

# Abstract Book

## Euro-MIC COST Action CA20130



**Editors:** Torben Lund Skovhus and Amanda Bolvig Norbury



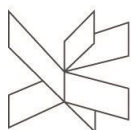
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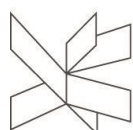
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## WELCOME NOTE

Dear Delegate,

Welcome to the **Euro-MIC Closing Workshop and Conference in Horsens, Denmark!**

We are delighted to host you at this closing event of the **European MIC Network – New paths for science, sustainability and standards**. Over the course of this initiative, Euro-MIC has fostered a vibrant and collaborative community dedicated to advancing our understanding and control of **Microbiologically Influenced Corrosion (MIC)**.

The primary aim of Euro-MIC has been to bridge the gap between disciplines—bringing together **materials scientists, engineers, microbiologists, chemists, and integrity managers**—to promote synergistic collaboration and communication. This ethos has guided our journey, encouraging meaningful interaction between academia and industry to tackle MIC challenges with innovative, sustainable, and standardized approaches.

This conference marks the conclusion of a remarkable chapter, showcasing the achievements, insights, and future directions inspired by Euro-MIC. The programme features cutting-edge research, interdisciplinary discussions and workshops that reflect the network’s commitment to scientific excellence and industrial relevance over the past 4 years.

We are especially proud to include sessions that highlight:

### **MIC Moments with the Chairs**

### **MIC Momentum: Catalysing Collaboration**

### **Understanding and Managing MIC in Real-World Systems**

### **Experimental Testing Strategies for MIC and Antifouling**

In addition, we offer an insightful company visit at Grundfos, a city walk in Horsens, guided tour at the Danish industrial museum, and delicious Danish cuisine and music at a local microbrewery. We will cap off the event with a memorable conference dinner at “The Prison.” Don’t miss out on these exciting opportunities!

This event is not only a celebration of scientific progress but also a testament to the power of collaboration.

We hope you find the conference inspiring, insightful, and enjoyable. Let’s continue to build new paths for MIC science, sustainability, and standards—together.

Warm regards,

*Euro-MIC Organising Committee*



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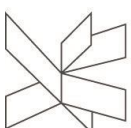
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## TALKS

### Practical Outcomes of the EUROMIC COST Action and Future Directions

**Richard Eckert**, *Microbial Corrosion Consulting*

This keynote talk highlights the practical applications of several outcomes and deliverables from COST Action 20130 (EUROMIC) from 2021 through 2025, on microbiologically influenced corrosion (MIC). First, efforts toward developing a common interdisciplinary language (ontology) for terms related to MIC and practical experimental guidelines for MIC testing in the laboratory using field-collected samples, are examined. Next, practical outcomes from CA20130 related to improved assessment and management of MIC are discussed, including the common theme of using multiple lines of evidence (MLOE) to characterize MIC. The role of standards as related to MIC management is also reviewed, as are the contributions from EUROMIC to a number of international standards under development. Finally, EUROMIC's efforts to help develop the next generation of multidisciplinary MIC researchers and technical experts in materials science, microbiology, engineering, chemistry, material science, and asset management, are discussed. Lessons learned throughout the project and challenges that still remain to be addressed by future research efforts are presented.



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## Current Practices and Knowledge Gaps in MIC Management

**Zsuzsanna Kecskés Maconkai**, *Ludovika University of Public Service*

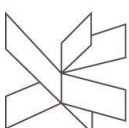
This presentation shares the results of a survey carried out within the Euro-MIC COST Action. The aim was to explore how professionals from academia and industry across several European countries currently approach the detection, monitoring, and mitigation of Microbiologically Influenced Corrosion (MIC). The survey also looked at the level of MIC-related knowledge among experts, and where they turn for updated information.

The questionnaire was developed jointly by members of Working Groups 1 and 3, translated into several languages, and distributed in over 20 countries. A total of 85 responses were collected from professionals working in research, oil and gas, nuclear energy, and other industrial sectors. The data were then analyzed systematically.

Results indicate that while most respondents include MIC considerations in their corrosion strategies and have dealt with MIC-related issues, tools such as real-time monitoring systems and molecular methods are still rarely used. Visual inspection and metallographic analysis are the most common techniques applied in practice.

Participants also reported various challenges in MIC assessment, including the need for skilled personnel, high costs, and limited access to advanced tools. There is a clear interest in more practical, rapid, and cost-effective MIC monitoring solutions, as well as in improved standardization and stronger collaboration between research and industry.

Overall, the findings highlight the need for more effective knowledge sharing, broader use of innovative technologies, and more consistent practices to support MIC management across sectors.



## **Ontology study: Harmonizing Microbiologically Influenced Corrosion (MIC) terminology across industries**

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**2. Judit Knisz**, Ludovika-UPS

**3. Richard Eckert**, Microbial Corrosion Consulting

**4. Torben Lund Skovhus**, VIA University College

Microbiologically Influenced Corrosion (MIC) poses a significant challenge in industries such as oil and gas, marine, water treatment and distribution, and power generation. Although these sectors follow standards that include MIC terminology developed by international organizations, definitions often vary, leading to communication gaps among stakeholders. To bridge this gap and improve collaboration between academic and industry professionals, a standardized glossary of MIC-related terms is essential. In response to this need, we developed a comprehensive glossary aimed at eliminating misunderstandings and promoting clearer communication across industrial and academic sectors.

In this study, standards published by global organizations — including the American Society for Testing and Materials (ASTM International), NACE International (NACE), the Association for Materials Protection and Performance (AMPP), Det Norske Veritas (DNV), the International Organization for Standardization (ISO), and the Energy Institute (EI) — as well as online glossary sources and scientific literature from multiple industries were reviewed. Commonly used terms were identified, their definitions collected, and then compared to determine similarities, differences, and gaps. Finally, these definitions were clarified to develop a consistent and clear glossary.

The analysis of the documents showed that common MIC terms are not consistently defined across existing standards and glossaries, with significant variations observed among different industry sectors. By integrating AI-assisted tools with expert evaluation, a harmonized list of MIC terminology with precise definitions was created. This ontology study lays a foundation for bridging the knowledge gap between academia and industry and offers a unified language to support MIC research and asset management.



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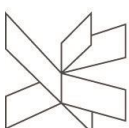
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## **Influence of microbial activity on DGR canister lifetime: MIC potential of bentonite microorganisms**

- 1. Kateřina Černá**, *Technical University of Liberec, Liberec, Czech Republic*
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Long-term storage of high-level radioactive waste in deep geological repositories (DGRs) depends on engineered and natural barriers. In the Czech concept, waste is sealed in stainless steel canisters encased in carbon steel and embedded in compacted bentonite, which limits water flow and radionuclide migration. However, bentonite hosts microbes that may cause microbiologically influenced corrosion (MIC), particularly electrochemical MIC (EMIC), which threatens canister integrity. While most studies focus on sulfate-reducing bacteria (SRB) and copper, the risk of EMIC in steel systems is less understood. This study identified bentonite-derived microbes capable of inducing EMIC and quantified corrosion under DGR-like conditions. Anaerobic lab experiments targeted nitrate-reducing bacteria (NRB), heterotrophs, SRB, acetogens, and methanogens. Carbon steel coupons were incubated in various media, including synthetic bentonite pore water and NRB/SRB-specific broths. A two-stage experiment enriched MIC-active consortia. Corrosion was highest in Nitrate Broth (NRM), R2A, and Postgate media. To simulate worst-case scenarios, dynamic flow cell experiments were run with BAM Berlin, comparing NRM and R2A under dynamic vs. stationary conditions. Dynamic flow increased corrosion dramatically—up to 12-fold in sterile and 6.5-fold in biotic NRM samples and 10-fold in R2A samples. These results highlight the potential role of NRB in EMIC, emphasize the influence of environmental conditions on corrosion rates, and support improved long-term safety assessments for DGRs.

**Acknowledgments:** Supported by project LUC23160 (Inter-Excellence, Ministry of Education, Czech Republic) and COST Action Euro-MIC [CA20130].



## Setup and validation of an in vitro platform to evaluate the performance of antibiofilm surfaces for marine application

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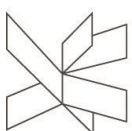
Most marine antifouling coatings release toxic compounds, requiring safer alternatives. During coating development, high-throughput in vitro testing is a valuable tool for screening before performing in situ testing. In order to obtain reliable results, in vitro testing should mimic the hydrodynamics that are relevant to the desired application.

In the lab, we are using microtiter plates (MTPs) under controlled agitation to mimic the hydrodynamics surrounding ship hulls following a Computational Fluid Dynamics (CFD) study. This study revealed that the average shear rate attained on the bottom of MTPs agitated in optimized conditions is similar to the reported value for a ship hull in docking [1]. Optical Coherence Tomography (OCT) images, combined with CFD analysis, revealed that the shear-rate field at the biofilm surface is highly heterogeneous, particularly in rough biofilms [2]. In vitro results were validated by prolonged immersion of biocidal foul-release silicone (PDMS)-based marine paints in the Atlantic Ocean, demonstrating that lab tests reliably predict in situ outcomes [3].

Recently, we developed polyurethane-based marine paints with a cyclam-based Fe(III) complex, which reduced biofilm thickness and biovolume by 60%, and porosity by 97% [4]. Remarkably, iron leaching stayed below 0.8 ppb, indicating long-term effectiveness. In situ testing of the optimized paint formulation will enable us to assess its antifouling performance and longevity.

### References:

- 1) Romeu, et al, *Environ. Microbiol.*, 2019. 21(11): p. 4411-4424.
- 2) Romeu, et al, *Biofilm*, 2024. 7: p. 100204
- 3) Silva, et al, *Environ. Res.*, 2021. 198: p. 111219
- 4) Carvalho, et al, *Molecules*, 2025. 30(4): p. 917



## Improving MIC Experiments Through Field-Relevant Design

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Microbiologically influenced corrosion (MIC) presents growing challenges across industrial sectors such as oil and gas, cooling water systems, and utilities. Defined as corrosion influenced by microbial presence or activity, MIC is a complex, interdisciplinary phenomenon. Despite advances in understanding microbial mechanisms and contributing factors, the field remains fragmented, and the translation of laboratory findings to real-world systems is limited due to the artificial nature of many experimental setups.

This presentation will describe a laboratory experiment designed to investigate MIC using carbon steel coupons exposed to drinking water and corrosion products from a distribution system affected by severe corrosion. Molecular microbiological methods (ATP biomass measurement and shotgun metagenomics) and chemical analyses (redox potential, dissolved oxygen, pH, iron, manganese, and other parameters) were combined with SEM-EDX and 3D optical microscopy.

