International Symposium on Corrosion and Fouling

Two natural curses for a ship's hull

Antwerp Maritime Academy
3 April 2017

http://corrosion.hzs.be

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This workshop is supported by: The NATO **Science** for **Peace** and **Security** Programme

Programme of the symposium

08:00 - 09:15	Registration
09:15 - 09:30	Welcome by Capt. P. BLONDE, General Director Antwerp Maritime Academy
09:30 - 10:10	Prof. Dr. Rob MELCHERS, University of Newcastle, Australia Modelling, prediction and factors in the corrosion of steels in marine environments
10:10 - 10:30	Remke WILLEMEN, Senior Lecturer, Antwerp Maritime Academy, Belgium The economic benefit of a long-term coating strategy
10:30 - 11:00	Coffee break
11:00 - 11:20	Prof. Dr. Yves VAN INGELGEM, Vrije Universiteit Brussel (VUB), Belgium Monitoring as a tool to continuously assess the state of health of metallic structures in marine conditions
11:20 - 12:00	Johnny ELIASSON, Chevron Shipping, USA Discussions on optimizing coating performance inside and outside ship hulls
12:00 - 12:30	Panel discussion Moderator: Dr. Geert Potters, Antwerp Maritime Academy, Belgium
12:30 - 13:30	Lunch
13:30 - 14:10	Prof. Dr. Geoff SWAIN, Florida Institute of Technology, USA Biofouling Risk and Biofouling Management
14:10 - 14:30	Raf MESKENS, Senior Lecturer, Antwerp Maritime Academy, Belgium Anti-fouling protection on a ship's hull: evaluation of recent developments and formulation of innovative alternatives
14:30 - 14:50	Dr. Francis KERCKHOF, Royal Belgian Institute of Natural Sciences, Belgium Hitchhiking across the world's oceans: fouling and introduced species
14:50 - 15:20	Coffee break
15:20 - 15:40	Dr. Corina PRENT, ACOTEC, Netherlands Microbial corrosion, myth or reality?
15:40 - 16:00	Prof. Dr. Colin JANSSEN, University of Gent, Belgium A brief overview of potential harmful effects to marine ecosystems of ship-associated technology
16:00 - 16:20	Elodie LETRAY, CMA Ships, France Managing Hull Fouling by a ship-owner
16:20 - 17:00	Panel discussion Moderator Dr. Geert Potters, Antwerp Maritime Academy, Belgium
17:00 - 18:30	Closing remarks, social event and reception

Objective of the symposium

Corrosion and fouling are two major problems affecting all shipborne commercial activities.

National and international experts will present overviews about current evolutions, challenging case studies and new possibilities of state-of-the-art monitoring systems.

The symposium seeks for answers on the following questions:

- What is maritime corrosion and how can we fight it?
- How can we measure the speed of corrosion?
- How to balance sustainability in an economic way?
- How to make a coating lifetime lasting?
- What is maritime fouling and how can we fight it?
- How to compare one anti fouling coating with another in an objective way.
- Microbial corrosion, myth or reality?
- Are ships ecologically friendly?
- Are ships influencing the biodiversity?
- How does a ship owner manage hull fouling?

On purpose the fundamental scientific approach was abandoned a little bit in favor of the immediate applicability. The objective is that this symposium is accessible to everybody with a sound interest in ships and the sea. The symposium focuses on all ship related professions such as ship owners and managers, national and international rule makers, classification societies, insurance companies, stevedores, port captains and officers, present and future ship captains and officers.

We hope to meet and greet you on the 3rd of April and wish you an enjoyable symposium!

Abstracts of plenary presentations

Modelling, prediction and factors in the corrosion of steels in marine environments

Rob Melchers
The University of Newcastle, Australia

Recent applied research focused on the severity and progression of the marine corrosion of steels is reviewed. Protective measures such as protective coatings and cathodic protection are not always possible, effective or even cost effective. A model for marine corrosion prediction for steel as a function of time is outlined. The model is based on theoretical concepts but is calibrated to actual field data drawn from field exposure results from a wide variety of compatible sources, ranging from the Tropics to sub-Arctic conditions. The important difference between initial and short-term 'corrosion rates' versus longer-term corrosion is noted. The effects of water salinity and water velocity are described, also based on field studies. The effect of microbiological corrosion and when it can be important are described and its modelling are described. Steel composition is discussed briefly but is not a significant factor for low carbon structural steels. As well as 'general' corrosion, consideration is given also to the progression of pitting corrosion and the mechanism under which it occurs in the medium to longer term. This is important in understanding the effectiveness of coatings and cathodic protection for already corroded steels surfaces. The work described has been applied to a number of practical projects. These are outlined and include corrosion of steel sheet piling, ballast tank corrosion, corrosion inside bulk carrier ship holds and corrosion of FPSO mooring chains.

The economic benefit of a long-term coating strategy

Remke Willemen
Antwerp Maritime Academy, Belgium

When a ship reaches the end of its service life it is broken down at a demolition site to recover steel and other useful items. The recycling process itself imposes risks to the human health and safety, as well as to our habitat by sending toxic components into the atmosphere and the maritime environment. Not all parts and products can be recycled and thus waste, toxic and non-toxic, is generated. Extending the service life of a ship can contribute to the protection of human life and the environment.

The same is valid when looking at the service life from the ship construction point of view. If the service life of a ship is extended less ships have to be built. To estimate the energy consumption of steel production Javaherdashti (2008) suggests that the energy required to produce one ton of steel is approximately equal to the energy an average family consumes over 3 months and roughly worldwide one ton of steel turns into rust every 90 seconds (Javaherdashti, 2008). The service life of a ship is not determined by the external battering of the ship's hull by wind and waves but mainly by the internal gradual corrosion of the ballast tanks (Thapar, 2013). The latter implicates that a coating with a longer service life will have a direct impact on the life cycle of the ship, the toxic components send into the atmosphere and the energy consumption.

Most ballast tanks are prepared and coated according to the IMO Performance Standard for Protective Coating (PSPC), using a light-coloured epoxy coating that, when on board maintenance is being performed by the crew, should remain in a good condition for 15 years. Ship owners are not only pushed by international legislation (IMO, 2009) but also by commercial needs in preserving a good reputation, to keep the ballast tanks of their vessels in a good condition to avoid extra inspections and costs. Aiming to extend the service life of your vessel to 25 years with ballast tanks in a good condition, a full-recoat must be considered. Recoating is bad for the environment as toxic components are sent into the atmosphere.

Monitoring as a tool to continuously assess the state of health of metallic structures in marine conditions

Yves Van Ingelgem
Vrije Universiteit Brussel, Belgium

Ships tend to spend most of their operational life in challenging marine conditions. Other than for fixed structures the environment they reside in as well as the loads they are subjected to can vary significantly over the full operational life. This means that, in order to track the true 'state of health' of a ship in time one cannot only rely on design assumptions: a thorough follow-up based on continuous sensor readings turns out to be the way to go in optimal structural health management.

