifoulant in industrial cooling water systems. The most important criteria deciding the chlorine dosing frequency are intensity of fouling at a given location, cost and environmental discharge specifications. Accordingly, different types of dosing regimens are employed such as intermittent, continuous, semi-continuous, pulsed etc. Recent data indicate that newer methods of chlorine administration may help reduce the chlorine inventory and thereby reduce the environmental burden caused by discharge from power plant cooling systems.

As biofouling essentially is an interfacial problem, the required biocide concentrations must be available at the water-substratum interface, rather than the bulk water. Therefore, we have attempted to test the use of porous surfaces as a biocide delivery vehicle using dynamic experimental system. The logical approach is to deliver the right concentration of biocide at the very interface, so that effective concentration is maintained at the actual site of fouling, leaving the bulk water concentrations largely negligible. Our results indicate that chlorine reduction to the extent of about 70% can be easily achieved by using porous ceramic surfaces in place of conventional bulk water continuous chlorination for controlling mussel fouling. Carbon dioxide (CO2) has the potential to be utilized as a molluscicide for control of mussel fouling. The synergetic effect of chlorine (commonly used antifouling chemical) and CO2 to most important fouling mussel species would be desirable, because any reduction in chlorine inventory used for fouling control will preserve the environment of the receiving waters. An attempt has also been made to estimate the economic considerations of CO2 in combination with sodium hypochlorite, by applying the present results in industrial cooling water systems.

New methods such as microencapsulated pellets (commercially known as BioBulletts) and biological agents (pathogens, parasites, predators or competitors that reduce populations of the target species) have also been investigated. Environmental and cost factors will play very important roles in deciding whether some of these technologies will be finally accepted by utilities as a replacement of chlorination. It is, therefore, necessary that emphasis may continue to be placed on research aimed at development of environmentally benign biofouling control technologies.

About the Speaker:
Dr Sanjeevi Rajagopal earned a Ph.D. degree from University of Madras, India in 1991 and a D.Sc. degree from Radboud University Nijmegen, Netherlands in 1997. He has extensively worked on the several aspects of biofouling and invasive species in tropical, subtropical and temperate environments. He joined the Department of Animal Ecology and Ecophysiology, Radboud University Nijmegen, Netherlands in June 1994 and also working as a Senior Scientist in IMARES, Wageningen University, The Netherlands since July 2010. He is presently involved in the development of novel (CO2), environmentally sound (heat treatment), chemical (chlorination) and non-chemical technologies (biological control) for the control of macro-fouling in raw water systems. In March 1994, he was a recipient of the Young Scientist award from Rotary International (District 3000), Illinois, USA and visited Argentina, Paraguay and Brazil as a Rotary International Ambassador (GSE member) of goodwill and understanding. He is an Advisory Member of Groupo Ecologista, University of Misiones, Argentina and a Member of numerous societies, including The Marine Biological Association of the United Kingdom and The British Ecological Society, England. He has published more than 100 scientific papers in International journals and has edited two books.

**Challenges and opportunities for understanding and managing biofouling in marine aquaculture**

By Dr Oliver Floerl, Senior Scientist and programme leader at SINTEF Fisheries and Aquaculture, Trondheim Area, Norway

Abstract

The development of biofouling assemblages on aquaculture infrastructure or on culture organisms themselves poses considerable challenges to the industry. Aside from impacting farming operations, biofouling can affect stock health and quality, and contribute to depletion and deposition impacts of aquaculture farms. Aquaculture farms can also provide habitats and dispersal pathways to non-indigenous biofouling species. Unfortunately, neither the finfish nor shellfish aquaculture industries have found fully reliable and sustainable solutions to prevent or manage the unwanted development of biofouling. However, because marine aquaculture is a rapidly growing global industry expected to play an increasingly important role in providing food security, it is imperative to strengthen our efforts at finding solutions and best-practice management for biofouling on farm surfaces. To start off the session for Biofouling in Aquaculture at the 2014 ICMCF I will provide a broad overview of biofouling in finfish and shellfish farming, and of its known and potential impacts on the industry and the environment. While doing so I will highlight our most critical knowledge gaps and provide suggestions for R&D priorities that will help us minimize the unwanted consequences of aquaculture biofouling.