The results show that while the addition of culture media seems to accelerate corrosion, the underlying mechanisms differ significantly from those observed under field-relevant conditions. Notably, a high relative abundance of an iron-reducing bacterium—previously unreported in drinking water corrosion—was detected in nutrient-free conditions. This finding expands our understanding of the microbial diversity potentially involved in drinking water-related MIC and highlights the need for further investigation.

These findings underscore the value of shotgun metagenomic sequencing in MIC studies and the importance of applying a multiple lines of evidence (MLOE) approach, even in controlled laboratory experiments.



## **Comprehensive Evaluation of a Novel Volatile Corrosion Inhibitor Formulation for St37 Carbon Steel in Chloride Media**

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**2. Ahmet Korkmaz**, *3-S Engineering Company*

**3. Eslem Dinç**, *Duzce University*

**4. Husnu Gerengi**, *Duzce University*

In this research, the influence of a volatile corrosion inhibitor (VCI) blend, which includes boron-amine complex, carboxylic acid, and ester groups, on the corrosion behavior of St37 carbon steel in a 3.5% NaCl solution was assessed. To determine how well the VCI protects against corrosion, electrochemical impedance spectroscopy (EIS) and Tafel polarization (TP) tests were performed. Moreover, tests following the TL-8135-0043 standard were carried out to confirm the effectiveness of the inhibitor. In addition, scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDAX) were employed to investigate the protective coating created by the inhibitor on the steel's surface. The EIS findings indicated a notable enhancement in corrosion resistance correlating with higher VCI concentrations. Analysis of Nyquist plots revealed that the VCI provided 71.24% protection. Characterization results illustrated that the inhibitor adheres to the surface, which impedes charge transfer and decreases the corrosion rate. TP tests suggested that the VCI functions as an anodic-type inhibitor, mainly inhibiting anodic dissolution. The VCI test was conducted according to the TL-8135-0043 standards, showing no corrosion signs on metal samples covered with VCI-infused paper for up to 30 days. SEM and EDAX evaluations affirmed the inhibitor's adhesion to the metal surface, leading to the development of a protective layer.



## **Evaluation of tools to identify and monitoring Microbiologically Influenced Corrosion (MIC) in infrastructure and the effect of mitigating actions**

**1. Elsemiek Croese**

**2. Renske Veenendaal**

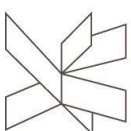
**3. Silke Douma**

**4. Dianne Schootstra**

**5. Rob Elzinga** – *Microbial Analysis b.v.*

To be able to control Microbial Influenced Corrosion (MIC) it is important to collect information on the environment, the corrosion process and the microbiology in a system as evidence to understand the threat for MIC to occur and the contribution of MIC in occurring corrosion.

With regards to infrastructure, MIC may be involved in any construction where iron is used, such as sheet piles. This leads to problems like deterioration, damage to surfaces and leakage. Additionally, it can lead to disturbance of protective measures, such as coating or cathodic protection. It is important to use a multi-disciplinary approach of microbiologists and engineers to develop a proper mitigation strategy for MIC at infrastructure. Several monitoring tools are available, each having advantages and disadvantages and new tools are developed constantly with the goal to find specific markers with a good correlation to severe MIC. Via a selection of real-life cases and laboratory results, we will evaluate MIC monitoring tools in order to determine which techniques are most applicable for identification and monitoring MIC, considering also effect of mitigation actions in these situations.



## Microbial Adaptations That Enhance Corrosion

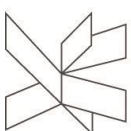
**Amelia-Elena Rotaru**, *University of Southern Denmark*

Microbiologically influenced corrosion (MIC) poses a major threat to infrastructure in anaerobic environments. Our recent work reveals that MIC is not just driven by microbial presence, but by specific adaptations and interspecies interactions that can accelerate  $\text{Fe}^0$  corrosion.

We identified a highly corrosive methanogen, *Methanococcus maripaludis* Mic1c10, which corrodes steel through a surface-anchored, glycosylated hydrogenase. This adaptation enables direct electron uptake from  $\text{Fe}^0$  without enzyme secretion—localizing attack at the cell–metal interface and leading to pit formation.

Beyond individual physiology, we demonstrate that microbial interactions, whether competitive or cooperative, frequently influence corrosion outcomes. In both lake and marine sediment consortia, methanogens and acetogens compete for electrons from  $\text{Fe}^0$ . The winners control the redox landscape and dictate corrosion severity.

This work shifts the MIC paradigm: from static microbial profiles to dynamic interaction networks. Understanding these mechanisms may offer new possibilities to predict, monitor, and ultimately control corrosion in industrial systems.



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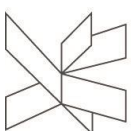


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## Balancing antimicrobial activity with cytotoxicity in MIC mitigation coatings: from ammonium to phosphate systems

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- 4. Rafael Martín-Rapún**, *INMA*
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- 7. Andrea Koerdt**, *BAM*
- 8. Scott G. Mitchell**, *INAM*

MIC is primarily driven by sulfate-reducing bacteria (SRB) and methanogenic archaea (MA), whose biofilm formation accelerates corrosion and diminishes the effectiveness of traditional countermeasures such as cathodic protection and biocides. The effectiveness of the traditional MIC mitigation approaches, such as cathodic polarization, remains uncertain, particularly in complex dynamic environments, such as marine and wastewater systems. As part of our MIC mitigation research, we developed prototype polyoxomolybdate-based ionic liquids (POM-ILs),  $[(\text{CH}_3(\text{CH}_2)_6)_4\text{N}]_2[\text{Mo}_6\text{O}_{19}]$  and  $[(\text{CH}_3(\text{CH}_2)_6)_4\text{N}]_4[\text{Mo}_8\text{O}_{26}]$ , as protective coatings for brass surfaces. These materials demonstrated strong antimicrobial activity, hydrophobicity, and exceptional resistance to acidic conditions.<sup>1</sup> When applied as coatings, POM-ILs form durable, acid-resistant, biocidal layers that effectively prevented microbial colonization and corrosion. Electrochemical impedance spectroscopy and electron microscopy confirmed the formation of protective films capable of withstanding harsh marine environments. While the performance of these coatings highlights their potential as a dual-function solution for both corrosion mitigation and microbial control; one potential limitation is their acute cytotoxicity and thus potential ecotoxicity, if liberated into aqueous ecosystems. Thus, building on this foundation, we are currently investigating second-generation POM-ILs that incorporate phosphonium cations with more balanced antimicrobial, anti-corrosive, and cytotoxicity profiles. This ongoing work aims to address concerns over environmental toxicity and microbial resistance associated with conventional ammonium-based systems. Early findings suggest that these new materials maintain strong antimicrobial activity and offer improved biocompatibility.



## Green Synthesis of Metal Nanostructures for Antifouling Applications

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The transition to a greener, healthier society depends on the sustainable use of materials, especially in critical infrastructure such as water treatment, renewable energy, and marine systems. A major challenge in these environments is biofilm formation on surfaces exposed to water. This phenomenon is closely associated with Microbially Influenced Corrosion (MIC), which accounts for nearly 20% of all corrosion in aqueous systems, resulting in significant environmental and economic losses.

Traditionally, industries have relied on toxic biocides to control microbial growth. However, due to their persistence and ecological impact, there is a growing need for safer, sustainable antifouling strategies. This work explores two complementary green approaches to mitigate MIC and biofouling, offering environmentally friendly alternatives to conventional treatments.

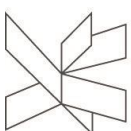
The first strategy involves assessing the antifouling and anti-MIC potential of previously developed biocide-grafted TiO<sub>2</sub> anatase nanoparticles [1]. These materials form stable, non-leaching antimicrobial surfaces that provide long-lasting protection and enhance durability in corrosion-prone environments.

The second strategy focuses on biocatalysis uses the high specificity and low environmental impact of natural enzymes for the development of novel enzyme-metal bionanohybrids [2]. It integrates enzymatic activity with the structural and antimicrobial properties of metal nanoparticles. These hybrids remain effective under extreme industrial conditions and inhibit microbial growth through the controlled release of metal ions.

Together, these two approaches, biocidal-grafted and biocatalytic nanohybrids, enable the development of advanced, non-toxic antifouling technologies. They align with green chemistry principles and offer a promising path forward for reducing biofilm formation and MIC in sustainable industrial applications.

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Ferreira, O. et al. (2025). Journal of Cleaner Production. <https://doi.org/10.1016/j.jclepro.2025.144937>.  
BioNanoAct MSCA-PF project: <https://nanobiomitig.pt/index.php/msca-pf-nanobioact/>.



## **CORRASBlue – Co-creating a digital twin for coastal corrosion risk management through stakeholder involvement**

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**4. Torben Lund Skovhus**

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**10. Yaiza Gonzalez-Garcia**

**11. Pedro Vinagre**

**12. Anette Alsted Rasmussen**

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**16. Maria Salta**

**17. Lars Vendelbo Nielsen**

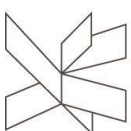
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**20. Constantinos Hadjistassou**

Unchecked corrosion in coastal environments poses a significant threat to marine ecosystems and the sustainability of the blue economy. It contributes to heavy metal pollution, disrupts sediment dynamics, and accelerates infrastructure degradation. Global estimates suggest corrosion could cost 20–30 billion EUR over the lifetime of marine installations, with 4–10 billion EUR potentially avoidable through better mitigation practices. Despite advances in infrastructure design, many projects prioritize functionality over long-term durability, increasing the risk of preventable corrosion failures. Corrosion protection remains one of the most effective short-term strategies for enhancing material sustainability. Given the harsh and complex marine conditions, coordinated efforts among stakeholders—such as asset owners, regulators, material producers, and engineers—are essential to support informed decision-making and ensure resilient, long-lasting infrastructure.

The CORRASBlue project brings together a multidisciplinary consortium from 10 countries to tackle this issue head-on through the development of a novel Coastal Corrosion Risk Management (CCRM) digital twin platform. This platform will integrate real-time sensor data, environmental parameters, and microbiologically influenced corrosion (MIC) insights to support predictive maintenance and lifecycle management of marine assets. This presentation will showcase how stakeholder feedback is essential in shaping the requirements, priorities and functionalities of the digital twin system. Their inputs will not only ensure the final platform will be scientifically robust but also aligns with real-world operational needs and regulatory



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frameworks. By embedding stakeholder perspectives into every phase of development, CORRASBlue aims to deliver a practical, scalable, and impactful solution for corrosion risk management—contributing to a more resilient and sustainable blue economy.