When on a trip as well as when in port ships are subjected to various kinds of loads:

- Periodic mechanical loads through waves, currents, wind as well as rotating equipment
- Extreme mechanical loads in case of storms or collisions
- Corrosive loads that vary in time with location, temperature, state of health of the coating

- Abrasive loads in case of special cargo such as bulk goods or in the dredging industry
- Various kinds of fouling

These in turn have a significant influence on the ship's availability and performance, thus on the economic value to be gained from operating it. Unexpected or excessive degradation can lead to unplanned downtime. Cracks or leaks can lead to spills or even loss of the ship. Excessive abrasion leads to increased replacement costs and fouling results in increased fuel consumption and reduced cooling/heating capacity.

The good thing however is that all of these phenomena can be followed nowadays using a well-chosen combination of sensors. Mechanical loads and deformations, including fatigue, can be tracked using accelerometers and strain gauges. Corrosion activity can be followed using ER probes, coupons or PermaZen technology. Fouling can be made visible by specific sensors as well or tracked from derived parameters such as heat transfer coefficients. Finally, all of these are coupled with operational parameters such as temperatures, speed, fuel consumption, metocean conditions, position, ...

In order to avoid downtime, minimize fuel consumption and have a maximal return on investment (ROI) it is paramount to be able to predict failure in order to allow for cost-effective maintenance. Based on modern-day big data techniques together with solid physics and a number of the listed (novel) sensoring techniques such can be achieved through continuous monitoring. Additional benefits include the ability to determine the real age of the vessel compared to the design life set forward, leading to an improved and quantitative decommissioning strategy. Furthermore, the knowledge obtained in a solid integrity monitoring program is ready to be implemented in future generations of ships that will in turn be gifted with a more extended operational life. The presentation will provide an overview of the available sensor techniques and how these can be combined into an efficient monitoring tool for the state of health of an operational vessel.

Discussions on optimizing coating performance inside and outside ship hulls

Johnny Eliasson
Chevron Shipping, USA

The definition of success in coating usage is meeting the expectations. As such it is vital that the end user have a clear idea of what these expectations are. The providers cannot be the ones that decide on the expectations. Coating data sheets offers a range of choices in terms of surface preparation and application conditions, all of which may not generate a performance that meets the expectations. The painting manufacturers are under pressure to make things easy for the constructing yard, and there is nothing wrong with that as long as the final product also meets the needs of the ship. If the intent of the application is make something look good only during a visit of a dignitary, and the ship is to be retired soon after a minimum approach is highly appropriate. However, if it is a new ship with a 25-year service life expectancy a more robust approach is the more cost effective approach. This presentation will focus on the common modes of failure and what can be done at onset to offset those risks to increase the chance of meeting the expectations of a 25-year performance of the coatings applied. Much of the discussions will touch on ballast tank coatings as the performance of those have an influence on the ships' service life.

Biofouling Risk and Biofouling Management

Dr. Geoffrey Swain
Center for Corrosion and Biofouling Control
Florida Institute of Technology

Biofouling in some form or manner is ubiquitous to all marine environments. Its manifestation is dependent on the biogeographical setting, season, aquatic setting, structure, substrate and operational characteristics. Understanding the type of fouling that may occur is essential to estimating risk and implementing a biofouling management solution. It enables decisions to be made at the design phase of projects. For example, is it possible to incorporate a fouling allowance into the design so that no fouling control methods are required? If there is a requirement for fouling control; what is the design life, what are the operational requirements, what are the environmental conditions, what regulations apply, and what are the economic limitations? Examples of the how an understanding of biofouling risk may be used to enhance biofouling management will be given.

Anti-fouling protection on a ship's hull: evaluation of recent developments and formulation of innovative alternatives

Raf Meskens
Antwerp Maritime Academy

Marine fouling, or the growth of marine organisms on fully or partly submerged structures, is an unwanted phenomenon in the marine industry. Bio fouling will increase the hydrodynamic drag of ships, causing an increased fuel consumption, promote the corrosion of the metallic structures and trigger undesired transport of invasive species (IMO and the environment 2009, 2009). The impact is economic as well as environmental. More fuel consumption is synonym for more CO2 and other detrimental emissions, corrosion entails coating and the introduction of toxic substances in the sea and air and the transport of hitch-hikers: non-indigenous species towards locations without natural enemies will harm the local delights of the marine environment.

In 2001 the IMO adopted the "International Convention on the Control of Harmful Anti-Fouling Systems on Ships". This convention entered into force 17 September 2008 and prohibited the use of harmful organotins in anti-fouling paints used on ships. A mechanism was established to prevent the future use of other potential harmful substances in anti-fouling systems. The ban on organotins confronted the marine industry with a major challenge. TBT's (TriButylTin) have a negative impact on the marine biotope but till today no equally efficient, harmless, substance has been found. The search for an efficient, economic and ecological friendly novel anti-fouling paint is high on the agenda of IMO, governments, paint producers, ship owners and environmental organizations.

All major marine coating producers bring to the market very similar products. Broadly speaking, the present hull anti-fouling systems focus on the following three generic types of AF-coating: firstly, hard coatings, usually biocide-free vinyl esters, reinforced with glass platelets. In actual fact this is not a real anti-fouling coating since fouling will appear over time but it resists mechanical cleaning, even with hard brushes, exceptionally well. Secondly, we have a whole range of soft/smooth paints, often based on silicones or fluoropolymers, rendering the hull surface so slippery that latching onto becomes difficult. Basically, this type of coating cleans itself by means of the speed of the ship, the organisms with little adhesion will flush of easily. Finally, the most popular type of fouling protection, have a toxic additive incorporated in the topcoat. Predominantly these additives are copper based products reinforced with booster biocides. Three different techniques are being used to release these toxins in a more or less controlled way. The most primitive system, dating from the 50's, consist out of a soluble matrix, in general colophony mixed with copper, arsenic, zinc, mercury or iron oxides. A few years later, the binder became non-soluble, acrylic resins, vinyl resins or chlorinated rubber polymers were being used together with copper and zinc oxides with or without organometallic compounds. Presently mainly self-polishing copolymers are being used whereby biocides are leached under a controlled manner. While sailing, the paint abrades and constantly a new layer of coating, mixed with zinc- or copper oxides emerges.

Each of the above described AF-coatings has a very specific and limited field of application. Selecting the correct coating for a specific ship is far from self-evident. Important differences do exist within each coating type, dependent on the manufacturer. Unfortunately, no real objective means of comparing these products exists, neither on performance nor on ecological impact.

The aim of this project is to establish an impartial test-protocol and build a platform for testing AF-coatings in a statically and dynamically manner. With knowledge of type, composition and performance of the anti-fouling paints tested we can advise the ship owners in an objective way and evaluate the ecological impact of a paint through a well-founded life cycle analysis.

Hitchhiking across the world's oceans: biofouling and introduced species

Francis Kerckhof

Royal Belgian Institute of Natural Sciences, Belgium

Biofouling and introduced species are one of the causes of a changing biodiversity in the marine environment. In this talk I will address the topic of hull fouling and introduced species i.e. species introduced by human activities beyond their native range into new areas. In their new habitat, such species pose a threat to native biodiversity because they may alter local communities, and have unwanted economic effects. Hence the introduction of non-indigenous species is recognized as a major threat to the marine environment, and, for example tackled in EU legislation such as the MSFD.

Shipping, with ballast water and hull fouling, is an important vector for species introductions into the marine environment and since the dawn of maritime transport hull fouling has remained an everlasting nuisance, not only because it reduces the ships' speed and clogs intakes and pipes, it also impacts marine biodiversity, for, as biofouling, species are transported all over the world's oceans and introduced into areas beyond their natural distribution.