About the Speaker:

Dr Oliver Floerl has a B.Sc. in Marine Biology from the University of Wales and a Ph.D. in Environmental Science from James Cook University, Australia. Oliver has 15 years of experience
as a researcher. During this period he developed and led a wide range of projects relating to the survey, characterization and management of biofouling organisms in the aquaculture, shipping and boating, and oil and gas industries. His other main area of expertise is in marine biosecurity, particularly the management of invasive species and disease risks associated with shipping and aquaculture. Oliver has worked with a diverse range of clients including governments, industry, academia and NGOs, and in a variety of geographical regions including Australia, New Zealand, the Indian Ocean, Europe and Norway.

**The Tanker Industry perspective – modern antifouling systems: experience and impacts**

By Mr Tim Wilkins, Regional Manager Asia-Pacific; Senior Manager, Environment, INTERTANKO

Abstract:
Growing focus on efficiency coupled with invasive species legislation is renewing the industry’s interest in antifouling systems. An overview of the experience of INTERTANKO’s members in using modern anti-fouling systems will be provided. With this backdrop of experience, consideration as to the operational and regulatory impacts to the owner of using certain systems will be will be provided against the mounting pressure from local, national and international environmental regulators.

About the Speaker:
Tim Wilkins manages INTERTANKO’s Asia representative office in Singapore, representing member’s interests in the Asia-Pacific regions. He is responsible for coordinating and managing INTERTANKO’s environmental agenda, liaising with environmental, national governmental and international organizations, including the International Maritime Organization (IMO) and the United Nations Environment Program (UNEP).

**The Effect of Antifouling Paints on Long Term Hydrodynamic Performance of Ships in Relation to Energy Efficiency**

By Dr Noriyuki Sasaki, Fellow, Monohakobi Technology Institute, Japan

Abstract:
There are many different types anti-fouling paint systems currently applied on ships in the market. However, the effect of these paints on the ship hydrodynamic performance is complex and not easy to evaluate accurately. This is based on the fact that the ship’s hydrodynamic performance will be affected by not only the weather such as wave, wind
and current but also rather complex and unpredictable bio-fouling and ageing effect of the hull roughness and propeller. In this lecture, the recent research works related to this area will be reviewed and a practical prediction method for the long period ship performance will be introduced by taking into account the roughness and bio-fouling effect. The reflections on the recently introduced IMO criteria for the energy efficiency will be discussed.

About the Speaker:
Dr Noriyuki Sasaki is an advisor with the Monohakobi Technology Institute (MTI) of NYK group and National Maritime Research Institute, Japan. The MTI conducts many projects related to Fuel Saving and some of them are research projects of paints/maintenance of hull surface.

**Hull Efficiency: A Review of 100 In-water Hull Cleanings and their Impact on Reducing Fuel Consumption and Emission on Ocean Going Vessels**

By Mr Daniel Kane, Vice President, Propulsion Dynamics, Long Beach, California, USA

Abstract:
Through utilization of a hull efficiency analysis technology named CASPER® the audience will be presented with case studies on 100 inwater hull cleanings on tankers, bulkers and containerships and the corresponding reductions in fuel consumption and emission. Underwater photos before and after hull cleanings will be presented along with precise speed and fuel consumption analysis. In addition, separating the effects of hull fouling from propeller roughness and long term hull coating performance after the inwater cleanings will be discussed. The International Maritime Organization [MEPC 63/23] has determined that hull condition an important factor in the Ship Energy Efficiency Management Plan and the International Standards Organization has established a working group [ISO-TC8-SC2-WG7] performance monitoring.

About the Speaker:
Daniel Kane is Co-Founder and V.P. of Business Development for Propulsion Dynamics Inc. founded in 2003. He has a Bachelor of Science Degree, Mechanical Engineering, from Cal State Los Angeles.
Prior to joining Propulsion Dynamics, his experience includes 10 years as a sales engineer for technical products furnished to the US Navy. He is a member of the SNAME “Ship Efficiency Panel” and co-authored a chapter of SNAME’s Energy Efficiency Guide. In addition, he is on the advisory council to International Maritime Organization through National Association of Corrosion Engineers on hull and propeller condition. Daniel is member of SNAME and Royal Institute of Naval Architects. Propulsion Dynamics provides hull and propeller performance monitoring and trim optimization for more than 400 vessels worldwide.
Managing fouling - regulatory challenges and opportunities

By Dr Noami Parker, Manager, Science Policy, Ministry of Primary Industries, New Zealand

Abstract:
(Under Construction)

About the Speaker:
Dr Parker is a marine biologist with a background in phytoplankton ecology and has been working at the science/policy interface for many years. She is currently employed as Manager of Science and Skills Policy at the New Zealand Ministry for Primary Industries. She has been involved in science and regulatory issues to do with biofouling invasions and managing biofouling on ships for about 12 years, including representing New Zealand at the International Maritime Organisation on this issue for the last eight years. She was also recently elected as Vice Chair of the Marine Environment Protection Committee of the IMO for 2014.