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## POSTERS (alphabetically by title)

### **A time-based corrosion model for World War I ammunition at the Paardenmarkt, North Sea, Belgium**

**1. Katrijn Verhasselt, AMA**

**2. Wikke Witteveen, AMA**

**3. Raf Meskens, AMA**

**4. Joeri Horvath, AMA**

**5. Geert Potters, AMA**

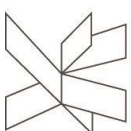
Ammunition at the Paardenmarkt has been corroding in a marine environment, without any known protection against corrosion. This corrosion started immediately when the ammunition was dumped (1919-1920) and continues to this day, 105 years later. In order to estimate the current condition of the shells, constructed with brass cartridge, steel shell and zamak fuse, an extensive three-year experiment was conducted, in which metal coupons representing the materials used in the construction of these shells, in various configurations (buried, on top of the sand, half upright) and in different salinities (seawater, fresh water, brackish water). Based on the outcomes of those experiments, predictive modeling of corrosion was undertaken, using the power-law equation:

$$D(t) = k t^n$$

where  $D(t)$  represents the damage (e.g., mass loss or pit depth) in mm at time  $t$  in years,  $k$  is a material- and environment-specific constant, and  $n$  reflects the rate of corrosion progression. Fitting of these parameters was performed with the `scipy` module in python (Jones, Oliphant, & Peterson, 2001), and these fitted parameters subsequently used in Monte Carlo simulations to estimate the accumulated corrosion loss for 105 years.

Accumulated metal loss due to corrosion of the different metals was estimated at  $(0.544 \pm 0.048)$  mm for zamak when combined with steel, versus  $(15.2 \pm 3.2)$  mm for zamak alone, and at  $(5.78 \pm 0.79)$  mm for steel versus  $(2.5 \pm 1.2)$  mm for steel when combined with zamak. The accumulated material loss for zamak is the only averaged value that exceeds the assumed thickness at construction.

Leakage of the most part of the munition at the Paardenmarkt is therefore very probable. Based on the simulations, 95% of ammunition is already leaking. The cause of the leakage for this type of munition would be the corrosion of the zamak fuse in 98% of penetrated munition. If ammunition is not yet leaking, penetration is expected in the coming 30 years. These findings are in line with observations from the traces of TNT and chemical warfare agents in the water column and from the leakages seen by experts at the military dismantling facility at Poelkapelle, Belgium.



## Antimicrobial High-Entropy Alloy-Based Materials Against MIC

- 1. Bogdan Postolnyi**, *University of Porto, Sumy State University*
- 2. Dumitru Mitrica**, *National R&D Institute for Non-Ferrous and Rare Metals*
- 3. Arcadii Sobetskii**, *National R&D Institute for Non-Ferrous and Rare Metals*
- 4. Laurentiu-Florin Mosinoiu**, *National R&D Institute for Non-Ferrous and Rare Metals*
- 5. Laura-Madalina Cursaru**, *National R&D Institute for Non-Ferrous and Rare Metals*
- 6. Razet Basnukaeva**, *B. Verkin Institute for Low Temperature Physics and Engineering of the National Academy of Sciences of Ukraine*
- 7. Radu-Robert Piticescu**, *National R&D Institute for Non-Ferrous and Rare Metals*
- 8. Alexander Pogrebnyak**, *National R&D Institute for Non-Ferrous and Rare Metals, Sumy State University, Institute of Materials, Faculty of Materials Science and Technology in Trnava, Slovak University of Technology in Bratislava*

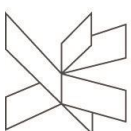
High-entropy alloys (HEAs), formally introduced in 2004, constitute a modern and rapidly advancing class of materials that challenge conventional alloy design principles. Unlike traditional alloys based on one or two primary elements, HEAs typically consist of five or more principal elements, each present in significant amounts (generally ranging from 5 to 35 at.%), resulting in a highly disordered atomic structure. This unique composition imparts exceptional properties such as superior mechanical strength, thermal stability, corrosion resistance, and structural adaptability, often surpassing those of conventional materials. HEA-based materials also encompass coatings, composites (e.g., nitrides, carbides), and additively manufactured components.

Microbiologically influenced corrosion (MIC) presents a significant and growing global challenge, demanding innovative and resilient mitigation strategies. Beyond its substantial economic impact, MIC poses serious risks to human health, ecosystems, and environmental sustainability. The accelerating development of AI, additive manufacturing, and robotics, as well as the intensifying consequences of climate change, is expected to broaden the scope and severity of MIC.

This study investigates the potential of HEAs as a dual-function material platform for MIC mitigation, leveraging their intrinsic corrosion resistance and capacity to incorporate antimicrobial elements. The multi-principal element framework enables the strategic integration of antimicrobial constituents, offering a synergistic approach to combat MIC. We highlight the most compelling published studies, including our own findings, identify existing challenges, and propose future directions for deploying HEAs in MIC-prone environments. HEAs are positioned as a promising foundation for next-generation corrosion-resistant and antimicrobial technologies [1].

**Acknowledgments:** The authors gratefully acknowledge the Euro-MIC COST Action CA20130 (European MIC Network – New Paths for Science, Sustainability and Standards) for inspiring the conception of this project, for introducing the MIC topic, and for its commitment to fostering collaborative research and supporting the LabsArena.com materials research sharing platform.

**References:** [1] B. Postolnyi et al., *Appl. Phys. Rev.* 12, 2025. <https://doi.org/10.1063/5.0228866>.



## **Biofouling and MIC Mitigation in the Marine Environment**

**1. K. Pregeljč, FS-UL**

**2. E.A. Trdan**

**3. Gimnazija Ledina**

**4. D. Klobčar, FS-UL**

**5. U. Trdan, FS-UL**

Biofouling and microbiologically influenced corrosion (MIC) occurs when organisms attached to submerged surfaces form a biofilm, leading to corrosive attacks. While traditional methods, such as protection with bioactive agents, remain effective in mitigating this phenomenon, more environmentally friendly alternatives are being sought. This study evaluated the effectiveness of a self-polishing anti-fouling coating on two commonly used materials. The study examines and assesses the extent of biofilm formation, corrosion and its by-products, as well as changes in sample mass. The results indicate that the coating is effective, but complete surface coverage is essential for optimal performance. As expected, shorter immersion times result in smaller degree of corrosion degradation and lower corrosion rates of aluminium alloy compared to the low-carbon steel.



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## **Bridging the Gap Advancing Regulatory Science Tools for Biofilm Research through Standardisation**

**Theo Zacharis**, *Greek Scientists Society*

Regulatory science plays a critical role in enabling informed decisions on product safety, efficacy, and environmental impact. However, advancements in biofilm research have outpaced regulatory frameworks, creating a significant disconnect between academic innovation and regulatory guidelines. This gap limits the effective adoption of cutting-edge in vitro and in vivo models, research tools, and methodologies for product evaluation and approval.

This presentation highlights the urgent need for harmonisation in biofilm research, focusing on the development of a CEN/CENELEC Workshop Agreement (CWA) as a cost-effective, flexible approach to standardisation. A CWA provides a platform for collaboration among academic researchers, industrial stakeholders, and regulatory bodies to develop consensus-based frameworks that address validation protocols, ontology, and testing methodologies.

By establishing guidance documents, this initiative aims to:

- Accelerate the integration of validated tools into regulatory decision-making.
- Enhance product evaluation for public health and environmental safety.
- Foster alignment across academia, industry, and regulators in Europe.

Through this COST Action, we propose the creation of a multidisciplinary network to identify gaps and prioritise the development of pre-standardisation documents. The outcomes will lay the foundation for future formal standards, driving innovation while ensuring strong regulatory pathways for biofilm-related products.

**Keywords:** Regulatory Science, Biofilm Research, CEN/CENELEC Workshop Agreement, Standardisation



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## Chemical Strategies Against MIC in Reinforced Concrete: A Comprehensive Inhibitor Review

**1. Husnu Gerengi**, *Duzce University*

**2. Muhammed Maraşlı**, *Fibrobeton R&D Company*

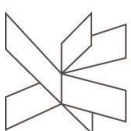
**3. Moses M Solomon**, *University of Nottingham*

**4. İlyas Uygur**, *Duzce University*

Reinforced concrete remains a fundamental material in modern construction, yet it is increasingly vulnerable to microbiologically influenced corrosion (MIC), a process initiated by microbial metabolic activity that compromises both steel reinforcement and surrounding cementitious matrix. Microorganisms such as sulfate-reducing bacteria (SRB), acidogenic bacteria, and nitrifiers produce aggressive byproducts—including sulfuric and nitric acids—that disrupt the protective oxide film on steel and deteriorate cement hydration products. These biochemical attacks result in structural deterioration, including cracking, delamination, and eventual loss of mechanical integrity, especially in wastewater systems, coastal infrastructure, and chemical processing facilities.

While conventional inhibitors such as nitrites provide partial protection by forming passive layers and reacting with corrosive species, they are hindered by ecological risks, sensitivity to environmental variables, and microbial resistance. Recent interest has shifted toward organic-based inhibitors (e.g., amines, fatty acids) and vapor-phase solutions like migrating corrosion inhibitors (MCI), which are more environmentally benign and capable of penetrating concrete pores. Nevertheless, their long-term reliability in microbial ecosystems remains a point of concern.

Innovative strategies—including bio-inspired inhibitors, nano-carrier systems responsive to microbial pH shifts, and slow-release antimicrobial encapsulations—are under investigation to enhance durability and selectivity. However, practical deployment faces significant hurdles due to the complexity of biofilms and evolving microbial consortia. Moving forward, effective MIC control will require integrative approaches combining materials science, microbiology, and real-time corrosion monitoring. These efforts are essential for prolonging the lifespan of reinforced concrete infrastructure and reducing the environmental and financial costs of degradation in the face of growing operational and climate-related stresses.



## Comparison of corrosion characteristics of 3.5% NaCl and synthetic seawater with four natural seawaters for alloys of Ag-Cu-Zn system

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The study aims to compare the corrosion test results of an unbuffered 3.5% NaCl solution and synthetic seawater (SSW) against natural seawater (NSW). This comparison directly shows how well these solutions simulate seawater. The synthetic seawater was made using nine salts, unbuffered, and pH adjusted to 8.1. The seawater used in the research was from four different seas surrounding the Balkan Peninsula. The alloys subjected to investigation contained 25-60% silver, 26-52.5% Cu, and 14-22.5% Zn. Most of the results are for the Ag<sub>43</sub>Cu<sub>37</sub>Zn<sub>20</sub> alloy. The corrosion current values were close for all solutions but varied up to 25%, ranging from 6.5 to 8.1 mA/cm<sup>2</sup> for the previous alloy. These values increase in the following order: 3.5% NaCl, SSW, and NSW, which is consistent with their values of the open circuit potentials (OCP), that decreased in the same order. However, the chemical composition of the solutions after dynamic polarization and potentiostatic polarization has shown the opposite. Corrosion rates in these conditions were 3.5% NaCl > SSW > NSW, which was confirmed by the weight loss method. This contradiction shows that the initial corrosion rate changes over time in the opposite direction when comparing these corrosion environments. The results suggest that SSW better simulates seawater than a 3.5% NaCl solution due to its more similar pH value to NSW, possessing a certain buffered potential (which NaCl solution does not) and more similar mineral composition.