While ballast water is being tackled in various legislations and regulations, hull fouling remains an important cause of introductions, especially since the ban of the very effective anti-fouling agent TBT (Tributyltin). During the past decades, the chances for species to survive their journey and ultimately to colonise areas beyond their natural distribution has greatly increased, because maritime transport has become increasingly faster and more intense. Moreover, the permanent establishment of migrants is aided by the growing availability of artificial hard substrata in coastal areas and climate change. Barnacles (Cirripedia), probably the most common fouling organisms, are a good illustration of the ongoing changes as many species have nowadays established populations far beyond their original distribution.

Microbial corrosion, myth or reality?

Corina Prent
Acotec, The Netherlands

More and more evidence has been found that micro-organism can cause corrosion either by their metabolism or by creating an acidic micro-environment. Evidence of microbially induced corrosion (MIC) has even been found in the deep sea. When it develops, microbial corrosion, is a fast form of corrosion, unpredictable in its occurrence.

Harbours are experiencing increasingly more problems with microbial corrosion especially when steel berths are only protected by cathodic protection. Protective coatings can improve protection against corrosion but most paint systems have a limited life time expectation of maximum 15 years. Current ISO, NACE and NORSOK test methods are not capable of predicting the life cycle of a protective coating system and to take into account the protection against MIC. Only a few commercial available coatings give a long lasting general corrosion protection for over 25 years.

Because the life time of the applied coating is much shorter than the expected life time of the ships, regular inspection and maintenance of the protective coating becomes important. However, in most cases, coating maintenance and the choice of coating on itself is cost driven. Proper application is also an issue.

Several accidents involving ships have as root cause corrosion. For example, the sinking of the Nakhodka (1996), the Erica (1999), the Castor (2000) and the Swanland (2011) were caused by corrosion, possibly MIC. Amongst others, these incidents have resulted in the new IMO PSPC regulations with regard to ballast tank protection.

Research has shown that there is the possibility of occurrence of MIC in ballast water tanks but until now real time testing for MIC in ballast tanks in a very early stage is difficult.

A brief overview of potential harmful effects to marine ecosystems of ship-associated technology

Colin JANSSEN
University of Gent, Belgium

Managing Hull Fouling by a shipowner

Elodie LETRAY
CMA-CGM, France

The CMA CGM Group is a leading worldwide shipping group. The company operates on all seas, with a young and diversified fleet of 536 vessels.

CMA CGM's guiding principle, places the protection of the environment at the heart of its policy as a sustainable and an accountable core point. Since 2009, we have implemented numerous technical energy efficiency improvements on CMA CGM owned vessels fleet. Our group has achieved a 50% CO2 reduction over the last 10 years and has set a new ambitious target of -30% by 2025, presented at COP 21 Paris. This is why, despite the last year fuel price decrease, CMA CGM group pursues its investment program in innovation. On top of that, while looking forward on a pure economical aspect, the introduction of the World Wide ECA, confirmed for 2020, introduce a milestone for a future of expensive energy. Hence, the future price of bunker is very uncertain but most experts would claim that "new" low sulfur fuel oil would be closer to the price of MGO than HFO.

Out of these initiatives mentioned above, the carbon footprint can be improved by maintaining the initial frictional resistance of the ship. That means keeping the hull and the propeller blades surface smooth and free from any fouling. To operate the hull in optimal condition, CMA Ships (the ship management branch of CMA CGM group) has adopted the following solutions:

1. A strategic selection of the Underwater Coating at Newbuilding stage or during Dry Docking operation. CMA Ships tries to select the best Antifouling considering variations in operations of the ships. Therefore, we need to have a perfect understanding of the performance of existing antifouling.
2. An Intermediate solution between two Dry Docks. Today to ensure optimal performance, it is inevitable to implement an Underwater Maintenance program including propeller polishing, hull inspection and Hull cleaning.

It is not an easy way to undergo hull cleaning in an optimal condition. We are facing to numerous constraints that needs to be addressed (such as: numerous ports don't authorize in water hull cleaning, a lack of information concerning the impact of hull cleaning technologies on underwater coatings, non-application on silicone paint inside Chinese shipyard).

Abstracts of poster presentations

Biofouling and anti-fouling research @ILVO

Devriese, L.I., De Witte, B., Cooreman, K., Hillewaert, H., Delbare, D., Hostens, K., Polet, H.
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Marine biofouling causes serious problems for a wide range of maritime industries around the world, and in return, anti-fouling agents cause concern about their potential to negatively affect the marine ecosystem. The Institute for Agricultural and Fisheries Research (ILVO) is on one hand involved with sustainable aquaculture systems and efficiency of fisheries methods, and on the other hand with environmental quality and ecosystem health. The aim of this abstract is to present the skills available @ILVO to test biofouling formation on hard substrates, to provide insights on emerging contaminants in anti-fouling coatings in the marine environment and to develop alternative environmentally friendly antifouling agents.

Characterization of biofouling and its dynamics: from microfouling to macrofouling.
Microfouling involves the first steps in the biofouling process. As the process of biofilm formation is dynamic, primary colonizers (microbial communities) provide essential information on the fouling process and a microfouling assay is needed to understand the fouling mechanisms. @ILVO, microfouling formation is evaluated through DNA metabarcoding, which allows the taxonomic identification of the first species colonizing the surface, which are invisible by the eye at that stage. The methodology, based on 16S rDNA and ITS2 amplicon sequencing for bacterial and fungal communities' composition respectively, was originally developed @ILVO for biofouling assessment on plastic debris.

Macrofouling occurs in a next stage of the biofouling process, and involves the settlement and growth of higher organisms on underwater or intertidal surfaces. Methodology shifts as macrofouling characterisation can be done by stereomicroscopy. A group of taxonomic experts with many years of experience in morphological identification of hard and soft substrate species is resident @ILVO.

Determination of toxic antifouling agents and development of environmentally friendly alternatives.
An unfortunate drawback of antifouling still is the unavailability of environmentally safe and adequate alternatives to TBT. The industry remains forced to fall back on leaching extreme toxic biocides, all having their respective and often unknown severe sub-lethal effects. One example is the commercial application of up to 80% copper oxide (64% copper) coatings on ship hulls. ILVO has expertise in copper and zinc determinations in marine environments, in co-operation with CODA-CERVA. Recently, an analytical procedure has been developed @ILVO to determine a wide variety of toxic booster biocides at environmentally low concentrations. @ILVO, focus is also on research on environmentally friendly alternatives, hereby inspired by the fouling-free marine organisms. Numerous species of several phyla possess mechanisms to remain fouling-free during their whole lifetime and even thereafter. However, the complexity of the antifouling process, reflected by the many hundreds of described and structurally different chemical compounds all or not in combination with topographical properties slows down the search for safe and preferably natural antifoulants.

