Blue-Antifouling: Innovating in Application to Keep Up With the Modernization of Naval Power

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ABSTRACT

Undoubtedly, Blue Biodiversity is recognized as an invaluable source of natural resources. In the marine context, bioprospecting can significantly influence society's perception of the oceans, representing an advance in Brazil's political-strategic position. To accompany the modernization of Naval Power and innovate the technique of applicability of antifouling products, Blue-antifouling, which is not a biocide, promotes prevention in the maintenance of maritime equipment. This contributes to operational stability and directs the country to advance research in the areas of Marine Science and Technology. The Blue Amazon Management System (SisGAAz), by monitoring macroalgae blooming areas, becomes an essential tool for boosting the country's bioeconomy. Seaweed, a natural source of alginate composed of alginic acid units and calcium ions, has the ability to gel. Alginate hydrogel, used in the synthesis of amphiphilic polymers synthesized through polymerization, induces self-association forming stable micelles and creates a hydrated layer in the living works of vessels. Cross-linking can be accomplished through physical mixing or the principles of ecologic chemistry, combining hydrophilic and hydrophobic polymers. Blue-antifouling is a high-performance hydrogel that uses hydrodynamics to prevent biofouling.

KEYWORDS: *Blue-antifouling, Naval Political-operational-strategy.*

1. INTRODUCTION

Marine biofouling, consisting of the unwanted accumulation of organisms in the living works of vessels, represents a vector for biological invasions that impact local ecosystems and cause various damages. This condition leads to high maintenance costs, resulting in increased fuel consumption and greater hydrodynamic resistance in the center of the fairing. Furthermore, it destabilizes the propeller propulsion systems and can also obstruct the sea chests and cause damage to the steering system. According to Dr. Ricardo Coutinho, Head of the Biotechnology Department at IEAPM, since 1987 research has questioned the effectiveness of conventional antifouling paints and their environmental impacts (Source: Agência Marinha de Notícias - AMN, accessed on June 11, 2024). One of the main objectives of the Brazilian Navy is to develop a biocide-free antifouling, with bioresources from the Blue Amazon. Brown algae, found throughout the Brazilian coast, are a natural source of alginate, a biodegradable polymer (Muller et al., 2011). Polysaccharides extracted from algae have the property of forming colloidal solutions and retaining molecules, thus controlling water activity in a system. This helps repel the adhesion of encrusted organisms, allowing their removal by hydrodynamic forces (Bobbio, 2003). According to Nogueira (2017), Brazil does not have alginate extraction processing, importing a large quantity of products containing these substances. According to Arnt (2001), the country is still not keeping up with the pace of global growth in biotechnology. It is necessary to integrate bioresources with socioeconomic development to guarantee the country's productive autonomy. In accordance with Figueira (2014), sustainable exploration of the Blue Amazon integrates its resources with Brazil's socioeconomic reality, encouraging rational and balanced use. This could contribute to the reversal of the rejection of the request to extend the Brazilian continental shelf, according to article 76 of the UNCLOS (Arruda, 2014). In this context, Blue-antifouling emerges as an opportunity to boost the national bioeconomy, returning the country to its maritime roots, promoting the search for sustainable development and full achievement (BRASIL, 2020).

2. GENERAL OBJECTIVE

Modernize antifouling applicability to ensure efficiency within the Naval Force's operational standards.

2.1. SPECIFIC OBJETIVES CONCOMITANT WITH THE BRAZILIAN NAVY

• Monitor the proliferation of algae in the Blue Amazon (SisGAAz);

• Manage the ecological form of the bioproduct derived from Marine Algae;

• Produce Blue-antifouling to prevent maintenance of naval equipment.

2.2. BLUE-ANTIFOULING

Blue-antifouling reduces the adhesion of marine organisms to the living works of vessels, allowing sea water to sweep from the bow wheel to the stern during navigation. According to the guidelines of the Military Strategic Program 2040 (PEM 2040), hydrodynamic technology plays a strategy to maintain the integrity of the submerged parts of vessels, providing modernization in the Naval Force.

