

# NON-TOXIC COATED STRUCTURED FILTERS: A NON-BIOCIDE RELEASE STRATEGY FOR BIOFOULING CONTROL

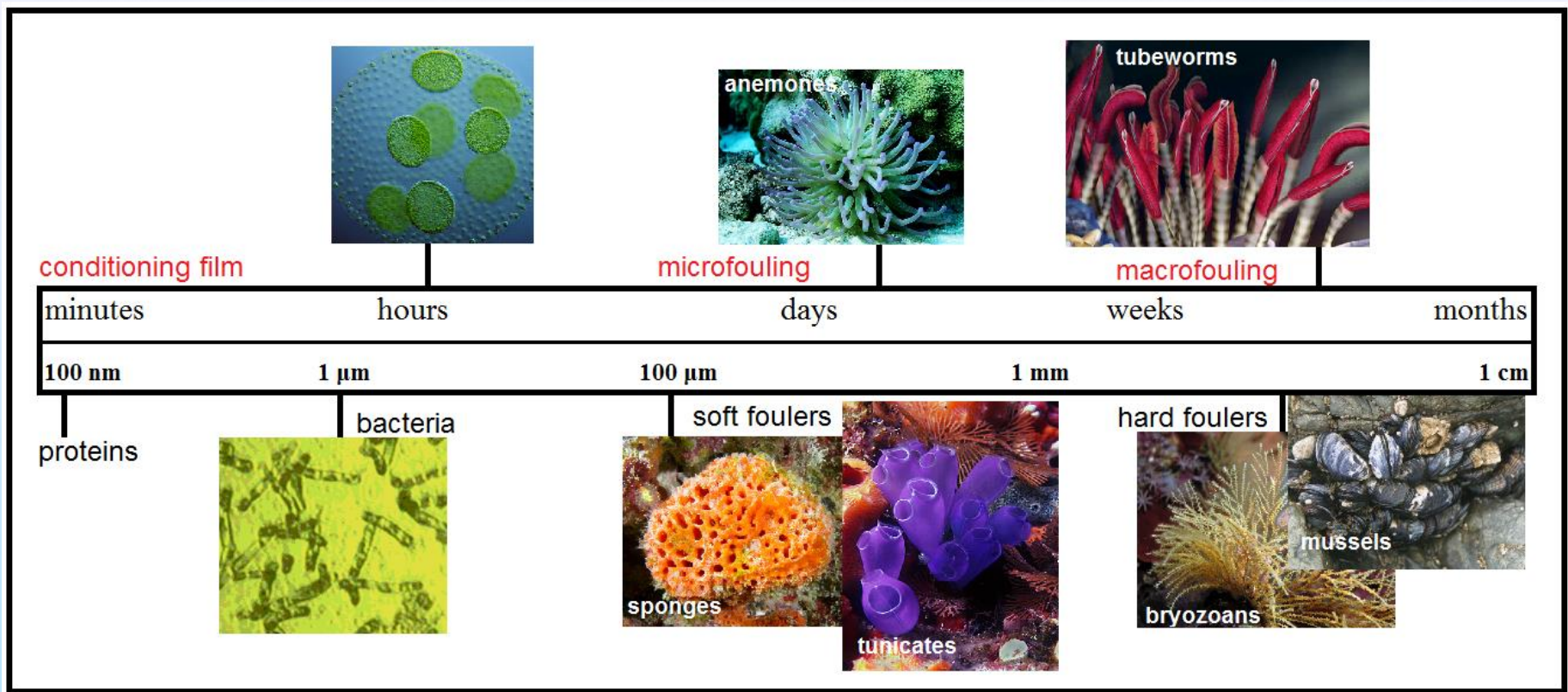
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2ND INTERNATIONAL ELECTRONIC  
CONFERENCE ON WATER SCIENCES (ECWS-2)  
16-30 NOVEMBER, 2017

# Biofouling

**Biological fouling: an spontaneous colonization by a diversity of micro/macroorganisms on submerged surfaces.**



Adapted from Nurioglu et al., 2015 and Almeida et al., 2007

# Biofouling Burden!



**WARNING**

**Environmental penalties**

**Economic impacts**

**Health problems**

Water contamination (freshwater/seawater) by biofouling attach on industrial surfaces causes serious penalties on several applications: such as water circuits, desalination systems, marine transport.