Prevention of biofouling by bio-inspired photocatalytic nanocoatings

Sergey Dobretsov

Department of Marine Science and Fisheries, College of Agricultural & Marine Sciences, Sultan Qaboos University, P.O. Box 34 Al Khoud 123, Sultanate of Oman

Center of Excellence in Marine Biotechnology, Sultan Qaboos University, P.O. Box 50 Al Khoud 123, Sultanate of Oman

Biofouling is undesirable growth of organisms on submerged installation and it has heavy economic penalties. Current methods of antifouling defense (AF) are based on usage of toxic biocides that kill marine organisms and pollute the environment. The natural AF defense mechanism of some seaweeds that inhibits biofouling by production of reactive oxygen species (ROS) inspired us to mimic this process by fabricating ZnO nanorod photocatalytic coating. AF activity of fishing nets modified with ZnO nanocoating was compared with uncoated nets (control) and nets painted with commercial copper-based AF paint. One-month experiment in tropical waters showed that nanocoatings reduced bacterial abundances by 3-fold compared to the control and had higher antifouling performance over AF paint. Metagenomic analysis of prokaryotic and eukaryotic fouling organisms using MiSeq next generation sequencing platform proved that nanocoatings compared to AF paint were not selectively enriching communities with the resistant and pathogenic species. The proposed bio-inspired nanocoating is an important contribution towards environmentally friendly AF technologies.

Use and misuse of anodic protection in ballast tanks.

Kris De Baere[1,], Raf Meskens, Remke Willemen[1],Helen Verstraelen[1], Geert Potters[1,2]*
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For some 140 years, steel is the common construction material for commercial ships. Together with this, relatively stable, substance a persistent enemy popped up: corrosion. Two long-established methods are being used to fight this never sleeping enemy: either through the use of coatings, creating a barrier between the electrolyte and the steel or by way of using sacrificial anodes or impressed current, lowering the potential of the steel structure until it becomes cathodic. This article will focus on the correct use of sacrificial anodes in ballast tanks, since these tanks are the most vulnerable to corrosion, especially on board double hull ships due to increased temperatures, inherent wet/dry situations, omnipresence of seawater, storage compartment for ship's structural elements.

An in-situ survey of >170 ballast tanks on board merchant ships lead to two principal conclusions: First, epoxy coatings in ballast tanks, remain overall in intact condition for approximately 5 years and afterwards degrade with 1.7% surface per year. Secondly, statistical analysis of the database did not show any distinctive advantage of the presence of sacrificial anodes, hence leading to the alarming conclusions that, probably, for many years anodes have been used without any significant impact on corrosion or corrosion rates. We studied this phenomenon further in depth and found that a cathodic protection system will only generate a distinguishable advantage if installed and maintained meticulously. Calculating the total mass of zinc required to lower the potential of the metallic structure sufficiently is rather easy, distributing the anodes correctly throughout the tank to obtain an even and correct potential is already a lot more complicated. Till today, any legal obligation to install sacrificial anodes in ballast tanks, is lacking. Consequently, there are no rules promoting a correct weighing and spreading out of the sacrificial anodes. Very often, the design and installation of the cathodic protection system is done by the vendors of the zinc or aluminum anodes. Their and the ship's interest are not always the same.

A simulation package, CPMaster, developed by Elsyca, Belgium allows the visualization of the polarization of a metallic structure induced by sacrificial anodes or impressed current. By way of example one of the ballast tanks of the Flanders Harmony, a 28-year-old LNG carrier, was modelled and the results were compared with the outcome of a detailed tank inspection held during dry-dock in Bahrain 2013. The resemblance between the in-situ observation and the simulation model was satisfying. Although the tank was in a splendid condition, taking into account the age of the ship, there was still plenty of room for improvement. The cathodic protection system was oversized and the anodes were not distributed in a uniform way, the sacrificial anodes might even be responsible for the massive quantity of blisters in the tank.

Finally, we conclude that cathodic protection using sacrificial anodes is a useful technique only if the system is well proportioned, installed, maintained and evolves together with and in function of the condition of the tank. If one is not prepared to follow up the system in a proper way it is better to abandon cathodic protection all together and invest the money gained in an improved coating system.

Development of a test platform for anti-fouling coatings.

Raf Meskens[1,], Remke Willemen[1], Geert Potters[1,2], Kris De Baere[1], Silvia Lenaerts[2]*
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Marine fouling, or the growth of marine organisms on fully or partly submerged structures, is an unwanted phenomenon in the marine industry. Bio fouling will increase the hydrodynamic drag of ships, causing an increased fuel consumption, promote the corrosion of the metallic structures and trigger undesired transport of invasive species (IMO and the environment 2009, 2009).

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A well applied ballast tank coating = green ballast tank coating

Remke Willemen[1], Helen Verstraelen[1], Raf Meskens[1], Geert Potters[1,2], Kris De Baere[1]*
[1] Antwerp Maritime Academy, Antwerp, Belgium.
[2] Dept. Bioscience Engineering, University of Antwerp, Antwerp, Belgium.
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When a ship reaches the end of its service life it is broken down at a demolition site to recover steel and other useful items. The recycling process itself imposes risks to the human health and safety, as well as to our habitat by sending toxic components into the atmosphere and the maritime environment. Not all parts and products can be recycled and thus waste, toxic and non-toxic, is generated. Extending the service life of a ship can contribute to the protection of human life and the environment.

The same is valid when looking at the service life from the ship construction point of view. If the service life of a ship is extended less ships have to be built. To estimate the energy consumption of steel production Javaherdashti (2008) suggests that the energy required to produce one ton of steel is approximately equal to the energy an average family consumes over 3 months and roughly worldwide one ton of steel turns into rust every 90 seconds (Javaherdashti, 2008). The service life of a ship is not determined by the external battering of the ship's hull by wind and waves but mainly by the internal gradual corrosion of the ballast tanks (Thapar, 2013). The latter implicates that a coating with a longer service life will have a direct impact on the life cycle of the ship, the toxic components send into the atmosphere and the energy consumption.

Most ballast tanks are prepared and coated according to the IMO Performance Standard for Protective Coating (PSPC), using a light-coloured epoxy coating that, when on board maintenance is being performed by the crew, should remain in a good condition for 15 years. Ship owners are not only pushed by international legislation (IMO, 2009) but also by commercial needs in preserving a good reputation, to keep the ballast tanks of their vessels in a good condition to avoid extra inspections and costs. Aiming to extend the service life of your vessel to 25 years with ballast tanks in a good condition, a full-recoat must be considered. Recoating is bad for the environment as toxic components are sent into the atmosphere.

The impact of sacrificial anodes and coatings of inland and marine vessels on water quality in the docks of the port of Antwerp

Svetlana Samsonova, Wim Van Steelandt & Eric de Deckere

The docks in the Port of Antwerp is one of the waterbodies for which the status has to be reported in function of the European Water Framework Directive. The criteria that have to be reached are well described and the Antwerp Port Authority is following up the needs and possible measures to improve the water quality in the docks. For this purpose the continuous monitoring of selected water parameters along with the assessment of the emissions from the diffuse sources are organized in the port area.

The number of specific port activities is monitored and is an integral part of the water emission inventory, such as *shipping, road traffic, railways, engineering structures placed into water or on the shore of a harbour*. The emissions of Zn and Al resulting from corrosion of sacrificial anodes of ships and the emissions of Cu and PAH's caused by the leaching of hull coating products are calculated based on the activity rates and emissions factors for shipping from the year 2010 when 14 887 marine ship visits and 92 759 inland ship visits were registered.