Risk Assessment for Vessel Biofouling – How good are we at predicting risk and compliance?

By Dr Graeme Inglis, Principal Scientist – Marine Ecology, National Institute of Water and Atmospheric Research, New Zealand

Abstract:
The transport of biofouling and discharge of ballast water by vessels are recognised as the most important contemporary pathways for the global spread of invasive marine organisms. While international measures to manage risk from ballast water have been under development for almost two decades, policy makers have only recently begun to draft preventative measures for vessel biofouling. If they are to be implemented efficiently, any new regulatory requirements will need to be supported by risk assessment frameworks that are capable of distinguishing vessels that have unacceptable levels of biofouling or which may be carrying species of concern from those that do not. Risk assessment frameworks developed for ballast water have taken both species-specific and more generic approaches to evaluate risk, based on environmental-matching and the recent voyage history of the vessel, but have generally suffered from a lack of data on the organisms present in the discharge to test the accuracy of their predictions. The task for biofouling risk assessment is, perhaps, even harder. While risk for ballast water is greatest for recent port-to-port cargo movements, the development of biofouling assemblages is integrated over the service life of a vessel's antifouling coatings, which may span up to 5 years of operations. During that time, the vessel may have visited several hundred different ports in many different global regions and
been exposed to several thousand species of biofouling organisms. In this paper, I discuss the results of recent scientific surveys of in-service vessels that have attempted to identify useful predictors of biofouling risk based on the vessel type, its operations (including its antifouling measures) and voyage history. I describe the predictors that offer the most promise for use by border-authorities in screening protocols and discuss the prospects for misclassification of high- and low-risk vessels (Type I and Type II errors).

About the Speaker:
Dr Graeme Inglis is a Principal Scientist at the National Institute of Water and Atmospheric Research Ltd (NIWA) in New Zealand and Programme Leader for NIWA’s marine biosecurity research programme. He has published more than 140 peer-reviewed scientific papers, technical reports and popular articles and has provided training and technical advice on the management of invasive marine species in New Zealand, the Middle East, South East Asia, the Pacific, Europe and Australia, including as a Technical Advisor to the IMO GlobalLlast programme.

Graeme’s research on biofouling has been directed at developing better tools to characterise, assess and manage risks from invasive species in shipping pathways (both recreational and commercial). Recent projects have included an analysis of risk factors from a survey of more than 500 international vessels, evaluation of management options for biofouling on different vessel types, and a study of the importance of hub ports in accelerating the spread of invasive species within shipping networks.

Invited Lectures:

Mussels, crabs and slime: filthy bottoms travelling the globe

By Dr Justin McDonald, Principal Research Scientist – Biosecurity, Department of Fisheries, Western Australia

Abstract:
About 90% of world trade or 80% of the world’s commodities are carried by sea. The international character of shipping is reflected in the fact that it is common to see a fouling community in one port almost identical to one in another part of the world. This trend has been greatly accelerated by globalisation of trade and travel, with vessels now moving more regularly and covering greater distances in shorter timeframes. Yet despite this global homogenisation of fouling there is always the threat of a new pest species being introduced. The Asian green mussel *Perna viridis* is a listed pest species in many parts of the world and in Australia has a history of incursions into Western Australia. This
species has wide tolerances that should enable it to establish in ports in Western Australia. It has been detected as fouling on a range of vessels, yet to date has not been recorded as established anywhere. Compare this to the recent detection of the colonial ascidian Didemnum perculidum, a tropical species with limited reported compatibility and that has limited history of incursions. Yet since 2010 this species has exploded in its spatial coverage across our state. This talk explores the fouling risk posed by vessels to Western Australia and how increased vessel movements and changes in climate will influence our invasive species risk.

About the Speaker:
Dr Justin McDonald is a marine ecologist specialising in marine invasive species. He has worked in academia, consulting and government. His previous work has included everything from analysing video to detect change in seagrasses to identifying and mapping benthic faunal communities to tropical sponge ecology. He managed the marine biosecurity surveillance program in ports and harbours around New Zealand. Justin now leads a small research team at the Western Australian Department of Fisheries. This group is responsible for protecting the aquatic resources of Western Australia from invasive species. His current work profile covers designing marine pest surveillance programs through to providing scientific input to responses and providing advice on broader marine biosecurity issues for Western Australia.