# Biofouling Burden!



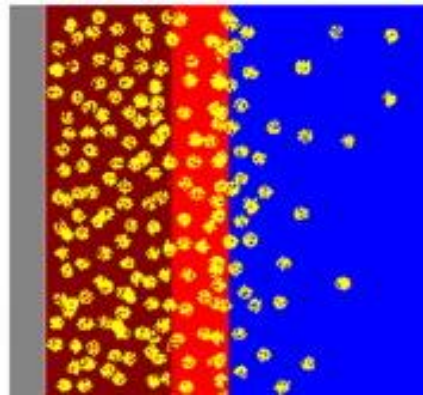
- **Invasive species**
- **Harmful pathogens** into water in fluid transport systems
- **Maintenance costs** (Biocorrosion can affect up to 20%)
- **Fuel consumption** increases for operation conditions maintenance
- **Gas emissions** increases
- **Drag increase** on ships hulls (40%)
- **Pressure drop increases** in water flow industrial circuits



# Anti-Biofouling Strategies

Conventional antifouling strategies for biofouling mitigation are mostly based on the releasing of toxic agents!

## *Top Coat Antifouling Layer*



**BPR EU Regulation N°528/2012**

Is limiting the available  
antifouling agents

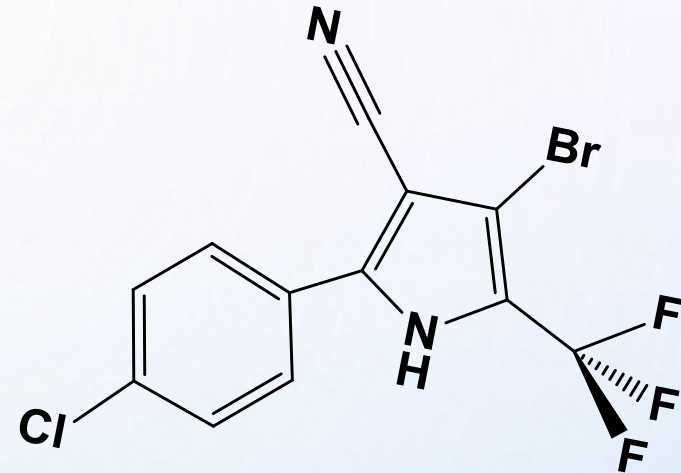
**SEVERE RESTRICTIONS! NEW SOLUTIONS ARE SOUGHT!**

# Booster Agents – Less Toxic?

## ECONEA

Activity against hard-shelled and soft-bodied invertebrate animal fouling organisms

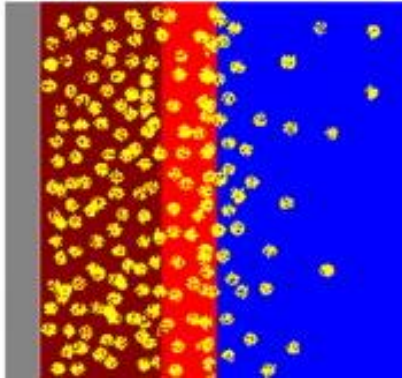
Unknown future ecotoxicity/accumulation effects



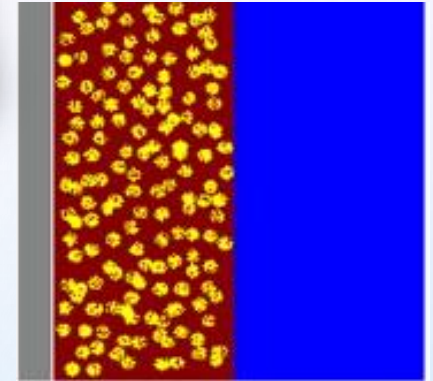
# Eco-friendly Solution

## Chemical immobilisation of bioactive agents

*Top Coat Layer*



*Top Coat Layer*



Efficiency

Low life-cycle

"A goal properly set is halfway reached"

*Zig Ziglar  
1926-2012*



Efficiency

Long-lasting

# Eco-friendly solution

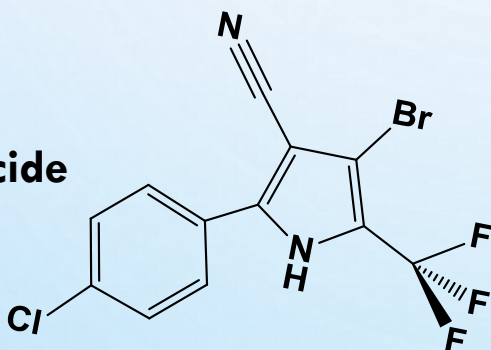
## Biocides Functionalisation (1<sup>st</sup> step)