The environmental quality standards (EQS) for water are regulated by the European Water Frame Directive. According to the monitoring data, the metals **Cd**, **Cu**, **Ag**, **Zn** are exceeding the EQS. For PAH's benzo(a)pyrene, sum (indeno(1,2,3-cd)pyrene + benzo-(ghi)perylene), fluoranthene are exceeding the targets. The study reveals the contribution of the diffuse sources in the overall emission picture:

- 899 kg of Al (or 44% of the net emissions of aluminium in the docks)
- **520 kg of Zn** (56%) from sacrificial anodes
- **5 393 kg of Cu** (92%) from coatings of marine vessels
- **11 kg of PAH's** (5%) from coatings of inland vessels with the following distribution: acenaphthene (7%), acenaphthylene (5%), anthracene (6%), benz[a]anthracene (4%), **benzo(a)pyrene** (4%), benzo[b]fluoranthene (4%), **benzo[ghi]perylene** (2%), benzo[k]fluoranthene (4%), chrysene (2%), dibenzo[a,h]anthracene (19%), phenanthrene (1%), **fluoranthene** (1%), fluorene (5%), **indeno[1,2,3-cd]pyrene** (18%), naphthalene (14%), pyrene (5%).

The new water emissions inventory is based on the activity data from the year 2015 and will be released in summer 2017.

Hydroacoustic Antifouling Systems

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Biofouling has a major impact on the global shipping industry. The fouling demands extensive efforts to clean the fouled vessels, increases the expenses for the shipping companies and worsens a number of environmental problems, such as carbon dioxide emissions due to increased drag, or the transport of organisms outside their habitat. In the past, toxic paints were found to be the solution for this problem. The ban of TBT (tributyltin), because of its negative impact on the environment, has led to the research of several other alternatives. Until now, however, no other equally effective product as TBT has been found.

Nowadays, scome scientific evidence points towards hydroacoustic antifouling systems. According to its manufacturers, hydroacoustic antifouling systems are an eco-friendly solution to biofouling on merchant ships. The system consists of transducers at the inner side of a ship's outer hull which emit acoustic ultrasound waves. The alteration of positive and negative pressure created by these waves result in cavitation bubbles. These bubbles make the hull an unattractive environment for the barnacles and mussels to grow on. The second working principle is resonation, capable of destroying single cell organisms, which are the feeding ground for fouling organisms. Studies have shown that the use of these acoustic antifouling systems are working well on specific frequencies, exposure time and amplitude. An hydroacoustic antifouling system is capable of keeping the outer platting of vessels free of the fouling barnacle *Amphibalanus amphitrite*. Therefore, a frequency of 23 kHz, an exposure time of 300 seconds and an amplitude of 20 kPa is the optimal configuration. (Shifeng, 2012). Before implementation of hydroacoustic antifouling systems, further research is still be done to investigate the impact of ultrasound on other marine life, as the frequencies used are within hearing range of sea mammals and pinnipeds.

SHIFENG, G. (2012).*A Study of Ultrasonic Effects on the Marine Biofouling Organism of Barnacle, Amphibalanus Amphitrite*, Doctoral dissertation, National University of Singapore.

Biomimicry in antifouling solutions

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Shipping industry is facing an ever-increasing pressure caused by the environmental impact of its activities. In many industrial fields, ranging from medical technologies to aeronautics, nature itself offers valid, ecologically sound alternative solutions to complicated problems. By means of this poster we look at biomimetic antifouling solutions for the ship's hull.

What is biomimicry? It is the study of the structure and function of biological systems and processes as models or inspiration for the sustainable design and engineering of materials and machines.

Inspired by nature, multiple studies and experiments tried to unveil how marine organisms cope with fouling. Different strategies could be identified. Next, some of these techniques were developed further into useful artificial antifouling solutions. Some of this research was even commercialized. Here, we wish to provide an overview of biomimetic maritime antifouling solutions. Good examples comprise:

- The Thorn-D self-adhesive foil (Micanti), which consist of a chaotic mass of nylon fibers, comparable to a thorny bush. Commercialised since 2012, it is said to improve fuel costs by 20%.
- Sharklet AF mimicks the denticles in the shark skin, increasing fluid flow at the hull surface, leading to a reduction in microorganism settlement.
- A similar way of thinking led to Shell's microtopographic surfaces (Dublin University), made in poly(methyl methacrylate), and inspired by observations of a crab shell immersed in a diatom culture

Nanoparticles in antifouling paint: an ecological solution?

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Fouling is a major problem in the shipping industry because it increases the drag of the ship, the fuel consumption and consequently the CO_2 emission. Fouling can consist of slime, algae and/or macro fouling like mussels, barnacles or crabs.

To avoid this accretion, antifouling paints cover the immersed parts of the hull. They prevent or limit fouling by using different techniques. Each constructor and developer uses his own formula. One of these methods adds nanoparticles to the top layer coating.

Nanoparticles are inorganic materials with a size ranging from 1 to 100 nanometres. They are essentially microscopically small crystal structures intentionally produced to repel micro- and macro fouling without having to resort to active biocides which are chemical active substance designed to destroy or eradicate or repulse harmful species.

Some examples of nanoparticles being used are: copper, silver, silicon dioxide, titanium dioxide. These products inhibit the development of nascent growth on submerged surfaces by producing an acid in contact with water or thanks to antimicrobial properties. Next, slipstream washes the remaining fouling away.

The main advantage of nanoparticles is that they seem to be eco-friendly compared with other antifouling paints on the market. However, initial studies indicate some bioaccumulation. These preliminary results are not certain yet due to the very active evolution of this technology. The findings of these studies also suggest that that human health may be affected by inhalation of nanoparticles.

In general, therefore, it seems that the new type of antifouling paint using nanoparticles is a good alternative to common paints. Nevertheless, there is some reserve concerning the bioaccumulation and the effects on little organisms after a long-term utilisation.

Was it a good idea to ban TBT from anti-fouling?

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TBT was one of the most effective anti-foulants that ever came in use, but at the same time the most troublesome substance ever deliberately introduced in the marine environment. By the 1980s some negative side-effects of TBT on the marine environment were recorded and in 1998 the use of organotins -like TBT- was banned. After this ban on TBT the shipping industry needed new alternatives that were as effective as TBT in keeping the hulls free from biofouling. But are these alternatives better for the marine environment and was it a good idea to ban TBT?

Booster biocides became the most commonly used alternative, albeit that some negative side-effects on non-target organisms became evident. These booster biocides have an even larger broad-spectrum impact on marine ecosystems than TBT. Concern arose because photosynthesis is affected by booster biocides, which has an impact on the entire base of the food chain. In comparison with these boosters, the ban on TBT is not a good idea because its alternative is an even greater threat to the environment.

Non-toxic anti-fouling strategies are also being developed. This is a positive trend since no harmful toxins are released into the marine environment and thus negative side-effects are rarely seen. A good example is the natural anti-fouling surface design.

Hull management, a change in mindset!