Chemical and Visual Cues for Gregarious Settlement in Barnacles
By Dr Matsumura Kiyotaka, Lecturer, Tokyo Institute for Biotechnology, Japan

Abstract:
Selection of suitable settlement sites in larvae of sessile marine invertebrates is a crucial process for survival and reproduction. In many barnacle species, gregarious settlement is also essential to ensure that mating neighbors are sufficiently close one the individual becomes an adult. How barnacle larvae settle gregariously?

Since the 1950s, response of cyprids, the settlement stage larvae in barnacles, to chemical cues from conspecifics have been thought to be one of the most important mechanisms leading to conspecific gregarious settlement in barnacles, and two types of proteinaceous settlement cues have been purified from the adult barnacle, Balanus (Amphibalanus) amphitrite. One is the substratum-bound pheromone, settlement-inducing protein complex (SiPC), and the other is the waterborne pheromone. SiPC is a high-molecular mass, previously undescribed glycoprotein but shares a 25% sequence homology with the thioester-containing family of proteins that includes the α2-macroglobulins. SiPC was also detected in “footprints” of cyprids, suggesting involvement of SiPC in both adult-larva and larva-larva interactions during settlement. The waterborne settlement pheromone of 32 kDa protein is suggested to be released into seawater and attracts cyprids. These chemical cues are definitely important in the settlement of barnacle cyprids although their receptors in the larva have not been identified. However, it has been
suggested that they only work over relatively short distance, indicating possible involvement of other species-specific signals in their gregarious settlement. How about visual signals?

Interestingly, the cyprid has one pair of compound eyes that appear only at the late nauplius VI and cyprid stages, but the function(s) of these eyes remains unknown. We recently showed that cyprids of *B. amphitrite* can locate adult barnacles even in the absence of chemical cues, and prefer to settle around them probably via larval sense of vision. We also show that the cyprids can discriminate color and preferred to settle on the red surface. Moreover, we found that shells of adult *B. amphitrite* emit red auto-fluorescence and the adult extracts with the fluorescence as visual signal attracted cyprid larvae to settle around it. To examine molecular mechanisms, two barnacle opsin genes, named Ba-op1 and Ba-op2, expressed in the larval stage of *B. amphitrite* were cloned, sequenced and characterized in expression profiles. The results suggested that the cyprids discriminate red fluorescence signal in adult shells by using the long wavelength sensitive opsin, Ba-op1, expressed in their compound eyes.

We propose that the perception of specific visual signals can be involved in behavior of zooplankton including marine invertebrate larvae, and that barnacle auto-fluorescence, as well as settlement pheromones, may be a specific signal involved in gregarious larval settlement.

About the Speaker:
Dr. Matsumura has been studying on larval biology of fouling organisms for 20 years in Japan, UK and Hong Kong. His research interests involve molecular mechanisms of larval settlement in barnacles, particularly on settlement cues. He also worked on development of DNA-based identification of marine invertebrate larvae. Dr. Matsumura is a lecturer at the Tokyo College of Biotechnology. He previously worked at the Fusetani Biofouling Project, JST (JAPAN), Marine Biological Association of the UK (UK), RIKEN (JAPAN), Central Research Institute of Electric Power Industry (JAPAN), Hong Kong University of Science and Technology (Hong Kong).

**Homologous but not similar: the adhesive proteins of stalked and acorn barnacles**

By Dr Anne Marie Power, Lecturer, Department of Zoology, School of Natural Sciences, National University of Ireland Galway, Ireland