E. R. Silva, O. Ferreira, J. C. M. Bordado Patent Application,  
WO 2016/093719 A1

NH–Biocide



Econea biocide

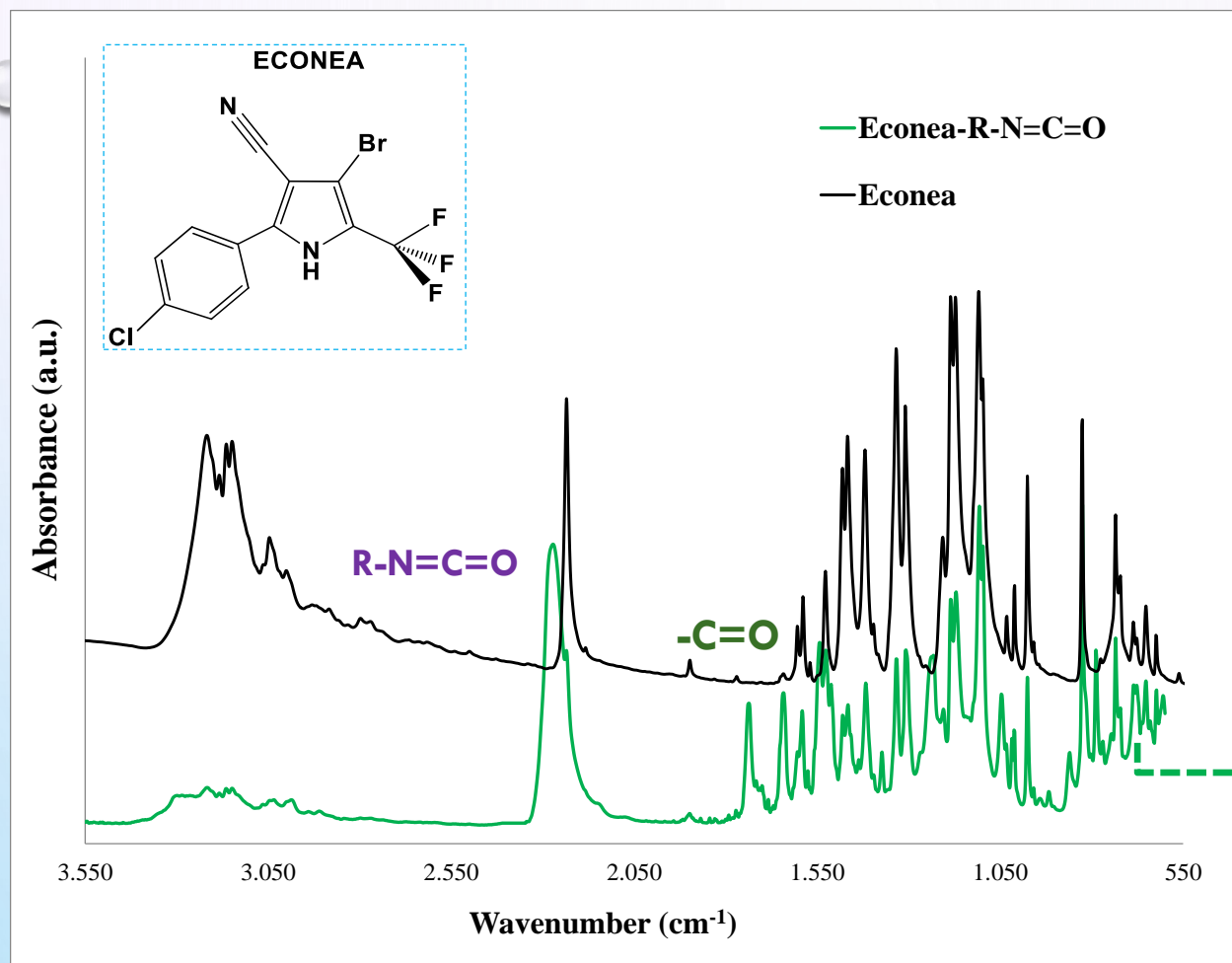


❖ Conversions higher than  
95% were achieved.





