by Sonia Manzo and Paolo Massanisso

Marine fouling: environmental concerns and counteracting strategies

Biofouling is ubiquitous in the marine environment and is a major problem for the shipping industry. The widespread use of toxicants in antifouling paints has resulted in high levels of contamination in the environment and has raised concerns about their effects on marine communities

The accumulation of unwanted matter on surfaces is a problem plaguing a variety of industries and human activities and is recognized by the term "fouling", which is related to both biofouling and inorganic fouling.

In particular, inorganic fouling is referred to deposits from corrosion, crystallization, suspended particles, oil and ice, whereas biofouling describes the growth of micro- and macro-organisms on surfaces.

Biofouling is ubiquitous in the marine environment and is a major problem for the shipping industry. Indeed, the growth of organisms on a vessel hull increases the frictional drag which reduces the ship speed and consequently requires increased power and fuel consumption to maintain the same cruising speed.

The need for effective antifoulants preventing against the settlement and growth of marine organisms on all submerged structures – i.e., not only ship hulls but also oil rig supports, buoys and fish cages – is recognized worldwide as being of significant economic importance. This requirement has been a driving force for the development of antifouling (AF) paints technologies, a global industry that is now worth approximately US$ 5 billion annually.

Consolidated antifouling measures include the use of coatings based on toxicants, traditionally incorporated into a paint matrix, that gradually leach from the surface layer. The widespread use of toxicants in AF paints, tributyltin in particular, has resulted in high levels of contamination in the environment and has raised concerns about their effects on

marine communities (shell malformation in oysters, mortality of mussel larvae and imposex in gasteropods), leading to policy actions to regulate their utilization. Therefore, to avoid these environmental alarms, the need has arisen for the continuous development of new non-toxic AF formulations, from non-toxic silicone-based coatings, known as foul release coatings, to innovative and new promising lines of research inspired by biomimetic solutions.

This special issue of EAI was born from the fundamentals of the Carisma project (Characterization and ecological risk analysis of antifouling biocides in the Southern Adriatic Sea), funded the by the Italian Ministry of Foreign Affairs, that aims to assess the quality of the portion of the Adriatic Sea between Italy (Apulia region) and Albania and, in particular, the environmental impact due to the use of antifouling paints. Actually, a large expertise in this field both in the analytical and ecotoxicological areas is far-back present at ENEA, as highlighted in the following section that provides a brief description of the "ENEA primary activities on antifouling biocides" and "ENEA main articles concerning antifouling biocides". This publication represents a wide-ranging reporting in the fouling/antifouling field and addresses a broad spectrum of the environmental issues. It wants to tackle and analyze the various aspects of fouling, with particular emphasis to biofouling, starting from the description of the biological phenomenon and of the main AF strategies, to the environmental impact, in terms of the amount of AF biocides released and the unwanted effects observed, reaching the definition of the ecological risk for the marine community. In addition, the legislative aspect is also addressed from different points of view: transposition and application, environmental protection and the REACH Regulation. In order to help readers, this issue is divided into three sections:

1) general characteristics of (bio)fouling and AF measures;
2) analytical aspects and environmental concerns of AF biocides;
3) national/international legislation.

We would like to thank all the contributors to this special issue and all experts in the field, coming from different public (such as ISPRA, CNR, the General Command of the Harbour, ASA and ENEA) and private Institutions (Boero Group and Shoreline), for sharing their expertise and experience with our readers. Moreover, we would like to extend our thanks to all the staff of EAI, Dr. Diana Savelli, Dr. Giuliano Ghisu and Dr. Carla Costigliola for their advice and assistance, and to Dr. Carlo Cremisini, Head of the Technical Unit for Environmental Characterization, Prevention, and Remediation (ENEA-UTPRA). Finally, it is our hope that readers will enjoy reading this special issue, the content of which will constitute a significant resource for all the Scientific actors and stakeholders, interested in this interdisciplinary field.

This publication represents a wide-ranging reporting in the fouling/antifouling field and addresses a broad spectrum of the environmental issues

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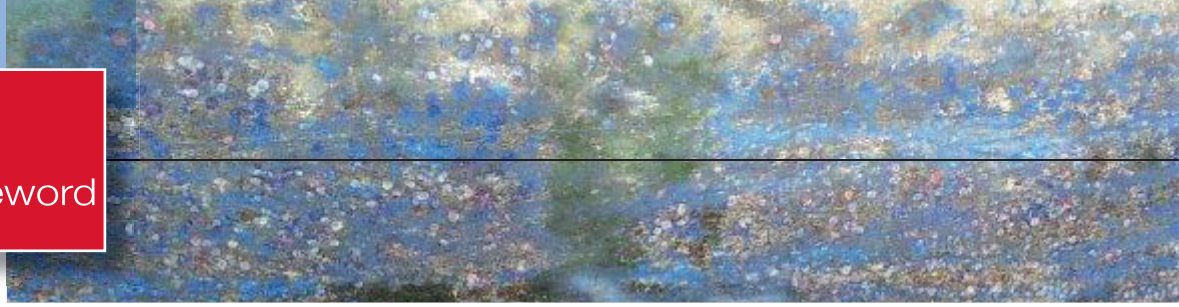
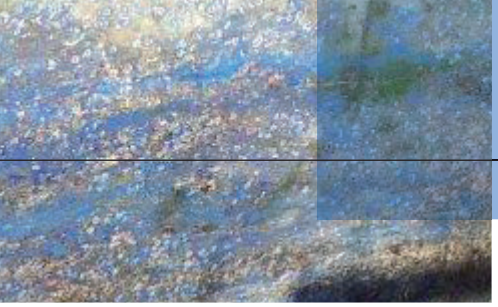


ENEA primary activities on antifouling biocides

International funded Projects	Years	Description and rule
HIC-TBT (EU-LIFE, 98ENV/NL//000199)	1999-2001	Assessment of the environmental distribution of TBT in Spain, Italy, Portugal in the North Sea in relation to its impact on marine life; development of communication strategies in order to sensitize the non-scientific community to the problem of TBT. Partner
OT-SAFE (EU – 5th FP, QLK1-CT-2001-01437)	2001-2004	EU-wide monitoring of contamination of fish products by organotin compounds and the related effect on human health, through the evaluation of the effect that cooking has on organotin compounds present in mussels. Partner
TBTIMPACTS (EU – 6th FP, INCO 510658)	2005-2009	Implications of TBT pollution and its ban, costs and benefits of TBT based antifoulants and other alternatives; environmental impact of organotin compounds in Europe and India coastlines and awareness towards this contaminant. Coordinator
CARISMA (Italian Ministry of Foreign Affairs, Projects of major importance in the Scientific and Technological Collaboration Executive Programmes with Albania, PGR00123)	2012-2014	Environmental impact of antifouling paints in the portion of the Adriatic Sea between Italy (Apulia region) and Albania and. Coordinator

Certification and stability studies	Years	Description
BCR 424, BCR 462, BCR 477, BCR 646, BCR 710	1991-2002	Preparation and certification of reference materials for organotin compounds in several environmental matrices (sediment, biota tissues). ENEA has acted as coordinator in BCR 447 and BCR 710 projects and as partners in the others certification campaigns.
BCR 462, BCR 477, BCR 710	2000 - present day	Stability studies on behalf of IRMM

ENEA main articles concerning antifouling biocides published in peer-reviewed journals in the analytical and ecotoxicological areas



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