**Keywords:** simulation, dezincation, Tafel extrapolation, corrosion rate, open circuit potential

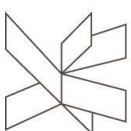


## **CORROSION PROTECTION AND MODERN INFRASTRUCTURE DEVELOPMENT**

**Rahman Nurkovic**, *Zmaja od Bosne 33-35, 71000 Sarajevo*

Currently, modern infrastructures utilize different materials such as metals, alloys, glass, plastic, wood, ceramic, silicate brick, and natural stones. The material's diverse composition, structure, chemical, physical, and mechanical properties with ease in utilization make metal utilization a priority for architects and civil contractors. The principal property that determines the quality and durability of infrastructure is corrosion resistance and weathering resistance. The corrosion of metals can cause damage to concrete, building stones, wood, and other materials, leading to corrosive destruction. The corrosion protection of the structural steel used in reinforcements, load supports, and frames has become extremely important to meet the demand of modern infrastructure having 100 to 120 years of service life. Corrosion is a primary cost to infrastructure, with direct costs from corrosion being many billions of dollars a year for refineries, chemical plants, pipelines, and similar structures. The direct costs to the economy due to corrosion range from 3 to 5% of a country's GNP (Gross National Product). The total cost, including indirect costs, not measurable directly, but which may include costs for safety and health, environmental degradation and the like, may be doubled.

**Keywords:** corrosion, protection, modern infrastructure, development, structural steel, coating



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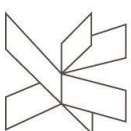
## Detection of MIC in Industrial Water Systems Using a Multiple Lines of Evidence Approach

**Nanni Noël-Hermes**, *Endures*

Many industrial water distribution systems still rely on aging mild steel pipelines, which are often only externally coated or protected through cathodic methods. Microbiologically Influenced Corrosion (MIC) is a particularly aggressive and often highly localized form of corrosion that can progress at rates not accounted for by conventional corrosion models (Little & Lee, 2007). Due to its complexity, MIC is frequently misdiagnosed or entirely overlooked. Most cases are associated with the water being distributed, leading to internal corrosion that typically goes unnoticed until leaks develop. Diagnosing MIC requires a Multiple Lines of Evidence (MLOE) approach, which must be tailored to each specific case (Knisz et al., 2023). This study aimed to assess the presence of MIC within an industrial water distribution network. This paper presents an investigation into MIC-related failures in such systems, guided by the MLOE approach. Several leaks were reported in the network, prompting the collection of water samples and the removal of affected pipeline sections for laboratory analysis. Visual inspections were followed by microbial sampling using swabs, and further analyses included cross-sectional imaging, Scanning Electron Microscopy (SEM) with Energy-Dispersive X-ray Spectroscopy (EDS), and Epifluorescence Microscopy (EFM). Water chemistry was assessed using Ion Chromatography (IC) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS), while surface-bound volatile sulfides were measured using Draeger tubes. Failure analysis revealed that internal corrosion, specifically uniform pitting, was the primary cause of pipeline degradation. Pits that penetrated the pipe wall were consistently located beneath tubercles several centimeters in diameter. SEM/EDS analysis showed that elements such as calcium (Ca), sulfur (S), and chlorine (Cl) were concentrated in distinct, layered zones within the corrosion products, while other elements were more uniformly distributed. Microbial biofilms were observed in close association with the corrosion layers and adjacent damaged areas. Surface-bound sulfides were detected in all samples. Corrosion-relevant microorganisms were identified using both the Most Probable Number (MPN) method and quantitative Polymerase Chain Reaction (qPCR). The findings indicate that the pipe perforations originated from the interior, with wall thinning corresponding to the locations of tubercles. Corrosive microbial byproducts were found within the corrosion layers, and an active biofilm community—likely dominated by sulfate-reducing bacteria—was present near the perforations. These results strongly suggest that MIC played a significant role in the observed corrosion.

### References:

Knisz, J., Eckert, R., Gieg, L. M., Koerdt, A., Lee, J. S., Silva, E. R., Skovhus, T. L. Stepec, A., Annie, & Wade, S. A. (2023). Microbiologically influenced corrosion—more than just microorganisms. *FEMS microbiology reviews*, 47(5), fuad041. <https://doi.org/10.1093/femsre/fuad041>. Little, B. J., & Lee, J. S. *Microbiologically Influenced Corrosion*, (Vol. 1, p. 272), Wiley-Interscience, ISBN 978-0-471-77276-7.



## Eco-Friendly Polyurethane Coatings for Safer Industrial Water Systems

- 1. Luciana C. Gomes**, LEPABE
- 2. Olga Ferreira**, BioISI
- 3. Patrícia Rijo**, CBIOS
- 4. João Gomes**, CERENA
- 5. Ricardo Santos**, Universidade de Lisboa
- 6. Sílvia Monteiro**, Universidade de Lisboa
- 7. Rita Guedes**, BioISI
- 8. Maria Luísa Serralheiro**, BioISI
- 9. Marisa Gomes**, LEPABE
- 10. Filipe J. Mergulhão**, LEPABE
- 11. Elisabete R. Silva**, BioISI

Biofilms pose serious problems in water-based systems by contaminating the food and water infrastructure and accelerating microbiologically influenced corrosion (MIC), which damages materials and increases maintenance costs. Hard-to-clean areas, such as depressions and dead zones, are particularly prone to biofilm buildup. Current decontamination methods rely on chemicals that produce harmful by-products, reinforcing the need for eco-friendly, long-lasting antifouling solutions to combat both biofilms and MIC.

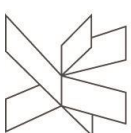
In this study, a novel non-biocide-release coating approach was applied to various polymeric matrices<sup>1</sup>, including polyurethane (PU)-based coatings, to produce antimicrobial ceramic filters for water bio-decontamination. The coatings incorporated grafted E-conea, a biocide known for its antimicrobial properties. The antimicrobial efficacy of these coated monolithic filters was evaluated against *Enterococcus faecalis* and methicillin-resistant *Staphylococcus aureus* (MRSA). A biocide leaching test involving a 45-day water immersion period was conducted to assess the stability of the biocide within the coating. A dynamic biofilm formation assay using *E. faecalis* was also conducted in a flow cell system<sup>2</sup> to assess the antifouling performance of PU coating formulations under shear conditions representative of water-based industrial systems.

Results demonstrated up to a 66% reduction in MRSA populations on PU-coated ceramic filters with grafted E-conea, with no detectable biocide release over the 45-day period. Furthermore, under dynamic flow conditions simulating industrial systems, biofilm formation by *E. faecalis* was reduced by approximately 60% after 48 h compared to pristine PU surfaces<sup>3</sup>.

These findings highlight the potential of PU-based biocidal coatings as a sustainable alternative for mitigating the environmental risks associated with biofilm development in water-based industrial systems, particularly in the food industry.

### References:

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3. Ferreira, O., Rijo, P., Gomes, J., et al. (2021) *Coatings*, 11, 323.



## **EuroMIC pilot – Cyprus**

- 1. Emenina Emil-Inyang**, *Environmental Health Research Centre, UNIC, Cyprus*
- 2. Helena S. Y. Patrickiou**, *Environmental Health Research Centre, UNIC, Cyprus*
- 3. Kyriakos E. Georgiou**, *Environmental Health Research Centre, UNIC, Cyprus*
- 4. Torben Lund Skovhus**, *Research Center for Built Environment, Climate and Water Technology, VIA, University College, 8700, Horsens, Denmark*
- 5. Edna N. Yamasaki**, *Environmental Health Research Centre, UNIC, Cyprus*

**Introduction:** Within the EuroMIC Working Group 5 (Standardisation) activities, we ran a pilot study to evaluate MIC from samples obtained from the drinking water pipes, utilizing available techniques at the University of Nicosia in Cyprus. This pilot was run as part of the CyMIC (MIC involvement in damaged water pipes) project (CONCEPT/0823/0479) financed by the Research and Innovation Foundation of Cyprus, under the Proof of Concept for Technology / Knowhow Applications RESTART 2016-2020 Programme. In cooperation with the EOAL (District Local Government Organization of Larnaca), we obtained pipe and drinking water samples during a scheduled work for replacing leaking pipes.

**Methodology:** Samples obtained were safely stored and brought to the lab at the University of Nicosia to be processed according to the protocol in “Pilot Study of a Laboratory-based MIC Test Procedure – COST Action WG-5; Wade, Wharton, Eckert, draft version 2.2”. The drinking water sample (fluid) obtained was autoclaved to remove potential microbial contaminants. The nutrient used in the experiments was 0.1% Luria Broth (Tryptone 10g/L, Yeast Extract 5g/L, Sodium Chloride 5mg/L, pH 7.0 at 25oC). A swab of the inside of plastic pipes (n=2) and the metal connector (n=1) was used as the inoculum. Four different experimental groups were set, with coupons incubated with or without nutrients, with or without inoculum, and evaluated at 30, 60 and 90 days. ATP levels, bacterial count estimation, pH, visual inspection and % weight loss were measured. Corrosion rates were also estimated.

**Results:** In all the samples examined, we detected the presence of bacteria. Microbial content was higher from inoculum coming from the metal connector compared with the plastic pipe and in the presence of nutrients. Higher microbial content was found in the fluid at Month 3, compared to the coupon which showed higher microbial content at Month 2. The initial pH of the water sample (fluid) was 7.9 and decreased with the incubation time to approx. 7.5 at Month 1 and 7.3 at Month 3. Photographic material showed a dark deposit on coupons, and the change in the color of the fluid from clear and transparent to a yellow-orange color, in all samples evaluated. Coupons percentage weight loss varied from 1.45 at Month 1 to 2.89 at Month 3, but it was observed in all samples evaluated, independently of the pilot conditions. Corrosion rate (mm/y) was estimated between 0.12 at Month 1 to 0.26 at Month 3.