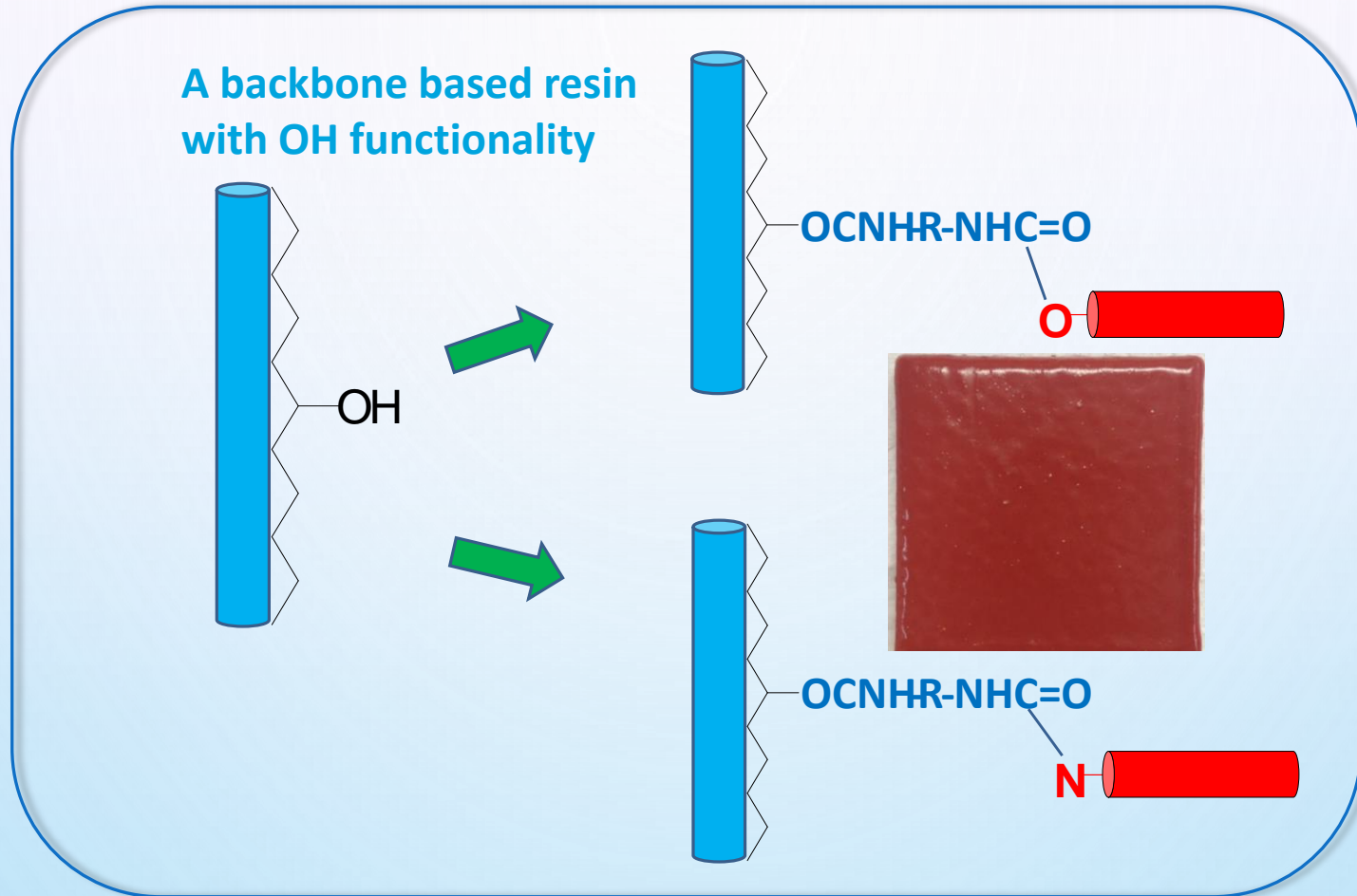
# After functionalisation



❖ FTIR spectra confirmed the functionalisation reaction effectiveness

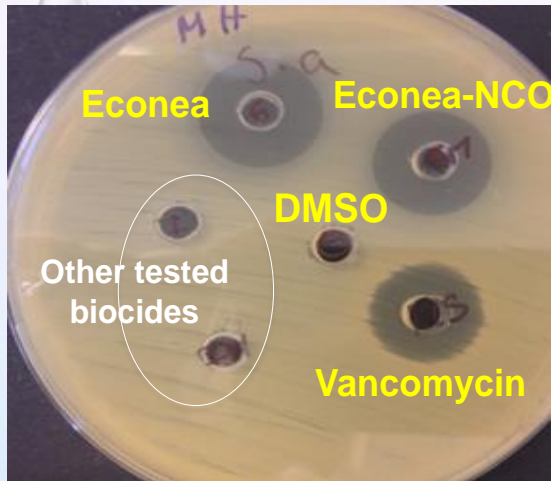
# Eco-friendly Solution

## Immobilisation via *Urethane linkage* (as example) (2<sup>nd</sup> step)

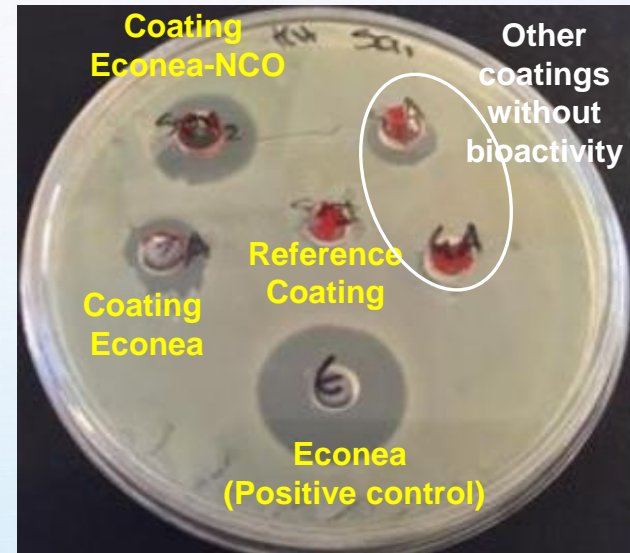