Furthermore, it aims to mitigate environmental impacts in the Blue Amazon (BRASIL, 2020). Marine natural resources have the potential to boost the bioeconomy, and the extraction of alginate can contribute to Brazilian autonomy in the production of bioproducts (Nogueira, 2017). Alginate is a polysaccharide extracted from the intercellular matrix of brown seaweed and plays an important role in protecting against oxidative stress in the sea. According to Draget et al. (2005), alginate hydrogels are widely used in biomedical applications, including dressings and implants, due to their biocompatibility and gelling capacity when exposed to divalent cations such as calcium and magnesium. Alginate-based Blue-antifouling consists of hydrophilic polymers, whose absorption capacity is optimized by the cross-linking process. As described by Oliveira (2019), it can occur chemically, involving synthetic copolymers and covalent bonds, or physically, through natural homopolymers and intermolecular interactions. According to Oliveira (2019), this material is an alginate hydrogel, containing both hydrophilic segments (attract water) and hydrophobic segments (repel water).

The composition of hydrophobic and hydrophilic polymer segments enhances their mechanical properties and provides an exceptional water absorption capacity, in addition to providing cross-linked structural integrity (Wei et al., 2024). As described by Liang (2023), it is an organic hybrid coating, comprising an amphiphilic polymeric network, combined with polydimethylsiloxane (PDMS) and components extracted from seaweed.

According to Callow (2011), this combination represents a new approach to high-performance silicone-based antifouling coatings. For Wei et al. (2024), polydimethylsiloxane is a silicone with hydrophobic properties. It is often used in hydrogels to provide water resistance and flexibility in humid or aquatic environments. According to data from BRASIL (2020), this application is a strategy that ensures prevention in the maintenance of Naval Force equipment, contributing to hydrodynamic performance by stabilizing the propeller propulsion systems. Furthermore, PDMS helps prevent damage to the rudder steering system and ensures the cleanliness of underwater lights.

2.3. BLUE-BIORESOURCE

Present in the intertidal zones of the Blue Amazon, the most important macroalgae are the brown, also known as pheophytes or pheophytes. These seaweed species have played an important role in coastal ecosystems, providing shelter and food for a variety of organisms.
In seaweed species, such as Sargassum cymosum (Mafra, 2001) and Sargassum filipendula (Bertagnolli et al., 2014), we find polysaccharides, including carrageenan (thickeners and stabilizers), fucoxanthin (health benefits), agar (used in the cultivation of bacteria and fungi) and alginate (gelling agents and antioxidants).
According to Wei et al. (2024), alginate is effective in preventing the adhesion of marine organisms. Natural antioxidants protect the material against biofouling, inhibiting the growth of microorganisms and reducing the formation of biofilms.
Described by Bertagnolli et al. (2014), the gelling and thickening properties of alginate make it a versatile and innovative component in the application of Blue-antifouling. In addition, the use of alginate is sustainable and less toxic to the marine environment.
As described by Arruda (2014), the Brazilian Navy (MB) has the task of acquiring essential equipment for the defense of the Blue Amazon, as a strategy for the sustainable exploitation of bioeconomic potential. The biotechnology applied to the treatment of Blue-antifouling, makes the living works of the vessel smoother, allowing the barnacles to detach in navigation with the friction of the water. This makes it possible for the thalassocycle to continue without harming marine life.
According to the National Defense Policy (PND), the conservation of the living resources of the Blue Amazon is of vital importance for the country. Barnacles act as filter feeders, feeding on plankton and organic particles suspended in the water, contributing to the purification of the oceans and to the maintenance of the life of other aquatic organisms.
In turn, algae also play a crucial role in marine ecosystems (Mafra, 2001). They are responsible for sustaining ocean life and serve as food for several species that inhabit seas, rivers and lakes.
The blooms of brown seaweed (Sargassum) have intensified annually, negatively affecting coastal biodiversity, fisheries and tourism. Climatic and environmental factors influence the growth of these algae (Bertagnolli et al., 2014).
According to Cicerelli (2015), algal blooms can be detected by remote sensing due to their optically active pigments. SisGAAz, by monitoring algal blooms, will be promoting environmental balance, boosting the economy, and strengthening Brazil's political-strategic stature.

