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Ships and marine technology — Marine environment protection — Testing of ship biofouling in-water cleaning systems

Navires et technologie maritime — Protection de l'environnement marin — Essais des systèmes de nettoyage des salissures biologiques sans sortir le navire de l'eau

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Foreword

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This document was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 2, *Marine environment protection*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Like all substrates placed in coastal waters, the wetted surfaces of ships are quickly colonized by a succession of diverse sessile or sedentary micro- and macro-organisms, collectively known as biofouling.[1][2][3] The adverse effects of biofouling on ships and their operations are well known and there is a long history of attempting various biofouling management approaches.[4]

Negative impacts of biofouling on the shipping industry include:

— reduced ship performance and fuel efficiency;[5][6][7][8]

— corrosion and decreased durability;[9][10]

— increased greenhouse gas emissions;[11][12]

— failure to meet associated legal/contractual requirements;[13][14]

— increased underwater noise;[15]

— unintended translocation of aquatic species.[16][17][18]

In recent decades, the importance of ship biofouling as a pathway for invasive aquatic species translocations has become increasingly apparent.[17][18][19][20][21] Entire biological communities can be moved around the world by oceangoing ships and a substantial number of species, including pathogens, can be introduced as a result.[22][23][24] While not all invasive aquatic species have immediate noticeable or significant impacts, a subset of invasive aquatic species have a broad range of effects on the aquatic environment and the communities reliant upon local ecosystem services.[25][26][27] Guidelines and regulations to prevent invasive aquatic species introductions via ship biofouling are beginning to emerge to protect environmental, economic, social, and cultural values (e.g. see References [12] [28] [29]).

The International Maritime Organization (IMO) defines antifouling systems (AFS) as various approaches used on a ship to control or prevent the attachment of unwanted organisms.[30] The primary AFS are coatings, applied during dry-docking to surfaces below the maximum waterline of ships, which are designed to either prevent macrofouling attachment (using biocides) or reduce adhesion (foul-release) to wetted surfaces.[31][32] In some areas (e.g. Baltic Sea), non-ablative or non-polishing hard coatings are used in combination with regular cleaning as a fouling prevention strategy.[33]

The service life of modern coatings for commercial ships is typically five years (e.g. see Reference [32] [34]). Despite substantial improvements over the past 40 years, surface coatings do not consistently prevent biofouling accumulation on all ship surfaces over the course of their service lives.[35][36] Accumulations tend to occur as coatings age[37][38] and when ships have extended stationary periods.[13][14][39][40]

Even when antifouling coatings are used, there are also substantial areas of ships' immersed surfaces that are more prone to biofouling[41][42][43][44] because they:

— cannot be painted (e.g. anodes);

— are prone to damage (e.g. bulbous bow, tug and fender points, areas below anchor chain);

— are challenging to coat (e.g. dry-dock blocking areas); or

— are sub-optimal for coating performance (e.g. gratings, rudders, propellers, and sea chests).

Given the existing limitations of coatings, especially during extended periods between dry-docking, in-water cleaning (IWC) of ship biofouling (within a coating's service life) is often required or advantageous.[12]

IWC of biofouling – used to either maintain or reset ship immersed surfaces to a hydrodynamically smooth state – is a common approach to increase ship performance and fuel efficiency between dry-dockings.[8][45] IWC is also recognized as beneficial for reducing both greenhouse gas emissions[11][12][46] and biosecurity risks.[47][48]

IWC systems typically involve the use of diver- or remotely-operated cleaning units (i.e. cleaning carts) that remove biofouling from hull surfaces.[49][50] IWC is generally described as either proactive or reactive.[47] Proactive IWC is the periodic removal or reduction of biofilm growth (i.e. microfouling or slime layer) on ship surfaces. Proactive IWC also removes newly settled or attached microscopic stages of macrofouling organisms, to ultimately minimize or prevent macrofouling growth.[47][51] Reactive IWC is typically used to remove already established macrofouling organisms.[47][52] Both proactive and reactive IWC can include debris capture, treatment and disposal.[48][52]

While IWC has the potential to provide significant ship operations and biosecurity benefits, there are two main IWC processes that can result in inadvertent environmental harm:

a) lack of, or incomplete, capture of dislodged debris by the cleaning unit; and

b) release of untreated, or incompletely treated, effluent from debris processing.[47][48]

Potential environmental impacts from these two IWC processes include:

— increased discharge of coating biocides and microplastics to ambient waters;[52][53][54][55]

— release of live biofouling organisms, their propagules, or pathogens, into local habitats;[24][52][54]

— diminished coating condition (e.g. dry film thickness [DFT] or scuffs and chips) that reduces antifouling performance and longevity.[45][56]

Given the potential for environmental harm, independent, transparent, and predictive testing of efficacy is needed to evaluate the performance of both proactive and reactive IWC systems. Such robust and standardized testing is critical for the responsible use of IWC systems and the success of biofouling-related policies and regulations.[48]

This document aims to provide standardized, science-based test procedures that produce the data (and level of confidence) needed by relevant stakeholders when assessing the development and use of IWC systems. This document is based on recent, related international efforts to develop IWC system testing protocols (e.g. see References [50] [57] [58]). It describes how to produce data and report on the efficacy and safety of IWC systems to clean various ship surfaces and for the capture and disposal of cleaning debris. The impartial data and reporting from testing under this document are intended to inform IWC service providers, ship operators, and relevant authorities on the performance of IWC. The procedures and methods in this document can also serve as a resource for technology developers, environmental regulators, and other stakeholders interested in the safe and effective use of IWC systems.