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Hull fouling has been a problem in the maritime world for a long time. In times where companies search for the best economic solution, many antifouling systems are old fashioned, toxic and firmly rooted in daily practices. This poses a huge threat to the marine environment. Today the irreversible effect on the environment is clearly seen. There is need for more stringent ecological regulations, which require new and innovative alternatives. Therefore, above all, a change in mindset is needed to look upon the problem from a larger perspective. In this regard the maritime industry should take on another approach. Why shouldn't hull fouling be managed on a more frequent time basis instead of fighting a losing ecological battle after a one-time application of toxic coatings and other antifouling systems? No pro-active antifouling system guarantees a hull which is 100% free of biofouling. With an eye on the future the change in mindset will contain a combination of multiple contributing factors, with hull cleaning becoming the standard treatment in every port.

Biographies of the speakers and organizers

Rob MELCHERS - Keynote Speaker

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Professor Melchers is Chair in Civil Engineering (since 1986) and Australian Research Council DORA Research Fellow at the University of Newcastle, Australia. Previously (2004-8, 2009-13) he held two consecutive 5 year ARC Professorial Fellowships. He is a Fellow Australian Academy of Technological Sciences and Engineering, Fellow of the Institution of Civil Engineers and Honorary Fellow of the Institution of Engineers Australia.

He graduated in Civil Engineering from Monash University. His PhD in structural engineering at Cambridge University made a major breakthrough by solving an 'unsolvable' structural optimization problem. Subsequently Melchers discovered a new Reciprocal Theorem in Elasticity Theory, recognized in University of Cambridge Prof. J. Heyman's 1996 book in the chapter entitled 'Betti, Maxwell, Müller-Breslau, Melchers'.

After some years in industry Melchers joined Monash University as an academic and turned his attention to structural safety that ultimately led to the current interest in deterioration and corrosion. He authored the text 'Structural Reliability Analysis and Prediction' in 1986 with second edition in 1999 and a third due 2017. In marine corrosion, the focus on actual corrosion under field conditions led to a strong interest in microbiological corrosion. As a result, Melchers has produced a set of new insights and prediction models, resulting in numerous keynote lectures and in prizes and awards, including:

- Eminent Speaker, The Institution of Engineers Australia, 2014 (national tour)
- John Connell Gold Medal for Structural Engineering, The Institution of Engineers Australia, 2013
- Jin S Chung Award, International Conference of Offshore and Polar Engineering, 2012
- Corrosion Medal, Australasian Corrosion Association, 2009

During 2009-13 Melchers was one of only two "International Visiting Scientists" in the European Community Marie Curie ITN 'Biocor' Project. During 2010-1 he was an industry-sponsored speaker on the topic of marine corrosion of steel for three international technical seminars hosted by mooring-chain manufacturer Vicinay-Cardenas.

The corrosion model developed by Melchers has been adopted for the corrosion of steel in seawater by the International Ship Structures Committee for condition assessment of aged ship and offshore structures, and, more recently, for the SCORCH joint-industry project on the corrosion of heavy-duty mooring chain and wire rope used for mooring

FPSOs. This work was funded by the world's leading oil companies, offshore operators and most major Classification Societies. (See www.fpsoforum.com/currentjips.html).

Most recently, Melchers together with Prof Chongmin from UNSW and industry partners Pacific-ESI and national agency Defence Science and Technology Group was awarded a large ARC Linkage project to develop the capability to predict the safety and condition of offshore structures including ships under extreme weather events and with deterioration of the structure.

R.Johnny ELIASSON - Keynote Speaker

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Johnny Eliasson has been in the marine paint industry for almost 40 years. After qualifying as a chemical engineer, he joined the Carboline International Co. ventures in Scandinavia. From this, Johnny gained significant insight into marine-related coating from both the manufacturing and application sides. He moved to South Korea to work initially for a paint supplier, and then for an end user before joining Stolt Tankers, initially in Houston, TX, then in Rotterdam as Manager.

He remained with Stolt for over 20 years and supervised the coating of more than 125 highly specialized chemical tankers. During his time at Stolt, Johnny became involved with the Tanker Structure Cooperative Forum (TSCF), an association of major ship owners, oil majors, and classification societies, and was instrumental in developing the TSCF's guide for implementation of International Maritime Organization (IMO) Rec. A798 (ballast tank coating recommendation). He also was a member of INTERTANKO's Technical Committee at IMO, primarily involved in work to develop the performance standard for protective coatings for ballast tanks.

Johnny also attended NACE International working groups and chaired the development of standards for the benefit of the marine industry, and is presently a member of the Coatings council at NACE an advisory group to the board of NACE.

In 2009 Johnny accepted an employment at the American Bureau of Shipping as Senior Principal Engineer and since 2013 Johnny is a Structural and Corrosion Engineer at Chevron Shipping Co.

Geoffrey W. SWAIN - Keynote Speaker

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Dr. Geoff Swain is a Professor of Oceanography and Ocean Engineering and the Director of the Center for Corrosion and Biofouling Control at the Florida Institute of Technology (FIT). His educational background includes a BS in Zoology (London University), MS in Oceanography (University of Southampton, UK) and a PhD in Engineering (University of Southampton, UK).

In the early 1970's he was a member of a team of scientists funded by the UK government for a two-year project to undertake a marine resources study of the Cayman Islands and to recommend policies to protect and maintain the quality of those waters. He returned to the UK and took an appointment at Southampton University, initially funded by the Royal Navy and then the Department of Energy, to research novel methods to control biofouling and corrosion. The research was initially directed towards ships, but latterly to problems that were being experienced in the North Sea oil industry. In the early 1980's he moved to Aberdeen, Scotland where he joined the Offshore Marine Studies Unit conducting corrosion and biofouling surveys on offshore structures in the North Sea. He joined FIT in 1984 and established the Center for Corrosion and Biofouling Control. The Center is fully staffed, has a laboratory on campus, static and dynamic seawater test facilities, two research boats and has active research grants with the Office of Naval Research and Industry. He designed the cathodic protection system for the Living Seas at Disney World, is active in dry dock and underwater inspections of ship hull coatings and cathodic protection systems and has published over 60 refereed articles on the subject. He is a member of the Marine Biological Association of the U.K., the National Association of Corrosion Engineers and the Society of Naval Architects and Marine Engineers.

Remke WILLEMEN

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Dra. ir. Remke Willemen (°1976) entered the maritime sector as a teenager involved in sailing. She graduated in Nautical Sciences at the Maritime Academy in 1998. She continued her studies and obtained an engineering degree in Maritime Technology at the Technical University in Delft. Her professional career started as a surveyor and joined the AMA as a teacher in 2012. Shortly after, she completes the corrosion team of the AMA and since November 2013 she commenced working on her dissertation involving "the influence of the application of a coating in ballast tanks of ships on the corrosion resistance of coatings".

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Dr. Yves Van Ingelgem is a civil engineer in materials science at the Vrije UniversiteitÂ Brussel (VUB). After completing his PhD, he created the Spin-Off company Zensor, that is providing sensor-based integrity monitoring solutions for infrastructure. The company provides monitoring solutions, but also developed a set of specific sensors that look at specific phenomena, such as corrosion. For the innovative approach within Zensor, which turns raw data from industrial monitoring into ready-to-use information, he won the first MIT Innovator of the Year award for under-35s.

Elodie LETRAY
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Graduated with master in Materials Engineering, I trained in several laboratories specialized in the control and characterization of materials (such as the SAFRAN Group's Composite Center of Excellence).