**Conclusions:** Microbial presence was detected in all conditions of the pilot, at all different time points, with higher microbial content from inoculum coming from the metal connector than from the plastic pipes. We could not perform additional experiments due to laboratory constraints, and currently we are looking into sending the material for profiling of the microbial content.



## Fluorine-Free Polymeric Thin Films Deposited via PECVD for Corrosion Protection of Copper Foils

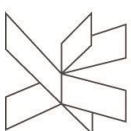
**1. Mehmet Gürsoy, KTUN**

**2. Kurtulus Yilmaz, KTUN**

**3. Mustafa Karaman, KTUN**

In this study, fluorine-free hydrophobic polymeric thin films were deposited onto copper foils using the plasma-enhanced chemical vapor deposition (PECVD) method to investigate their potential as corrosion-resistant coatings. The coatings were synthesized using 2-ethylhexyl acrylate monomer selected for their inherently low surface energy and chemical stability. PECVD allowed for the formation of uniform, conformal, and pinhole-free films at low substrate temperatures, which is critical for preserving the structural integrity of the underlying copper substrate.

Surface characterization by contact angle measurements confirmed the hydrophobic nature of the coatings, with water contact angles exceeding 100°, indicating a significant reduction in surface wettability. Morphological and chemical analyses via SEM and FTIR verified the homogeneous film formation and successful polymerization. The corrosion behavior of the coated and uncoated copper samples was evaluated under accelerated corrosive conditions. The films maintained their structural integrity and protective performance even after prolonged exposure to corrosive environments over several weeks, with no signs of degradation or delamination. These results highlight the long-term stability of the coatings and their suitability for real-world applications. The results demonstrate that fluorine-free PECVD-deposited thin films offer a promising, sustainable alternative for corrosion protection of metal surfaces, aligning with growing environmental regulations that restrict the use of fluorinated compounds.



## HALO-GUARD: Plant-based MIC-inhibitor for Sustainable Corrosion Control

**1. Jakob Lykke Stein**, Halorefine ApS

**2. Anton Karing**, Aalborg University

**3. Torben Lund Skovhus**, *Research Center for Built Environment, Climate and Water Technology, VIA, University College, 8700, Horsens, Denmark*

**4. Mette Hedegaard Thomsen**, Aalborg University

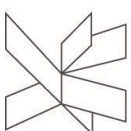
Microbiologically influenced corrosion (MIC) accounts for roughly 20% of global corrosion losses, posing serious risks to offshore pipelines and processing units. Conventional biocides like THPS and glutaraldehyde are effective but toxic, difficult to handle, and increasingly regulated. The HALO-GUARD project—led by Aalborg University, VIA University College, and Halorefine—proposes a sustainable alternative: halophyte-derived MIC inhibitors.

As soil salinization threatens half of the world’s arable land by 2050, salt-tolerant halophytes offer dual benefits: land reclamation and production of unique secondary metabolites. HALO-GUARD leverages this potential through a patent-pending cascade biorefinery that extracts:

1. Saline minerals
2. Food-grade phytochemicals
3. MIC-inhibitor concentrate
4. Lignin-rich residue for biochar

Pilot trials confirm scalable yields and potent biocidal activity. Bench-scale assays show the halophyte extract reduces steel corrosion by up to 93% and H<sub>2</sub>S generation by 99.8%, rivaling THPS. Studies with TotalEnergies and AAU biofilm reactors reveal selective targeting of sulfate-reducing bacteria—validated via 16S rRNA sequencing—while preserving benign microbiota. The extract also disperses biofilms, a feature lacking in conventional chemistries.

Beyond oilfields, the inhibitor shows promise in cooling systems, marine antifouling coatings, and industrial water treatment. HALO-GUARD’s circular approach—combining halophyte cultivation with integrated biorefining—marks a shift toward environmentally conscious corrosion control.



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## **Hydrogen storage and microbiologically influenced corrosion – improved test system for stability and durability of the materials and gas**

**1. Andrea Koerdt, BAM**

**2. Andre Abilio, BAM**

**3. Thomas Dimke, BAM**

**4. Oded Sobol, BAM**

Underground hydrogen storage (UHS) is a strategic step towards implementing the hydrogen economy. Achieving the required infrastructure by 2050 necessitates advancements in hydrogen-dedicated assets and the evaluation of existing infrastructure. The unique conditions in UHS require an experimental set-up to simulate UHS operating conditions, which allows to assess the readiness of current storage and transmission for hydrogen, and develop new technologies for material-resistance, operational-simulations, and risk-assessments. In addition to the physical/chemical conditions in UHS (e.g., salinity, hydrogen concentration, operating temperature/-pressure, water content), biological threats must also be considered. Therefore, we present here a high-pressure-set-up, developed for research/-industrial testing purposes.

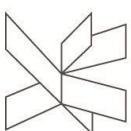
Currently, UHS-experiments for microbiologically-influenced-corrosion (MIC) are performed in standard autoclaves with relatively high volumes/pressures; they were primarily designed for material-specific investigations. While these methods provided some useful information for biological questions, they had significant limitations.

The novel UHS-simulation-set-up presented here is designed with a controlled independently temperature and pressure. Field samples can be used to mimic geology, water chemistry, construction materials, and microbiological conditions.

Most significant advantages of the set-up are:

1. It allows for liquid addition during the test, enabling the study of biocides or the evaluation of operating setups.
2. It permits liquid/-gas sampling during the test, allowing for more efficient monitoring of testing conditions and a better understanding of the process over time.

Additionally, a low-release function is added, which is particularly important for studying MIC to avoid negative side effects, on the material (e.g. polymers/corrosion product-layer/cells itself) which might occur due to the fast pressure release.



## **In situ electrochemical characterization of corrosion in the Ghent-Terneuzen canal**

**1. Wikke Witteveen, AMA**

**2. Gillian Rul, AMA**

**3. Katrijn Verhasselt, AMA**

**4. Raf Meskens, AMA**

**5. Joeri Horvath, AMA**

**6. Mihret Girma, AMA**

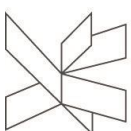
**7. Geert Potters, AMA**

Upon discovery of extensive microbiologically induced corrosion on the hull of a yacht in the marina of Zelzate in 2021, extensive surveys of corrosion patterns were conducted along the neighbouring Ghent-Terneuzen Canal. Four electrochemical tests were employed to characterize and assess their feasibility: Linear Polarization Resistance (LPR), Linear Polarization Curve (LPC), Cyclic Polarization Curve (CPC), and Critical Pitting Temperature (CPT). A floating setup with three electrodes was created, hooked up to a Palmsens 4 potentiostat (Palmsens, the Netherlands). The tests were conducted on two steel grades, S235 and 316L, which were exposed to canal water across different immersion times (one day, one week and one month) and on three locations (near Ghent in the south, in Zelzate and in Terneuzen, near the lock towards the Scheldt).

Analysis of the results highlights the performance and limitations of each method, revealing significant differences in corrosion patterns within a single water mass. LPR revealed that corrosion is highest in Zelzate and Terneuzen, and lowest in Ghent. probably due to differences in salinity. The method also indicated the formation and breakdown of a passivation layer, which was confirmed by the LPC test.

CPC showed that the passivation layer of 316L steel effectively develops over time, especially in Zelzate, and to a lesser degree in Ghent and Terneuzen. Erep values were consistently higher in Ghent, indicating a faster reformation of the passivation layer, probably due to the lower salt concentration. The critical pit potential increased with exposure time, and was highest in Ghent, indicating a stronger resistance to pitting corrosion. CPT followed a salt gradient as well, with Ghent having the highest CPT values, and Terneuzen the lowest, indicating a lower resistance to pitting corrosion.

These results may also have been influenced by microbial activities, as shown, for example, in Zelzate, where samples initially corroded rather fast, but where corrosion slowed down due to the build-up of a biofilm. As such, this research contributes to a deeper understanding of corrosion dynamics in the Ghent-Terneuzen Canal, emphasizing a larger need for targeted monitoring and mitigation strategies.



## **In situ investigation of microbial biofilm in drinking water pipes, a preliminary study for Cyprus**

**1. Helena S.Y. Patrickiou**, *Environmental Health Research Centre, University of Nicosia, Nicosia*

**2. Torben L. Skovhus**, *Research Center for Built Environment, Climate and Water Technology, VIA, University College, 8700, Horsens, Denmark*

**3. Kyriakos E. Georgiou**, *Environmental Health Research Centre, University of Nicosia, Nicosia*

**4. Edna N. Yamasaki**, *Environmental Health Research Centre, University of Nicosia, Nicosia Cyprus*

Cyprus is among the 5 most water-stressed countries in the world (World Resources Institute, 2023), and combined extreme heat during the summer, droughts, and significant water losses from the distribution system altogether play a critical role in drinking water availability. Among some of the problems experienced within drinking water (DW) networks is distribution losses, grouped under non-revenue water. The local district government departments have in place systems to detect leaks and programmed replacements of the obsolete water supply network.

The CyMIC (MIC involvement in damaged water pipes) project (CONCEPT/0823/0479) financed by the Research and Innovation Foundation of Cyprus, under the Proof of Concept for Technology / Knowhow Applications RESTART 2016-2020 Programme evaluated for microbial presence in metal and plastic pipes and DW samples obtained from scheduled works for replacing leaking pipes. Drinking water in Cyprus originates from dams that collect rainwater, boreholes and desalinated water. The process of obtaining DW from raw water involves pre-chlorination, aeration, flocculation, sedimentation, filtering, lime dosing and post chlorination of the treated water, before it reaches the consumers. DW undergoes microbiological and chemical controls in addition to evaluation of organic pollutants. While chlorination is the standard in Cyprus, other countries whose main source of DW is groundwater, ensure DW quality through a high-quality distribution network and the maintenance of a biostable water through biofilms that prevent pathogenic microbial growth.

In collaboration with the EOAL (The District Local Government Organization of Larnaca), we collected pipe and water samples at sites where leakages were detected and from scheduled works to upgrade the network. The samples were photographed and identified in situ, brought to the laboratory at the University of Nicosia premises. A water filter from a house in Nicosia was also evaluated. Samples evaluated consisted of asbestos pipe, plastic pipes and metal connectors and a filter obtained from a household in Nicosia. Photographic evaluation and ATP measurements were conducted on swabs obtained from the samples. Samples were also obtained for DNA analysis and stored at 4°C. One of the samples was used for the WG5 pilot study.

Collection of the material in situ was facilitated by the utility company but proved to be quite a challenge in trying to maintain samples free from soil contamination. In many cases, the pipes had been replaced and the samples given to us, preventing further analyses. Nonetheless, our results show microbial presence in all samples examined and were consistently higher in metal connectors (joints), compared with the plastic pipes. A profile of the bacterial species could not be performed due to financial constraints.