The methods and approaches presented in this document represent consensus among international technical experts on best scientific practices. However, it is also expected that some test methods will evolve or improve over time as collective knowledge of this complex issue grows. Performance and safety of IWC systems is context-dependent with many sources of variation across ships, environments, and associated biota. As a result, the use of this document does not guarantee that a specific IWC system will always, or under circumstances other than those used in testing, operate at the levels reported.

This document was developed so that all forms of IWC systems can be tested in a comprehensive and standardized way. However, this document also provides flexibility for conducting evaluations that are customized and appropriate for individual IWC system designs, operational requirements or limits, and providers' claims. It is expected that end-users will select appropriate aspects of this document to incorporate in any individual testing effort, depending on the specifics of the IWC system being evaluated, the function of the IWC system evaluation, and the resources available.

Ships and marine technology — Marine environment protection — Testing of ship biofouling in-water cleaning systems

1 Scope

This document provides detailed and rigorous procedures for the independent performance testing of all forms of ship in-water cleaning (IWC), including on all types of biofouling (i.e. biofilms/microfouling and macrofouling), all external submerged surfaces (i.e. hull and niche areas), and both proactive and reactive IWC systems with or without the capture, processing, and disposal of debris. This document also includes testing protocols and describes how to produce data and report on the efficacy and safety of IWC systems to clean various ship surfaces and for the capture and disposal of cleaning debris.

The development of specific IWC performance requirements, criteria, or standards is outside the scope of this document and is the responsibility of individual authorities, agencies, or administrations. Similarly, while some methods and approaches described in this document can apply to other ship biofouling management approaches, systems designed to kill or prevent biofouling on external surfaces without removal (i.e. without in-water cleaning), and systems that remove or treat biofouling on internal surfaces (e.g. seawater pipes) or external surfaces of intricate mechanical components (e.g. external parts of propeller shaft seal), are also outside the scope of this document.

2 Normative references

There are no normative references for this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
antifouling system
AFS
coating, paint, surface treatment, surface or device that is used on a *ship* (3.18) to control or prevent the attachment of organisms

3.2
antifouling coating
surface coating or paint designed to prevent, repel, or facilitate the detachment of *biofouling* (3.3) from hull and *niche areas* (3.16) that are typically or occasionally submerged

3.3
biofouling
accumulation of aquatic organisms such as microorganisms, plants, and animals on surfaces and structures immersed in or exposed to the aquatic environment

3.4
capture
process of containment, collection, and removal of *biofouling* (3.3) material, debris, and *waste substances* (3.20) from surfaces during cleaning in water or in drydock

3.5
cleaning system
equipment used for, or the process of, removal of *biofouling* (3.3) from the *ship* (3.18) surface, with or without *capture* (3.4)

3.6
data quality objective
qualitative and quantitative statement that clarifies study objectives, defines the appropriate types of data and specifies the tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions

3.7
dry film thickness
DFT
non-destructive means to measure the total coating thickness and wear on submerged ship surfaces through repeated measures using a digital DFT sensor

3.8
fouling rating
FR
allocation of a number for a defined inspection area of the *ship* (3.18) surface based on a visual assessment, including a description of *biofouling* (3.3) present and the percentage of *macrofouling* (3.13) coverage

3.9
hull area
largest proportion of *ship* (3.18) submerged surfaces, which are relatively flat or planar locations, have well-understood hydrodynamic conditions and employ common or traditional *biofouling* (3.3) management systems (e.g. *antifouling coating* (3.2))

3.10
independent testing organization
independent TO
appropriately independent (e.g. with no conflicts of interest), qualified, scientific contractor accepted to conduct third-party testing

3.11
invasive aquatic species
non-native or non-indigenous species to a particular ecosystem that can pose threats to human, animal, and plant life, economic and cultural activities, and the aquatic environment

3.12
in-water cleaning
IWC
intentional removal of *biofouling* (3.3) from a *ship's* (3.18) hull or *niche areas* (3.16) while in the water

3.13
macrofouling
biofouling (3.3) caused by the attachment and subsequent growth of visible plants and animals on structures and *ships* (3.18) exposed to water

Note 1 to entry: Macrofouling are large, distinct multicellular individual or colonial organisms visible to the human eye such as barnacles, tubeworms, mussels, fronds/filaments of algae, bryozoans, sea squirts, and other large attached, encrusting or mobile organisms.