In 2006, I joined CMA CGM Group with the position of Study Materials Engineer for the needs of the fleet of owned vessels.

Over the years with the creation of an "Efficiency & Technology" Department within CMA Ships entity, the increase of CMA CGM fleet, with huge container ships and the reinforcement of international regulations, my missions were increasingly numerous and varied.

My missions as an Efficiency & Technology Engineer specialized in Materials include:

- Propose actions to improve the energy efficiency of CMA CGM fleet;
- Monitor the performance of CMA CGM fleet;
- Be the privileged interlocutor for materials for different technical departments of CMA Ships (New Buildings, Fleet, dry dock ...);
- Bring my expertise in materials science in the event of damage to CMA CGM fleet.

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Colin R. Janssen Ph.D. (°1960) is full professor (gewoon hoogleraar) of Ecotoxicology at Ghent University, Belgium where he was (until 2-2014) department head of the Department of Applied Ecology and Environmental Biology (75 co-workers) at the Faculty of Biosciences. He holds a Master's degree in Zoology and obtained his Ph.D. in Environmental Sciences (1992, Faculty Bioscience Engineering) from the same university. He now teaches undergraduate and graduate courses in aquatic ecology, and environmental health & toxicology and risk assessment. C. Janssen currently co-supervises a research team of approximately 30 collaborators and (on average) 10 M.Sc. students/year which are actively studying the ecological risks of chemicals and other stressors in freshwater and marine systems, chemical stress and evolutionary ecology, and ecological risk assessment modeling/procedures for chemicals and environmental stressors including global change stressors. C. Janssen has been a guest professor at three universities in Europe and directs/or has directed research projects in Europe, South Africa and the USA. He has published more than 40 international papers of which approximately 325 are cited in the ISI Web of Science and has an h-index of 49, a total citation number of around 9500 and an average citation score of 30. The other main scholarly database Google Scholar lists 695 contributions attributed to C. Janssen and a total citation score of 13500 and an h-index of 68. A full publication list can be found at https://biblio.ugent.be/person/801000577613 and on www.milieutox.ugent.be. He has made approximately 100 presentations, many of which as key-note speaker, at scientific conferences. Janssen and members of his research team have made in excess of 400 contributions at scientific meetings; they have received 18 scientific awards. Janssen is the holder of the Honorary Chair Bauchau at the University of Namur Belgium (2004-2006). With this scientific track record C. Janssen ranks among the top 2% of his research field.

Next to his academic contributions to (applied and fundamental) research in the field of environmental health, C. Janssen has provided independent scientific services to numerous organizations. He was a member of the Publication Advisory Committee and the Metal Advisory Group of the Society of Environmental Toxicology and Chemistry (1997-2002) and has served as European Newsletter editor (1995-2001) for the same professional society. He was president of the International Society of Ecotoxicology and Environmental Safety (2004-2006) and was/is editorial board member of Environmental Pollution and Ecotoxicology and Environmental Safety. C. Janssen was an appointed member (until 2013) of the Belgian Health Council and acts or has acted as external advisor to various national environmental agencies and international organizations such as OECD, EU and WHO. In 1977, he was appointed as member of the EU Scientific Committee on Toxicity, Ecotoxicity and the Environment (SCTEE), he was re-elected in the EU Scientific Committee for Human and Environmental Risks (SCHER, 2004-2016) and chaired this committee during the past three years. He is currently the vice-chair of the Board of Directors of the Flanders Marine Institute and is chair of the scientific committee of this organization. C. Janssen has provided independent scientific advice to both national and international policy/regulatory institutions and to international industry organizations on fundamental science and regulatory issues concerning environmental quality criteria setting, risk assessments of new and existing substances and other issues related to environmental health.

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Corina Prent studied organometallic chemistry and polymer chemistry at the Rijksuniversiteit Groningen (1980-1987) and was a post-doctoral researcher on polymers at the Technical University of Eindhoven (1990-1991).

She was born in Rotterdam close to the harbor and started sailing at a young age. She has always had a special bond with water and currently lives along the Steenwijker a small river connected to the famous wetlands de Wieden and the Weerribben.

Between 1995 and 2013 Corina held management positions in reputed companies such as AVEBE, ICI, CIBA, BASF & TNO. At TNO she was head of the Maritime Performance Materials Centre were research on tribology, corrosion, corrosion protection and anti-fouling was carried out for both the Dutch Navy and private companies. Presently she works as R&T manager for ACOTEC and owns her own company CPSTERADVIES specialized consulting the technical Industry, with a focus on the chemical, maritime and off shore Industry.

Corina is an excellent people manager with international experience and a successful commercial and technical track record for global market and product development.

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Drs. Raf Meskens (°1968) obtained the degree of Master in Nautical Sciences at the Antwerp Maritime Academy in 2008. He has a supplementary degree in Safety and Environmental Technology, obtained at Agoria, Sector Federation of the Technological Industry. After his maritime career, sailing on board bulk carriers, ferry boats and dredgers with a final rank of Second Officer, he pursued a career on shore, first ten years as a P&I Surveyor and later on as head of the Logistics, Safety and Environmental Department at Antwerp Ship Repair. Never been out of the maritime community he joined the Antwerp Maritime Academy as a teacher in 2009. In 2013 he joined the corrosion team of the AMA and since November 2013 commenced working on his dissertation involving involving "anti-fouling protection on ships' hull - evaluation of recent developments and formulation of innovative alternatives".

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Francis Kerckhof is a marine biologist with 40 years of experience. He works at the Royal Belgian Institute of Natural Sciences, Operational Directorate of Natural Environment, Department of Ecology and Management of the Sea (MARECO).

He started his marine career by collecting sea shells along the Belgian coast to finally become a full scale scientific researcher with a broad taxonomic expertise at the Royal Belgian Institute of Natural Sciences. He is a recognised expert in the field of introduced species, and he is the Belgian delegate in the ICES Working Group on the Introduction and Transfers of Marine Organisms and the ICES Working Group on Ballast and Other Ship Vectors. He is also co-founder of the Belgian Strandwerkgroep (Beach Study Group), a natural history study group founded at a time when it was hard to find information about the marine environment and the interest in it was low.

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Capt. Dr. Kris De Baere (°1958) has a long lasting relationship with the Antwerp Maritime Academy. He started as a student in 1977 and obtained an academic master in Nautical Sciences in 1988 and his master mariners license f.g. in 1990. After 15 years at sea, mainly on board oil and chemical tankers, he returned to the AMA, as a lecturer, to pass on his love for the sea, mixed with a lot of knowledge and experience. In 1993 (till 2015) he became the dean of the faculty of Nautical Sciences. In 2007 he started together with Dr. Verstraelen and Dr. Potters the corrosion research group and in 2011 his research work has been awarded with a PhD - In situ study of the significant parameters governing corrosion in ballast tanks on board merchant vessels.

When he is not lecturing, climbing up and down ballast tanks, attending meetings or writing articles he becomes enchanted by antique maritime memorabilia and tries to put together the most exciting collection in the world (at least).