We could not confirm the potential involvement of MIC in the DW pipes that were evaluated. The biofilm present in the pipes could also be involved in the maintenance of a biostable and high quality DW.



## **Integrated Molecular Strategies for Accurate Detection and Mitigation of Microbially Influenced Corrosion in Harsh Oilfield Environments**

- 1. Genis Castillo-Villamizar, CIC**
- 2. Diego Quintero-Santander, CIC**
- 3. Pedro Santamaría-Galvis, CIC**
- 4. Valentina Tapia-Perdomo, CIC**
- 5. Julieth Maldonado-Pava, CIC**
- 6. Darcy Pinzón-Sierra, CIC**
- 7. Edinson Puentes-Cala, CIC**

Microbially influenced corrosion (MIC) is a major integrity threat in the oil and gas industry, responsible for up to 20% of corrosion-related failures. Conventional culture-based monitoring captures less than 1% of microbial diversity, overlooking key groups, particularly in high-temperature or high-salinity systems. Standard molecular tools, although more sensitive, detect total DNA, including that from dead cells, potentially overestimating viable populations and leading to misguided mitigation efforts. To overcome these limitations, we implemented a robust molecular monitoring strategy in several Colombian and Latin American oilfields. This approach integrates DNA sequencing, qPCR, and a novel viability assay that selectively amplifies DNA from intact cells based on membrane integrity. Together, these tools provide detailed, quantitative insights into microbial communities, both planktonic and sessile, including key MIC-associated groups such as sulfate reducers, acid producers, and methanogens.

In one case, the application of this strategy uncovered high concentrations of thermophilic, unculturable microorganisms in systems where culture-based methods had failed to detect significant microbial presence. This led to an alternating biocide injection strategy and operational adjustments, resulting in a reduction of up to 20-fold in localized corrosion rates. In another case, shotgun metagenomics and qPCR were used to rationally reformulate fourth-generation culture media, tailored to the system's chemistry and microbial metabolic needs. These new formulations, enriched with produced water and specific nutrients, improved the recovery of functional populations and enhanced early detection of aggressive taxa, informing biocide optimization and risk-based monitoring.

The viability assay, currently being field-validated, further improves accuracy by excluding signals from recently dead organisms, enabling real-time assessment of biocide effectiveness. This integrated framework strengthens MIC risk assessment, enhances decision-making, and supports proactive asset integrity management under extreme conditions, providing a replicable model for MIC surveillance across the industry.



## **LabsArena.com: Empowering Global Research through Shared Scientific Infrastructure**

**1. Razet Basnukaieva**, *LabsArena.com*

**2. Bogdan Postolnyi**, *LabsArena.com*

LabsArena.com is an innovative digital platform created to bridge a critical gap in the global research ecosystem — the disconnect between researchers who need access to scientific equipment and services, and the laboratories, manufacturers, and service providers who have the capacity and willingness to share or sell for them. While nearly 50% of scientists worldwide struggle to access essential research infrastructure, over 70% of providers report they could serve more users [<https://cordis.europa.eu/project/id/824173/results>]. This mismatch delays innovation, limits research output, and slows down R&D progress across sectors.

LabsArena.com functions as a collaborative, research-enabling ecosystem that allows researchers to easily search for and access needed equipment, services, and consumables — while enabling laboratories and manufacturers to list their instruments and capabilities for share or sale. It is designed to optimize the use of underutilized infrastructure and support smoother, faster, and more efficient collaboration across institutions, sectors, and countries.

By September 2025, LabsArena hosts more than 40 equipment and service providers from 20 countries, including the United States of America, Germany, France, Italy, and beyond. It features more than 500 listed items across key categories such as chemical and elemental analysis, microscopy and imaging, material characterization, synthesis and preparation, environmental testing, biotechnology, and additive manufacturing equipment. The platform uses an intuitive filter system, detailed lab profiles, and a growing review system to ensure transparency and trust.

LabsArena.com also played a vital role during the early stages of Russia’s full-scale invasion of Ukraine by launching the rapid-response initiative “Support UA Platform”, which connected Ukrainian scientists and students with research opportunities abroad. This effort enabled many to continue their scientific work in safer environments and laid the groundwork for deeper international collaboration.

Joining LabsArena.com is simple: labs and providers can sign up at LabsArena.com to create a profile, list equipment, and start collaborating, while researchers can search for needed equipment without registration. Whether you want to run an experiment, buy or sell equipment, or showcase your lab’s capabilities, the platform makes connecting easy and seamless.

Supported by the collaborative environment of Euro-MIC COST Action, we used the opportunity to promote LabsArena.com within the European research community. Engaging with experts in corrosion, surface science, and materials research enabled us to present the platform’s capabilities, receive valuable feedback, and build a foundation for future cross-border partnerships. These interactions have helped strengthen our direction toward a more interconnected European research infrastructure, with Ukraine as an active contributor.



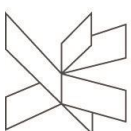
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Users have described LabsArena.com as “a powerful tool for labs to gain visibility and grow their networks”. Others highlight that, thanks to LabsArena.com, they avoided buying expensive equipment by partnering with nearby labs, saving both time and budget.

To explore all available opportunities and become part of the growing community, visit LabsArena.com website and follow us on LinkedIn, Facebook, and Instagram.



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## **Laser-induced nanostructuring of metal surfaces affects biofilm architecture and reduces biofilm formation**

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**2. Olga Iungin**, *Kyiv National University of Technologies and Design*

**3. Svitlana Rymar**, *Institute of Molecular Biology and Genetics, National Academy of Sciences of Ukraine*

**4. Iaroslav Gnilitskyi**, *NoviNano Inc.*

**5. Geert Potters**, *AMA*

Biofilms are hard to eradicate due to the matrix in which the bacteria reside, consisting of strong, adhesive and adaptive self-produced polymers such as eDNA and functional amyloids. Targeting a biofilm matrix may be a promising strategy to prevent biofilm formation. Applying a specific laser treatment to the surface of 316L stainless steel [1], we were able to introduce either conical spikes or conical grooves on a micrometer scale, both in an oxic and an anoxic atmosphere.

To investigate the antibiofilm efficiency of these nanostructured metal surfaces, two model strains, *P. aeruginosa* PA01 and *S. aureus* ATCC29423, were allowed to develop biofilms which were subsequently analysed using CLSM. The biofilm structures of both strains formed on these nanotextured metal surfaces, were modified considerably due to a substantial reduction in amyloid production or due to changes in eDNA surface adhesion, leading to significant reduction in biofilm biomass. Altering the topography of the metal surface, therefore, radically diminishes biofilm development, not by reducing of bacteria on the surface but by altering biofilm architecture. Surface nanotexturing can therefore be used to control bacterial fouling in a non-chemical manner using a low-cost and high-speed method of laser irradiation.

### **References:**

[1] Gnilitskyi, I., Rymar, S., Iungin, O., Vyshnevskyy, O., Parrisé, P., Potters, G., Zayats, A.V. & Moshynets, O. (2023). Femtosecond laser modified metal surfaces alter biofilm architecture and reduce bacterial biofilm formation. *Nanoscale Advances*, 5(23), 6659-6669.



## **Mechanical Properties of AR MiniBars™ Geopolymer Composites an Alternative to Steel Reinforcement**

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**2. Codruta Sarosi**

**3. Marioara Moldovan**

**4. Kinga Korniejenko**

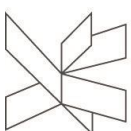
**5. Michał Łach**

**6. Leonard Miller**

**7. Nováková Iveta**

Many buildings generally use steel fibers to reinforce concrete and provide improved mechanical properties but over time, this advantage could be lost, due to corrosion of the steel. The high alkalinity of Portland cement conducts to corrosion of the glass fiber reinforced materials. The addition of big amount of zirconia (15–20 wt.%) [1, 2] to AR-glass fibers provides a higher resistance to corrosion compared to other glass fibers [3]. The polymer coating of the glass fiber surface AR MiniBars™ enhanced corrosion resistance to alkali degradation and the tensile strength of alkali-resistant filament yarns, the adhesion strength with cementitious matrices, and fracture energy of the composites

Geopolymer concrete reinforced with MiniBars™ could be an eco-friendly, innovative, durable, high strengthening material, substitute to common Portland cement for buildings. AR glass fiber MiniBars™ composites (AR MiniBars™) (ReforceTech AS, Royken, Norway) had 60 mm length and were utilized to strengthen the geopolymer matrix for the fabrication of unidirectional AR MiniBars™ reinforced geopolymer composites (AR MiniBars™ FRBCs). New AR MiniBars™ FRBCs were fabricated by adding different amounts of AR MiniBars™ (0, 12.5, 25, 50, 75 vol.%) in the fly ash geopolymer paste. Geopolymers were obtained by combining fly ash powder with  $\text{Na}_2\text{SiO}_3/\text{NaOH}$  2.5:1, which served as an alkaline activator. AR MiniBars™ FRBCs were cured for 48 h at 70 °C and tested for different mechanical properties. Fly ash, AR MiniBars™, and AR MiniBars™ FRBC were evaluated by optical microscopy and SEM. The addition of AR MiniBars™ showed increased mechanical properties for AR MiniBars™ FRBCs. The mechanical properties of AR MiniBars™ FRBCs heightened, then the geopolymer without AR MiniBars™: the flexural strength > 18.80–30.71 times, the flexural modulus > 4.07–5.25 times, the tensile strength > 3.49–8.27 times, and the force load at upper yield tensile strength > 3.6–7.72 times. The fractured surfaces and sections of AR MiniBars™ FRBCs were inspected by SEM and optical microscopy analyses and even though there was no chemical adhesion we had a good micromechanical adhesion of geopolymer to AR MiniBars™. These results obtained encouraged us to propose AR MiniBars™ FRBCs for construction application. AR MiniBars™ could replace in some applications the deformed steel bars, which are corrosive and more expensive.



## **Ontology study: Harmonizing Microbiologically Influenced Corrosion (MIC) terminology across industries**

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Microbiologically Influenced Corrosion (MIC) is a critical issue affecting numerous industrial sectors such as oil and gas, marine, energy production, and water treatment. Despite the frequent use of MIC-related terminology in international standards, inconsistent definitions across disciplines often hinder effective communication and collaboration. This study aimed to develop a standardized glossary of MIC-related terms to facilitate cross-sector understanding and enhance interdisciplinary research.