Abstract:
Barnacle adhesion underwater is an important phenomenon to understand for the prevention of biofouling and potential biotechnological innovations, yet so far, identifying what makes barnacle glue proteins ‘sticky’ has proved elusive. Examination of a broad range of species within the barnacles may be instructive to identify conserved adhesive domains. We add to extensive information from the acorn barnacles (order Sessilia) by providing the first protein analysis of the adhesive of *L. anatifera* (a stalked barnacle, order Lepadiformes). It was possible to separate the *L. anatifera* adhesive into at least 12 protein bands using 1D SDS-
PAGE. Intense bands were present at approximately 30, 70, 90 and 110 kD. Mass spectrometry of protein bands followed by de novo sequencing isolated 78 peptides of 7-16 amino acids in length. None of the peptides matched published or unpublished transcriptome sequences, but some similarity was apparent between *L. anatifera* and closely-related *D. fascicularis*. Antibodies against two acorn barnacle proteins (ab-cp-52k and ab-cp-68k) showed cross-reactivity in the adhesive glands of *L. anatifera*. We also analysed the similarity of adhesive proteins across several barnacle taxa, including *Pollicipes pollicipes* (a stalked barnacle in the order Scalpelliformes). Sequence alignment of published ESTs clearly indicated that *P. pollicipes* possesses homologues for the 19 kD and 100 kD proteins in acorn barnacles. Overall, several of the proteins described in acorn barnacles appear to have homologous proteins in stalked barnacles; cp-19k and cp-100k are also found in *P. pollicipes*, while cp-52k and cp-68k appear to be expressed in *L. anatifera* adhesive tissues. Homology aside, sequence similarity in amino acid and gene sequences tended to decline as taxonomic distance increased, with minimum similarities of 18-26%, depending on the gene. A curious result was the fact that several peptides were repeatedly found in proteins of different masses. Further studies will be necessary to resolve this issue which has been seen in several species and different laboratory contexts.

About the Speaker:

Dr Anne Marie Power is a faculty member at the National University of Ireland, Galway (School of Natural Sciences). Her research interests began in barnacle supply-side ecology. Since 2008 she has been researching adhesive gland morphology and adhesive proteins in stalked barnacles (*Lepas anatifera* and *Dosima fascicularis*) with the support from Science Foundation Ireland and the Irish Marine Institute. Her research has been featured in research highlights of *Nature* and *Scientific American* and recent activity in her lab can be seen on Facebook at ‘theamazinggoosebarnacle’.

**Marine biofilms associated with antifouling coatings: our friends or enemies?**

By Professor Sergey Dobretsov, Associate Professor, Department of Marine Science and Fisheries, College of Agricultural and Marine Sciences, Sultan Qaboos University, Muscat, Oman

Abstract:

Marine biofilms are multispecies communities composed of bacteria, microscopic algae and protozoa incorporated in an expolymeric matrix. Microorganisms in biofilms cause severe problems for marine industries. The growth of biofilms on ships promote settlement of propagules of some macrofouling organisms, increases microbial corrosion, shear stress and drag, eventually leading to higher fuel consumption and increased production of CO₂. Biocidal and non-biocidal paints effective at managing macrofouling organisms are less effective...
against microorganisms. Our knowledge of biofilms associated with antifouling coatings is limited. Recent studies employing molecular techniques indicate diverse microbial communities on antifouling coatings. In this talk I will focus on novel findings about diversity, density and the role of marine bacteria and diatoms in management of biofouling on antifouling coatings.

About the Speaker:

Sergey Dobretsov received his PhD in 1998 from St. Petersburg State University, Russia. He completed post-docs in Hong Kong, Germany and the US. Now he is an Associate Professor at the Sultan Qaboos University, Oman. He investigates biofilms on natural and man-made substrata, chemically mediated interactions between microorganisms and higher organisms, as well as novel methods of biofouling control. Dr. Dobretsov was a chair of the first microbial biofilm session at 16th International Congress on Marine Corrosion and Fouling in Seattle, USA in 2012. He is on the editorial boards of Marine Ecology Progress Series and Biofouling journals. He has authored over 65 peer-reviewed articles, 5 book chapters, and is a co-inventor on 4 international patents.

Managing underwater hull performance

By Dr Raouf Kattan, Coating Consultant & Managing Director, Safinah Limited; Visiting Lecturer, School of Marine Science and Technology, Newcastle University

Abstract:

This paper will provide an overview of the factors that owners should consider for optimizing hull performance to reduce drag and hence achieve fuel savings. It will consider issues at the design and new building stage, including coating specification that are increasingly overlooked and then look at factors to be considered once the vessel is in service and the options that are available to the owners for managing the underwater hull and the impact of speed and fuel penalties. The work draws on established research and experiences from work carried out by Safinah Ltd.