**No biocidal agent release from the coating** - preventing the contamination of the surrounded environment!

# BIOACTIVITY ASSESSMENT



## Well Diffusion Method for *Staphylococcus aureus*



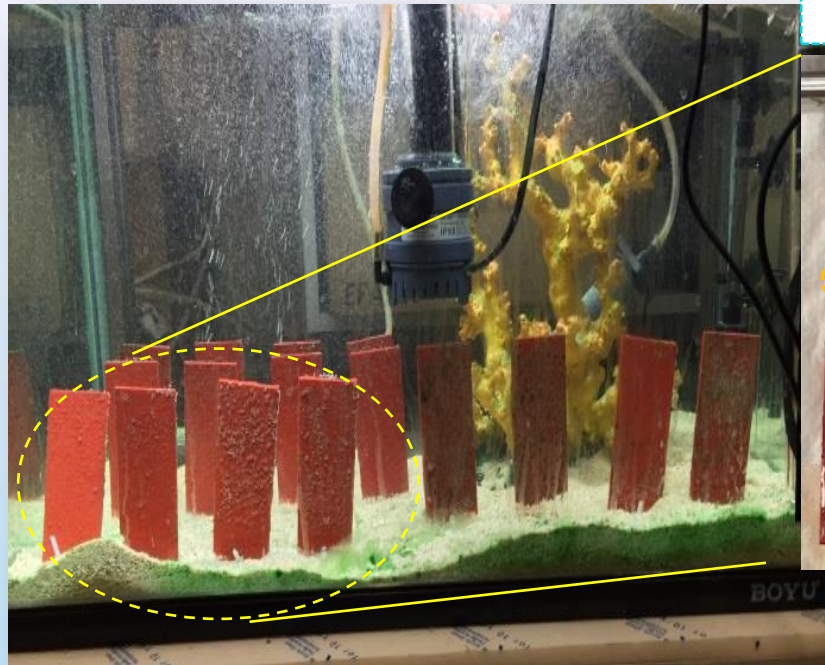
❖ Functionalization of the biocidal agent did not affect its bioactivity.