MIC-related terms were systematically collected from internationally recognized standards, online glossaries, and peer-reviewed literature. Advanced AI tools, including ChatGPT Plus (GPT-4o) and the SciSpace plugin, were employed to generate contextual definitions categorized by microbiology, chemistry, and engineering relevance. For each of the 351 identified terms, a dual-definition approach was applied: an AI-generated consensus definition and an expert-curated harmonized definition.

The analysis revealed that the majority of MIC terminology is derived from chemistry and engineering disciplines, with limited incorporation of microbiological perspectives. Key terms such as sulfate-reducing bacteria (SRB) and anoxic were often inconsistently defined or absent from the reviewed sources. Moreover, widely used concepts such as biocorrosion and microbially influenced corrosion were not formally included in any standards examined. These findings underscore the critical need for a unified, interdisciplinary glossary to ensure clarity and consistency in MIC-related communication.

Consequently, this study established a structured MIC glossary to resolve terminology inconsistencies and support shared understanding among researchers and professionals. The findings were also presented at the 10th International Symposium on Applied Microbiology and Molecular Biology in Oil Systems (ISMOS-10), where the study was honored with the Best Poster Award.



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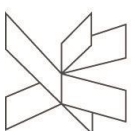


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## **OXIDIZING CHEMICAL PROCESS FOR WATER DECONTAMINATION AS COLLABORATIVE EU PROJECTS**

- 1. Andreu Ruiz**, *CHEMPLATE MATERIALS*
- 2. Morten Møller**, *ULTRAAQUA A/S*
- 3. Jorge Rodriguez**, *CIDETEC SURFACE ENGINEERING*

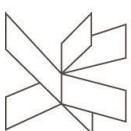
In the frame of European collaborative works, herein an Eurostars projects is presented with primary results aiming to validate, for water management for metal protection coating approaches. The project NANOZONE aims to develop decontamination approaches in rinsing water management devices within surface treatment equipment and large infrastructures when metal protection coating approaches are applied. Vulnerable surfaces of metal parts and metal-concrete junctions in larger infrastructures may be treated by applying with advanced oxidation chemical processes for elimination of contaminants in waters, prevention of corrosion and repairing proposes.



## **Polyoxometalate Ionic Liquids (POM-ILs) as Protective Coatings for Industrial Infrastructure and Cultural Heritage against Microbiologically Influenced Corrosion (MIC)**

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- 2. Mariella Malefioudaki**, INMA-CSIC, Uni Zaragoza, Spain
- 3. Nadja Sbeity**, BHT Berlin, Germany
- 4. Isabel Franco Castillo**, INMA-CSIC, Uni Zaragoza, Spain
- 5. Korinna Altmann**, BAM Berlin, Germany
- 6. Scott G. Mitchell**, INMA-CSIC, Uni Zaragoza, Spain
- 7. Carsten Streb**, Johannes Gutenberg University Mainz, Germany
- 8. Andrea Koerdt**, BAM Berlin, Germany
- 9. Oliver Hahn**, BAM Berlin, Germany

Corrosion of stone and metal due to acid rain and biodeterioration poses significant challenges for industrial and residential infrastructure, as well as cultural heritage, including statues and historical artefacts. A promising mitigation strategy involves thin, transparent films of polyoxometalate-based ionic liquids (POM-ILs) as chemical shields. Stone samples coated with acid-resistant, biocidal POM-ILs exhibited negligible corrosion when exposed to simulated acid rain, in stark contrast to the severe deterioration of unprotected samples. Additionally, their biocidal properties effectively prevent biofilm formation on coated surfaces. Following studies successfully explored the effectiveness of the coating against lampenflora growing in the Pommery Champagne cellar; and the long-term performance of POM-ILs under outdoor environmental conditions. So, POM-ILs have already demonstrated remarkable anticorrosion and antimicrobial properties against aerobic microorganisms and, being water-insoluble, do not leach into aquatic ecosystem. The current research project repurposes the POM-ILs, extending their application to metals, specifically targeting microbiologically influenced corrosion (MIC) in cultural heritage artefacts made of brass, carbon steel, cast iron, and bronze. This involves optimizing nanocoating adhesion to the metal surface and evaluating its protective efficacy against MIC caused by anaerobic microorganisms such as methanogenic archaea and sulfate reducing bacteria (SRB). This presentation will highlight POM-ILs as sustainable, high-performance nanocoatings for biocorrosion mitigation. It will showcase published success stories, discuss ongoing research and proof-of-concept results, and explore future prospects for these advanced materials in safeguarding metal infrastructure and artefacts across different industrial sectors as well as in the context of cultural heritage conservation.



## **Predicting marine corrosion rates of carbon steel using machine learning**

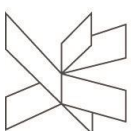
**1. Mihret Girma, AMA**

**2. Wikke Witteveen, AMA**

**3. Raf Meskens, AMA**

**4. Geert Potters, AMA**

Corrosion represents a significant challenge in materials science, particularly in marine environments where it leads to severe economic impacts and structural failures. This study investigates the application of machine learning (ML) techniques to predict corrosion rates of S235 carbon steel subjected to various marine conditions. A comprehensive dataset was collected from 46 different marine locations, encompassing environmental parameters such as temperature, pH, dissolved oxygen, chlorophyll concentration (Chl) and oxidation-reduction potential (ORP). Employing several ML algorithms including LightGBM, Gradient Boosting Regression, Random Forest and XGBoost were evaluated model performance before and after feature selection. Results indicate that feature engineering substantially improves predictive accuracy, with LightGBM emerging as the most effective model, achieving the lowest mean squared error (MSE) of 0.003 and highest  $R^2$  value of 0.8. Key factors influencing corrosion rates were identified, highlighting the importance of exposure duration, temperature, and pH. This research underscores the efficacy of machine learning in corrosion prediction and highlights the importance of feature selection in enhancing model performance, ultimately contributing to better material management and maintenance strategies in corrosive marine environments. Future work should explore a broader range of materials and additional influencing factors to expand the applicability of the predictive models.



## **SEM and XPS Characterization of Microbial Corrosion on Aircraft Aluminum Alloy Induced by a Manganese-Oxidizing Bacterium**

**1. Simge Arkan-Ozdemir, *UU***

**2. Esra Ilhan-Sungur, *IU***

The uncontrolled proliferation of microorganisms on the inner surfaces of aircraft fuel tanks can lead to adverse outcomes such as biofilm formation and microbiologically induced corrosion (MIC), thereby increasing maintenance costs and posing significant risks to flight safety. Among these microorganisms, manganese-oxidizing bacteria (MOB) play a significant role in accelerating corrosion processes on metal surfaces by oxidizing soluble  $Mn^{2+}$  ions and depositing manganese oxides. The resulting corrosive metabolites further promote metal oxidation and corrosion. A comprehensive investigation of the corrosive effects of MOB on aircraft fuel tank materials is essential to support effective mitigation strategies in the aviation industry and to advance scientific understanding of microbial corrosion.

In this laboratory-based study, a manganese-oxidizing bacterial strain, isolated from Jet A-1 fuel obtained from the fuel tank of a commercial passenger aircraft undergoing maintenance, was exposed to 7175-T7351 aluminum alloy — a material widely used in fuel tank construction — over an 80-day period. Biofilm development and corrosion products were thoroughly examined using advanced imaging techniques, including scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS), in combination with surface characterization methods such as X-ray photoelectron spectroscopy (XPS). A control system, prepared under identical conditions but without bacterial inoculation, was operated in parallel with the experimental setup and subjected to the same analyses to enable direct comparison.

At the end of the 80-day exposure, macroscopic examination of MOB-exposed coupons revealed brown deposits and tubercle formations on the surfaces. SEM analyses demonstrated that the bacteria were present both in a scattered manner on the coupon surface alongside corrosion products, and in dense clusters within pits located beneath the tubercles. The pits in the SEM images clearly indicated that the MIC by MOB on the 7175-T7351 aluminum alloy. Elemental analysis indicated high levels of oxygen (O) and aluminum (Al) in corrosion products under both conditions, while copper (Cu) was detected only in the presence of bacteria, particularly concentrated within the pits. XPS analyses further revealed the presence of various manganese oxides ( $MnO_x$ ) and oxides formed by metal ions dissolved from the alloy in the presence of MOB. Specifically,  $MnO_2$ ,  $Mn_2O_3$ , and  $Mn_3O_4$  were identified only under bacterial exposure.



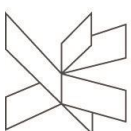
## Simulation of microbiologically influenced corrosion in Marine infrastructures

**1. Sara Taghavi Kalajahi, BAM**

**2. Torben Lund Skovhus, Research Center for Built Environment, Climate and Water Technology, VIA, University College, 8700, Horsens, Denmark**

**3. Andrea Koerdt, BAM**

Microbiologically influenced corrosion (MIC) presents a significant challenge in marine environments. This study investigates the behaviour of microorganisms and their impact on the corrosion process of carbon steel within Marine infrastructures. To simulate MIC an in-house experimental column was developed and inoculated with sediment and water samples from the North Sea. The system was operated under varying flow rates to replicate seabed movement conditions. Multiple molecular microbiological methods, surface analysis techniques, and other approaches were employed to assess the effects of different treatments. This study provides insights into MIC mechanisms in offshore environments and supports the development of strategies to monitor MIC in marine infrastructures.



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## **Spatial distribution of uniform corrosion of carbon steel in the canal Ghent-Terneuzen**

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**2. Gilles Hudders, AMA**

**3. Katrijn Verhasselt, AMA**

**4. Raf Meskens, AMA**

**5. Joeri Horvath, AMA**

**6. Mihret Girma, AMA**

**7. Geert Potters, AMA**

Upon discovery of extensive microbiologically induced corrosion on the hull of a yacht in the marina of Zelzate in 2021, an extensive search was conducted in the neighbouring Ghent-Terneuzen Canal to elucidate the impact of geographical and industrial factors on corrosion rates and their deceleration along the canal.

Coupons (in S235 carbon steel) of 60 x 60 x 3 mm were exposed up to 9 months at 40 different locations along the entire canal, and collected at regular time intervals. Mass loss due to corrosion was measured after a cleaning step in Clarke solution (ASTM G1-03(2017)e1). An asymptotic regression model was used to analyze the corrosion rates across eleven defined zones of the canal. Results indicate a higher stabilization of corrosion rates in the northern half compared to the southern half of the canal, with a faster deceleration rate observed in the northern regions.

These findings underscore the necessity for targeted monitoring and predictive systems to manage corrosion effectively. The model demonstrates that corrosion does not progress uniformly within a singularly interconnected harbour zone. Future research should focus on the detailed investigation of physicochemical aquatic parameters and specific microbial mechanisms contributing to corrosion, as well as the development of more refined protection strategies for marine infrastructure.