3.14
microfouling
biofouling (3.3) caused by bacteria, fungi, microalgae, protozoans, and other microscopic organisms that create a biofilm

3.15
multicomponent in-water cleaning system
multicomponent IWC system
system reliant on two or more individual components to achieve the required *in-water cleaning* (3.12)

Note 1 to entry: The use of each component shall be specified in the system standard operating procedures (SOP), e.g. the use of a hand tool for addressing *niche areas* (3.16) after the use of the main cleaning unit on hull surfaces.

3.16
niche area
subset of the submerged surface areas on a *ship* (3.18) that can be more susceptible to *biofouling* (3.3) than the main hull owing to structural complexity, different or variable hydrodynamic forces, susceptibility to *antifouling coating* (3.2) wear or damage, or inadequate or no protection by *antifouling systems* (3.1)

3.17
proactive in-water cleaning
proactive IWC
periodic removal of *microfouling* (3.14) on *ship* (3.18) surfaces to prevent or minimize attachment of *macrofouling* (3.13)

3.18
ship
vessel of any type operating in the aquatic environment, including hydrofoil boats, air-cushion vehicles, submersibles, floating craft, fixed or floating platforms, floating storage units, and floating production storage and off-loading units

3.19
reactive in-water cleaning
reactive IWC
corrective action during which *biofouling* (3.3) is removed from a *ship's* (3.18) hull and *niche areas* (3.16), either in water with *capture* (3.4) or in drydock

3.20
waste
dissolved and particulate materials or debris that can be released or produced during cleaning or maintenance, and can include biocides, metals, organic substances, removed *biofouling* (3.3), pigments, microplastics, or other contaminants that could have a negative impact on the environment

3.21
waste processing
treatment designed to remove or deactivate any particulate, dissolved material, or debris *captured* (3.4) during any form of *in-water cleaning* (3.12)

Note 1 to entry: Treatment can be a single stage such as physical separation (e.g. settling tanks, filtration, flocculation), selective media binding of compounds of concern, or disinfection of biological constituents of concern (e.g. biocides, UV, ultrasound) or a multi-staged, combined treatment approach.

4 Fundamental information needed for testing of IWC systems

4.1 Factors that can impact performance

Numerous factors can impact IWC system performance and the means by which comprehensive, standardized testing is performed.[48][52] These include, but are not limited to:

— ship [e.g. type, design, coating(s), ship and coating ages, operational profile, and routes];

— biofouling (e.g. life history stage, type, coverage, location);

— environmental conditions (e.g. visibility, swell, current, ambient water quality);

— the IWC system (e.g. unique design features, operational requirements and limits, cleaning procedures); and

— IWC system operator training and experience.

4.2 Fundamental parameters

Testing IWC systems is most appropriate and informative when performed under real-world conditions. However, the cost and complexity of full-scale operations on ships can prohibit extensive experimental replication, controls, and the isolation of single factors to measure their impact on overall performance and safety. Given the complexity of these variables, it is not feasible to examine all possible factors (singularly or in combination) that can impact IWC system performance and safety. Therefore, a list of fundamental parameters that shall be either documented, characterized, or specifically tested for, as part of any independent evaluation, is provided in Table 1. The listed parameters allow for linking test results to performance under specifically known (or measured) ship, biofouling, environmental, and IWC system characteristics. The experimental design and specific performance parameters for IWC system testing are described in Clauses 5 to 9.

Reporting for these parameters falls into three general categories:

— Documenting: information that shall be provided either by the ship owner, operator, IWC system service provider, or all three, which appropriately describes test conditions;

— Monitoring: information that shall be observed, measured or collected (e.g. direct observations of cleaning mobilization, operations, demobilization and environmental test conditions) and reported by the independent testing organization (TO) conducting the testing; and

— Testing: factors that shall be directly targeted or manipulated as fundamental test variables (e.g. a direct test of IWC system claims).

Table 1 — Test parameters and data required to assess IWC system performance

Ship parameters	Documenting	Monitoring	Testing
Ship type/function, age, size, and design drawings, with any relevant modifications (including complexities and niche areas)	X		
Ship recent routes/voyages and operational history over at least the past 12 months (including dry-docking, long idle periods, lay-up, and repairs)	X		

X Designates data or information required through documenting, monitoring, or testing for each parameter listed.

a Proprietary, or commercially sensitive, information on specific IWC technologies or approaches can be held confidential, provided enough basic information on system specifications, design, function, and operations are available to allow for an adequate understanding of performance and safety.

b For example, testing the IWC system service provider's claims on coating type (biocidal or fouling release), age or damage, which can influence environmental results.

c For example, testing the IWC system service provider's claims on fouling type/level/location and results from recent/relevant in-water biofouling inspections.

d For example, testing within specifications or to limits, including fouling (e.g. type, stage, and coverage), ship (e.g. size, materials, curvature, niche areas), coating type and appropriateness for cleaning, and environmental parameters (e.g. currents and visibility).

e For example, testing within specifications or efficacy limits.

f For example, testing within specifications or limits.