❖ Coatings with immobilized biocide are bioactive.  
**Promising result!**

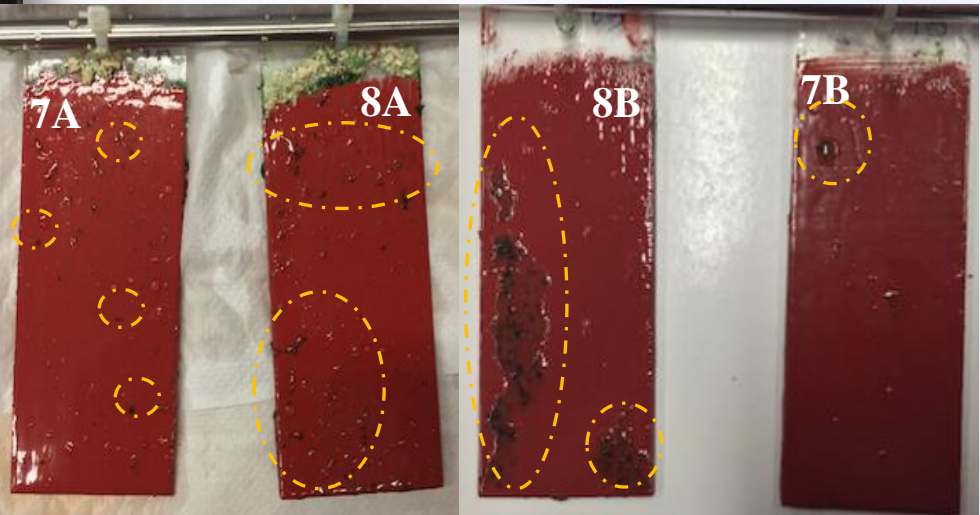
# PROOF-OF-CONCEPT

## 1. Simulated tests in an artificial seawater aquarium



Silicone based formulations (A)

Polyurethane based formulations (B).



7- With immobilised Ectonea-NCO  
8- Reference coating without biocide

**Coated prototypes exposed for 12 months!**

**Coatings with immobilised Ectonea show an improved antifouling behaviour.**

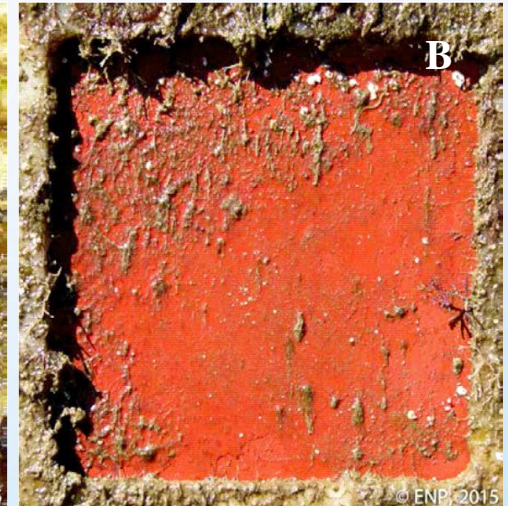
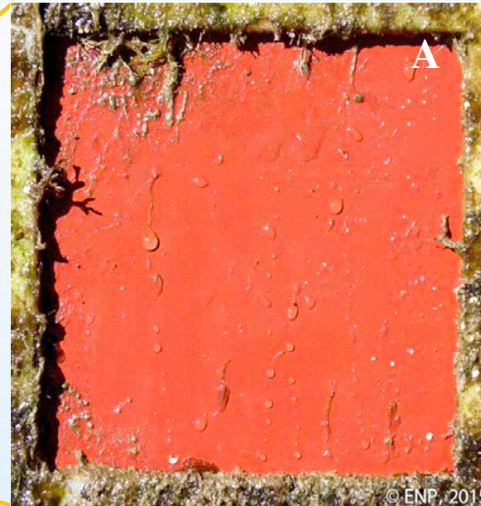
# PROOF-OF-CONCEPT

## 2. Real field tests- At relative *Stationary conditions*

Photos gently provided by ENP, SA



45 Weeks (11 months submerged)

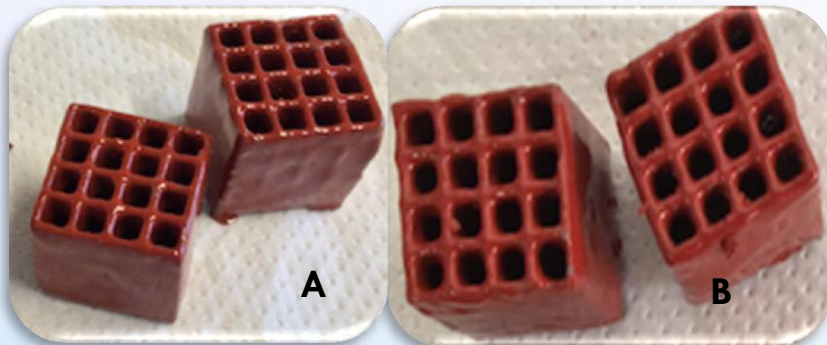


Pontoon for field tests in Estaleiros Navais  
de Peniche (ENP), SA

Coated prototypes, with silicone based formulations, exposed for about 11 months in Atlantic sea: (A) Econe-NCO and (B) Reference coating.