## Synthesis, Antimicrobial Activity, Cytotoxicity, and Ecotoxicity of Magnetic CuO/Fe<sub>2</sub>O<sub>3</sub>/CuFe<sub>2</sub>O<sub>4</sub> Nanocomposite

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**2. Andris Šutka**, RTU

**3. Mairis Iesalnieks**, RTU

**4. Mariliis Sihtmäe**, NICPB

**5. Alexandra Nefedova**, Institute of Molecular and Cell Biology and Institute of Physics, University of Tartu

**6. Angela Ivask**, Institute of Molecular and Cell Biology, University of Tartu

**7. Irina Blinova**, NICPB

**8. Mikhail Maiorov**, Institute of Physics, University of Latvia

**9. Mārtiņš Vanags**, RTU

**10. Toms Valdemārs Eiduks**, RTU

**11. Artūrs Plūdons**, RTU

**12. Anne Kahru**, NICPB

**13. Kaja Kasemets**, NICPB

In this study, we report the synthesis of a magnetic CuO/Fe<sub>2</sub>O<sub>3</sub>/CuFe<sub>2</sub>O<sub>4</sub> nanostructured composite, aiming to develop a multifunctional material with strong antimicrobial properties. The composite was thoroughly characterized by XRD, SEM, BET, XPS, DLS, and VSM analyses, confirming its nanoscale structure, high surface area, and magnetic behavior. The antimicrobial efficacy was evaluated against Gram-negative and Gram-positive bacterial and fungal strains, and mechanisms of action were described. The composite showed antimicrobial activity against all tested strains, with a stronger effect against Gram-negative bacteria.

In vitro cytotoxicity testing on human keratinocyte (HaCaT) cells indicated low toxicity. Ecotoxicological assessments using seawater environmental bacteria *Vibrio fischeri* and freshwater crustacean *Daphnia magna* showed low environmental impact at tested concentrations, supporting the potential for safe application in water treatment.

The findings highlight the CuO/Fe<sub>2</sub>O<sub>3</sub>/CuFe<sub>2</sub>O<sub>4</sub> composite as a promising candidate for antimicrobial applications, balancing biological efficacy with low levels of cytotoxicity and ecotoxicity.

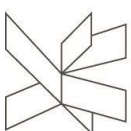


## TECHNOLOGICAL PROTECTION AGAINST MATERIAL CORROSION IN MODERN INDUSTRY

**Rahman Nurkovic**, *Zmaja od Bosne 33-35, 71000 Sarajevo*

Corrosion is a pervasive and costly issue with significant economic and environmental implications. Corrosion protection coatings play a vital role in safeguarding various industries against the detrimental effects of corrosion. This comprehensive review provides an overview of recent advances in corrosion protection coatings, focusing on organic, inorganic, and metallic coatings. The fundamentals of corrosion protection coatings are discussed, including the mechanisms by which these coatings provide protection against corrosion. Today, materials offer a wide range of applications due to their properties. Materials already exist which, if properly used, can remove 80% of corrosion loss. The review highlights recent advancements in organic coatings, such as the development of novel formulations, self-healing coatings, and the utilization of nanotechnology. Furthermore, the progress in inorganic and ceramic coatings, including surface modification techniques and the integration of organic-inorganic hybrid coatings, is explored. Additionally, the paper presents emerging trends in metallic coatings, covering alloy design, environmentally friendly options, and surface engineering techniques. Evaluation methods for coating performance and testing, including accelerated corrosion testing, are summarized. The review showcases the wide-ranging applications of corrosion protection coatings in various industries, accompanied by case studies. The challenges and opportunities in emerging sectors, such as renewable energy and aerospace, are also discussed. Lastly, the paper outlines future directions and challenges, emphasizing the importance of ongoing research and the integration of advanced materials for multifunctional corrosion protection. This review paper serves as a valuable resource for researchers, engineers, and practitioners involved in corrosion protection, providing a comprehensive understanding of recent advances and guiding future research endeavors.

**Keywords:** technological, corrosion protection coatings, advances, organic coatings, industry, inorganic coatings, metallic coating



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## The Importance of Phthalocyanines in the Development of New Generation Green Materials to Reduce Microbiological Corrosion in the Marine Environment

**1. Ece Tugba Saka**, *Karadeniz Technical University*

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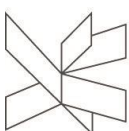
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Phthalocyanines are widely used as photoconductor materials in photocopying devices, chemical sensors, electro and photocatalysis processes, electrochromism applications, and photodynamic therapy and cancer treatment, in addition to their traditional uses as dyes and pigments. Phthalocyanines are macrocyclic compounds with an 18- $\pi$  electron system formed by the bonding of four pyrrole derivatives with azo-methine bonds. It is known that phthalocyanine molecules can form strong chelating complexes with metallic atoms due to their conjugated  $\pi$ -electrons, four nitrogen atoms with unshared electron pairs, and the presence of different side groups. Considering their thermal and chemical stability, they serve as excellent corrosion inhibitors for various metal/electrolyte systems in aqueous media and coating conditions.

SRBs are commonly found in natural or man-made water systems (or structures). They are frequently isolated from environments with extreme pH values such as sea, river, and lake sediments, hydrothermal vents, hydrocarbon seeps, highly saline microbial masses, acid-mine drainage areas, and soda lakes, as well as agricultural and industrial water systems such as oil fields, deep underground layers, waste treatment plants, and cooling towers. Furthermore, the 2.5°C increase in seawater temperature in the Sea of Marmara over the last 50 years and the sudden changes in seawater pH resulting from the increasing seawater temperature are among the reasons for the proliferation of SRBs. SRBs produce H<sub>2</sub>S by using sulfate (H<sub>2</sub>SO<sub>4</sub>), sulfide (H<sub>2</sub>SO<sub>3</sub>), thiosulfate (S<sub>2</sub>O<sub>3</sub>), or other sulfur compounds and can damage metal surfaces. They particularly have a detrimental effect on the durability of metal in the joints of water systems and structures. In this study, phthalocyanine, sodium alginate, and nano-cerium oxide-based polymeric coatings of varying thicknesses (50, 100, and 200 microns) will be prepared to prevent corrosion on structures containing C1018 carbon steel caused by SRBs proliferating in the Sea of Marmara. Phthalocyanine compounds, due to their macrocyclic structure, exhibit corrosion-reducing properties by interacting with metal or metal-containing surfaces. The aim is to prepare coatings containing these compounds, which have the potential to prevent or reduce corrosion and to determine their corrosion-reducing properties for microbial corrosion in the marine environment for the first time. Furthermore, by selecting cerium oxide as a polymeric coating, along with phthalocyanine molecules, and sodium alginate as a polymeric binder, we aim to create environmentally friendly and sustainable coating materials, both reducing corrosion and preventing harm to the marine ecosystem. Another aim is for this material to be non-toxic to human cells.



## **Uncovering Hidden Risk: Susceptibility to Microbiologically Influenced Corrosion (MIC) in Aircraft Fuel Tank**

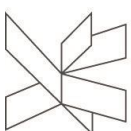
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Aircraft fuel tanks face a critical, yet often overlooked, threat: microbiologically influenced corrosion (MIC). This phenomenon arises from the formation of biofilms as a result of the uncontrolled proliferation of microorganisms on tank surfaces, which can compromise the structural integrity of the tank by causing perforations. Such failures extend beyond mere technical disruptions, potentially escalating into severe safety risks, including in-flight fires and catastrophic accidents. In the evaluation of MIC in aircraft fuel tanks, an integrated multidisciplinary approach—encompassing macroscopic inspections and bacteriological analyses of biofilm-derived samples—plays a pivotal role in enabling early-stage corrosion detection, elucidating the extent of damage across both surface and microstructural dimensions, and informing the formulation of robust and targeted mitigation strategies.

The investigation was carried out on the fuel tank of an in-service passenger aircraft during a scheduled monthly C-check. The inner surface of the aluminum alloy fuel tank was covered with a yellow epoxy-based coating. Nevertheless, during sampling, it was observed that the coating had deteriorated in certain areas, resulting in the exposure of the aluminum alloy. Biofilm samples were collected from both the intact coating and the exposed aluminum alloy regions on the inner surface of the tank. Subsequent analyses of these samples focused on the detection of anaerobic sulfate reducing bacteria (SRB), aerobic heterotrophic bacteria (AHB), and manganese oxidizing bacteria (MOB). In addition, corrosion products and corroded surface regions were assessed through macroscopic examination.

The investigation revealed that the inner surface of the tank was covered with a transparent and very thin biofilm layer. Notably, localized degradation of the epoxy-based coating had occurred, resulting in the direct exposure of the underlying aluminum alloy. Corrosion products with a brownish and black appearance were observed on the exposed surfaces of the aluminum alloy. Microbial analyses demonstrated a significant presence of MOB and AHB, with SRB present in comparatively lower numbers, within the biofilm formed on the aluminum alloy surface. The co-existence of these bacterial groups, each identified as a primary contributor to MIC, highlights a significant and multifactorial corrosion risk to the structural integrity of the system.



## What is happening on Mars?

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The exploration vehicle (Perseverance) of the American National Aeronautics and Space Administration (NASA) completed its journey to Mars in February 2021 and landed in the Jezero Crater. Perseverance landed in the Jezero Crater, as it contains areas where primitive life is preserved and vital processes for its formation could be investigated. The Jezero Crater bears multiple similarities with a lake on Earth, specifically Lake Salda in Türkiye, in terms of mineralogical and geological characteristics. According to the NASA exploration vehicle (Curiosity) 2018 data, serious corrosion damage was observed on the wheels (made of aluminium 7075 alloy) of the spacecraft. There is a possibility that the corrosion that occurs is caused not only by atmospheric corrosion, but it could also have a microbiological basis. To understand the corrosion mechanisms on Mars, the materials used in spacecraft, the atmospheric conditions of Mars, soil chemistry, and bacteria in it, must be studied under simulated Martian conditions. Lake Salda could provide a natural laboratory on earth in this respect. In this vein, this study aimed to investigate the effect of sulfate-reducing bacteria (SRB) isolated from Lake Salda on microbial corrosion of AA7075 alloy using electrochemical techniques. Electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization (PDP) methods were used to determine the microbial corrosion behaviour of AA7075 alloy. The biofilm and corrosion products were investigated using Scanning Electron Microscopy (SEM). According to SEM analysis, a rather dense biofilm was observed on the coupons. SEM images were consistent with the sessile cell counts. Corrosion rate values of the biotic coupon were higher than the abiotic coupon, indicating that aluminium 7075 alloy suffered corrosion by SRB biofilm isolated from Lake Salda.