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Dr Geert Potters (°1976) is a member of the corrosion team at the Antwerp Maritime Academy. Originally not trained as a maritime scientist but as a plant physiologist, he defended a Ph D on antioxidants and plant growth, and proceeded by investigating the use of bamboo in a sustainable green economy. However, as a proud inhabitant of Europe's second largest port, he found his way into the maritime sector, helped to set up the corrosion team in 2006, co-authored a decent amount of publications on the subject and was mentor for two PhD dissertations in Nautical Sciences at the Academy. Currently, he is looking for links between biology (micro-organisms) and the shipping world (sustained by a NATO grant), and tries to make future captains to feel involved and enthusiastic about sustainable development and a greener world. He writes for a popular scientific, journal, sings (though not in the lab) and likes to confuse honest sailors with words like "multivariate statistics", "environmental metagenomics" and "impact factor".

Corrosion publications at the Antwerp Maritime Academy

2009: In situ study of ballast tank corrosion on ships: part 1
Verstraelen Helen, De Baere Kris, Schillemans Willy, Lemmens Lucien, Dewil Raf, Lenaerts Silvia, Potters Geert
Materials performance, National Association of Corrosion Engineers [Houston, Tex.], ISSN 0094-1492-48:10(2009), p. 48-51

2009: In situ study of ballast tank corrosion on ships: part 2
Verstraelen Helen, De Baere Kris, Schillemans Willy, Lemmens Lucien, Dewil Raf, Lenaerts Silvia, Potters Geert
Materials performance, National Association of Corrosion Engineers [Houston, Tex.], ISSN 0094-1492-48:11(2009), p. 54-57

2010: Impact of tank construction on corrosion of ship ballast tanks
De Baere Kris, Verstraelen Helen, Dewil Raf, Lemmens Lucien, Lenaerts Silvia, Nkunzimana Tharcisse, Potters Geert
Materials performance, National Association of Corrosion Engineers [Houston, Tex.], ISSN 0094-1492Â -49:5(2010), p. 48-54

2013: Reducing the cost of ballast tank corrosion : an economic modeling approach
De Baere Kris, Verstraelen Helen, Rigo Philippe,dVan Passel Steven, Lenaerts Silvia, Potters Geert
Marine structures, ISSN 0951-8339-32(2013), p. 136-152
Full text (Publishers DOI): http://dx.doi.org/doi:10.1016/j.marstruc.2012.10.009

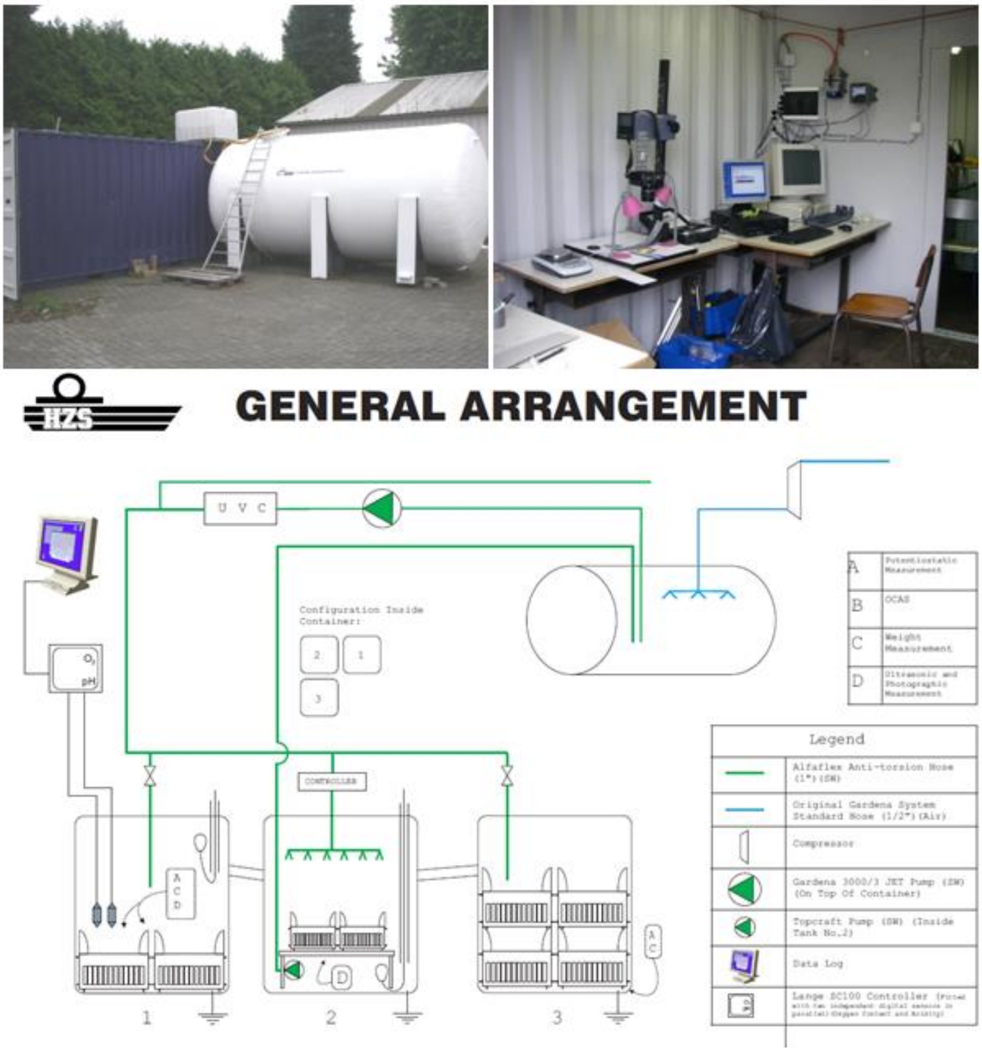
2013: Study on alternative approaches to corrosion protection of ballast tanks using an economic model
De Baere Kris, Verstraelen Helen, Rigo Philippe, Van Passel Steven, Lenaerts Silvia, Potters Geert
Marine structures, ISSN 0951-8339-32(2013), p. 1-17 Full text (Publishers DOI): http://dx.doi.org/doi:10.1016/j.marstruc.2013.02.003

2014: A field study of the effectiveness of sacrificial anodes in ballast tanks of merchant ships
De Baere Kris, Verstraelen Helen, Lemmens Lucien, Lenaerts Silvia, Dewil Raf, Van Ingelgem Yves, Potters Geert
Journal of marine science and technology, Society of Naval Architects of Japan, ISSN 0948-4280-19:1(2014), p. 116-123

2016: Assessment of corrosion resistance, material properties, and weldability of alloyed steel for ballast tanks
Kris De Baere , Helen Verstraelen , Remke Willemen , Jean-Pierre Smet , JÃ©rÃ´me Tchoufang Tchuindjang , Jacqueline Lecomte-Beckers , Silvia Lenaerts, Raf Meskens, Hwan Gyo Jung , Geert Potters.
Journal of marine science and technology, Society of Naval Architects of Japan, J Mar Sci Technol (2016).
doi:10.1007/s00773-016-0402-1, p. 1-24

2016: The economics of a long-term coating
Remke Willemen, Helen Verstraelen, Raf Meskens, Deirdre Luyckx, Koen Vastmans, Silvia Lenaerts , Geert Potters, Kris De Baere.
Submitted 10-2016 to the International Journal of Maritime Engineering

The AMA corrosion/fouling testing platform in the port of Ostend.



Corrosion lab set-up at the Antwerp Maritime Academy

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