# Coated Filters with Non-toxic Bioactive Coatings

Microbial attack cause serious human health infections (*E.coli*, *S. aureus*)  
Transmission from fluid transport systems (e.g. water purification)  
Non-Toxic preventive actions are urgent!



Ceramic Monoliths  
(200 cps)

Silicone based coating with immobilized E-conea (A) and Reference coating without biocide (B)

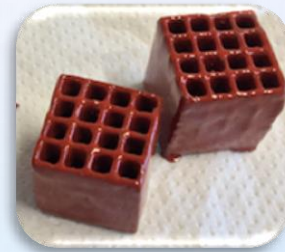
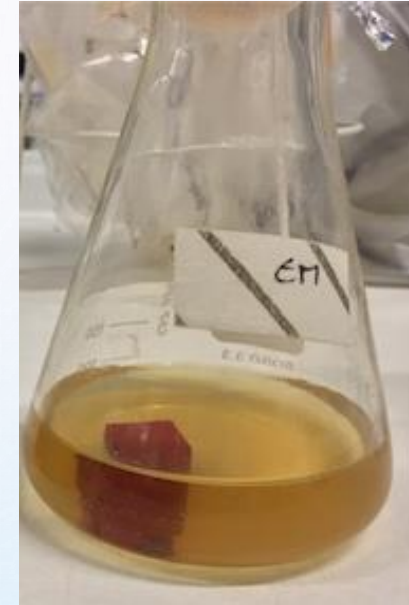
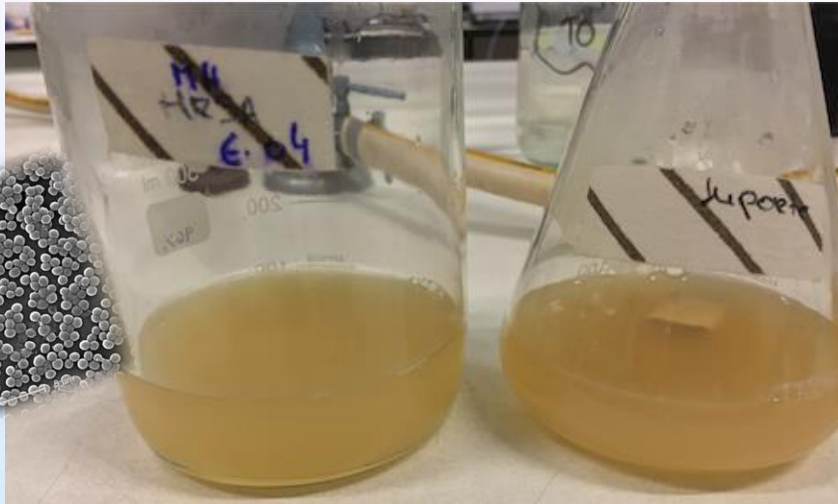
- ❖ Coated monolithic filters evidenced uniform polymeric layers and minimal increases of surface roughness.
- ❖ Adhesion tests are on-going: Cross cut and pull-off tests/others.