About the Speaker:

Raouff Kattan is a chartered engineer with a background in academia, seafaring, shipping, shipbuilding, and naval architecture, and specialist knowledge of coatings. He has worked with many leading shipbuilders on coating issues, from design to production, with a focus on improving productivity in coating processes. Working with ship owners, he has developed a performance specification approach to enable the correct technical assessment of alternative paint scheme proposals. He has worked with all of the world’s leading coatings companies, and headed product development teams for a multinational company. With major raw material
suppliers and equipment manufacturers, Raouff has enabled them to establish the added value of their products. He is an innovative thinker, often addressing problems for which there are no immediate or ready solutions. Raouf continues to implement an academic rigour in his work and is a visiting lecturer at the School of Marine Science and Technology at Newcastle University. He is the author of over 100 papers and articles relating to coating application, ship production, quality, and coatings.

**The New European Biocidal Products Regulation and its Implications for Antifouling Product Formulators – A Practical Review**

By Mrs Linda Jones, Independent regulatory consultant, Annex3 Consulting, Groningen, Netherlands

Abstract:

In the midst of other global regulatory schemes for biocides, the European Union system is one of the most comprehensive: its developments are followed and felt worldwide. Other government competent authorities have studied Europe’s advancements as an example, but also the global antifouling industry has closely watched these changes, with its product portfolio in mind.

Until now the attention was focused mainly on the active substances, their assessment under the vastly delayed Review Programme - as started under The EU BPD (Biocidal Products Directive 98/8/EC) - and on the active substances’ subsequent regulatory status. With relatively little practical experience under the Directive with respect to actual biocidal product formulations, the EU legislation underwent a major transformation through the introduction of the BPR (Biocidal Products Regulation (EU) No. 528/2012). Now, past the Regulation’s application date of September 1st, 2013, with the first active substance already approved under antifouling Product Type 21 and others to follow soon, regulatory procedures for product formulations are imminent; it is time to concentrate on the antifoulings.

This presentation looks at practical regulatory issues encountered by the antifouling industry as a result of EU biocides legislation. It will review the main differences between EU BPD and BPR, transitional measures, f.i. in relation to keeping existing product portfolio on the market, practical points to take into account when developing a new antifouling formulation and strategic and practical aspects to be considered before and during product authorisation. The various topics will be addressed mainly from a formulator’s perspective.

About the Speaker:
Impact of the Regulatory Framework on Innovation in the Antifouling Market – an Active Substance Supplier’s Perspective

By Dr Rodolphe Querou, Europe Regulatory Affairs Manager, Dow Microbial Control, Nice Area, France

Abstract:
Legislation is a key driver for innovation, as it can be either an incentive or an obstacle to the placing of new products on the market. For antifouling products, when evaluating the impact of specific regulatory provisions on innovation, it is necessary to take into account some basic characteristics of the market, when compared to other biologically active products like pharmaceuticals or plant protection products.

Through the example of the EU Biocidal Products Directive (BPD) recently replaced by the Biocidal Products Regulation (BPR), we will highlight how, by setting up a very high level of requirements for protecting human health and the environment and a very high cost of compliance, BPR has both created lots of space for new products but also unfortunately created barriers for innovation.

We will present our experience with the support of SEA-NINE™ anti-fouling technology through the BPR, the multiple challenges to achieve final approval, and how this experience can be helpful when considering the development of new active substances. Then within this difficult context, we will present how the development of new formulations or delivery systems for active substances, like our new SEA-NINE™ ACR, advanced controlled release technology, will probably be the basis for innovation in the coming years in regulated areas.

About the Speaker:
Dr Rodolphe Quérou is a Regulatory Manager for Dow Microbial Control, Europe. In this role he handles the regulatory and product sustainability support of a portfolio of biocidal active substances.
substances and biocidal products. In the past 10 years, Rodolphe Quérou has been involved in the support of SEA-NINE™ antifouling agent through the Biocidal Products Regulation in Europe and globally, as Dow Microbial Control global regulatory expert for the antifouling market. Rodolphe Quérou represents Dow Microbial Control at the CEFIC European Biocidal Products Forum and at the CEPE (European Council of the Paints, Printing Inks and Artist’s Colours Industry) and IPPIC (International Paint and Printing Ink Council) Antifouling working groups. Within these industry groups, he has participated in the early development of the European legislation on biocides and antifouling products. Rodolphe Quérou joined The Dow Chemical Company in 2009 via the acquisition of Rohm and Haas Company. Previously he has held a number of R&D and regulatory positions within the plant protection, fertilizer and biocides industry. Rodolphe has been involved in Biocides regulatory affairs since 2000. He graduated with a Master of Engineering in Agronomy from the Ecole Nationale Supérieure Agronomique de Toulouse, France and a PhD in Biology from the University Joseph Fourier Grenoble, France.