# Antimicrobial Activity of Coated Filters

***S. aureus* MRSA**  
CIP 106760 strain

**Uncoated  
Monolith**

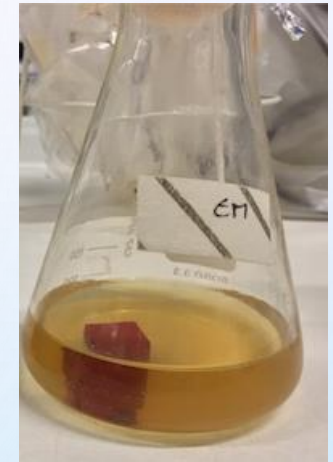
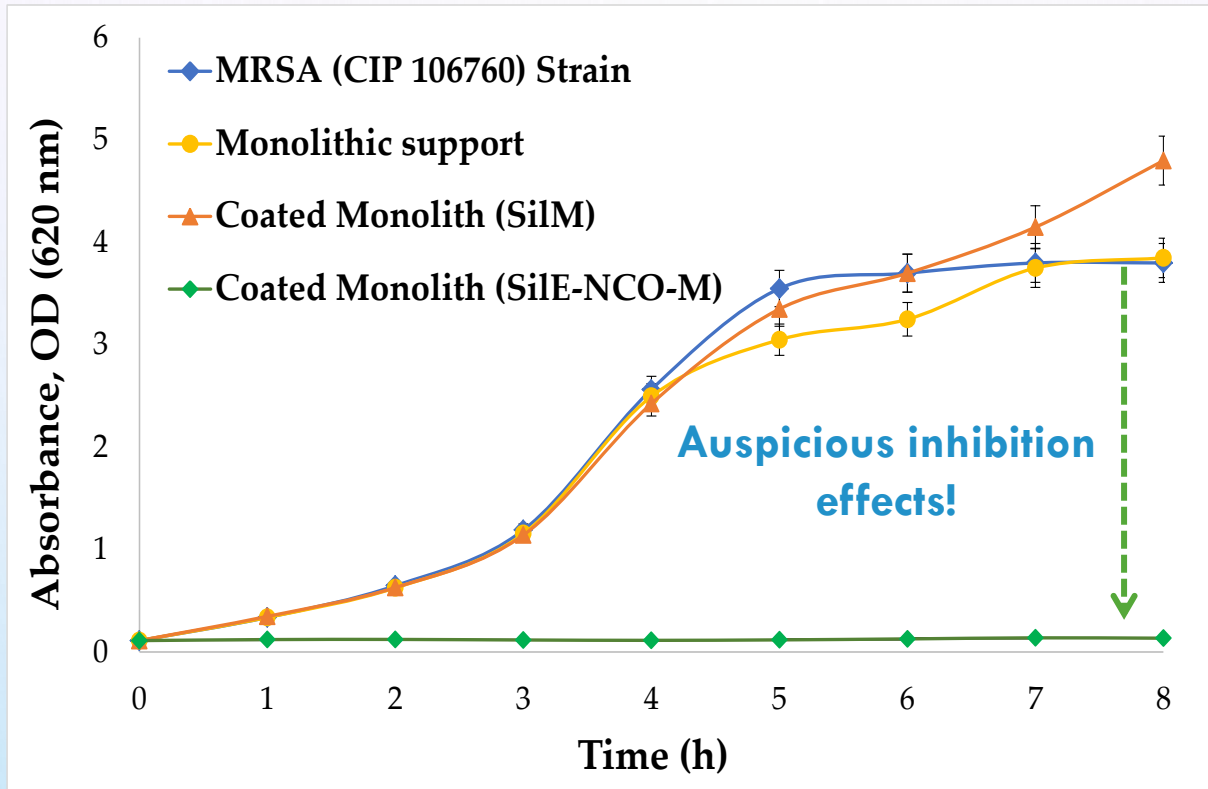
**Coated Monolith**



- ❖ An expected high inhibition growth effect for MRSA strain
- ❖ And a bacteriostatic behaviour was also observed!!!








# Antimicrobial Activity of Coated Filters



- ❖ A complete growth inhibition with the coated monolithic with a silicone based coating containing tethered Ecomea (SiIE-NCO-M).



# CONCLUSIONS

-  Econeia biocide was successfully tethered in polymeric coatings.
-  Promising antifouling behaviors, at simulated and real conditions, were obtained for silicone based coatings containing the tethered Econeia.
-  Auspicious antimicrobial and bacteriostatic behaviour was found for coated monolithic filters with the Econeia/silicone based coating.
-  The developed non-release biocidal coatings acting by contact, are able to avoid toxic agents releasing into the aqueous environment.
-  This approach is presented as a promising environmental friendly and long-lasting antifouling/antimicrobial alternative strategy for the bio-decontamination of waterborne systems.

**"It is the worst of times but it is the best of times  
because we still have a chance."**

**Sylvia Earle, Oceanographer**

**THANK  
YOU**



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**<http://intheochem.fc.ul.pt/newsite/envrem.html>**