3. Methodology Applied to Scientific Research

Through a qualitative method, concomitant with the knowledge obtained in the Maritime Professional Education (EPM), data were compiled for scientific investigation.
As a nautical instructor, valuable sailing practices have provided insights into factors that can affect the performance of the boat or watercraft.
My academic and professional trajectory also directed research, including:
Licentiate and bachelor's degree in Physical Education (UNIVALI);
Postgraduate in Physical Education Teaching Methodology (UNIASSELVI);
Specialization in Marine Sciences (IFSC);
Postgraduate studies in progress, Marine Biology (UNYLEYA);
International Master's student in Marine Science and Technology (FUNINBER/MEXICO);
Aquatic Rescue Operator (2009/2024 ANJOS DO MAR);
CBMSC GVC - 2009/2018 (SOUTH American champion of aquatic rescue);
CFAQ/2022 (MAC/MOM), CFAQ/2022 (MOP/POP), CFAQ/2023 (PEP - first place);
CAPTAIN AMATEUR - CPA I/2024, best grade DEL - Itajaí.
In the program 'The Good Sailor' Bombarco (2023/2024), I was ranked among the three best sailors in Brazil, making me a national reference in seamanship. During the program, I collected data for the research in parallel with the evaluation process.

3.1. DATA OBTAINED

In the 2023/2024 biennium, data were collected on the best companies in Brazil:

OKEN YACHTS: Designed by renowned Italian yacht designer Paolo Ferragni;

VOLVO PENTA: World leader in power solutions for marine applications;

FIBRAFORT BOATS: The largest manufacturer in South America;

STEP ON BOARD: The largest nautical architecture office in Brazil;

AZIMUT: Known for its range of luxury yachts;

PROPSPEED: The industry benchmark for FOUL-RELEASE coatings.

3.2. RESULTS

The effective antifouling solution was presented, reducing the incidences of biofouling. Its biocoating capacity creates a protective film over all metal parts and pieces of the vessels' live works. The tests indicated the following results:

- They reduce the friction of the vessel on the surfaces with the water;
- Reduction of the need for periodic maintenance of the engines;
- Reduction in fuel consumption, improving performance.

The innovative application technique (Figure 4) provided the live works of the vessels with a smooth surface, resulting in better efficiency of the propulsion system (Figure 1, Figure 2, Figure 3). In addition, it stabilized the ability to travel during navigation and reduced the risk of damage to government systems. The protection offered to the engine reduced vibrations and noise, with an average saving of 10% in fuel over the course of a year, varying according to the use and size of the vessel.
Biofouling in the transducer compromises performance by decreasing the clarity of details in the image. The antifouling ensured accurate signal transmission, not affecting the image quality, since it does not contain heavy metals in its composition.
Underwater lights generate heat, creating conditions conducive to marine growth. The bioproduct protected the underwater lights of the vessels (Figure 5). Conventional anti-fouling paints cannot be applied to the lights, as they are not transparent.
Finally, it ensured the stabilization of the operational capacity of marine equipment, being the ecologically sustainable alternative to repel biofouling.

3.3. Innovative thrre-step application method

1 - Wipe the surface with a dry cloth or using a tissue.

2 - Apply a thin layer of the clear coat (Blue-antifouling) with a brush.

3 - Let it dry and wait a minimum of 8 hours before putting the boat in the water.

3.4. Field test have proven the efficiency the blue-antifouling system

Figura 1

Azimut – Sem incrustações após 12 meses

Figura 2

Schaefer Yachts - 1 ano de navegação

Figura 3

Ferreti 68 - 2 anos após aplicação

Figura 4

Aplicação

Figura 5

Luzes subaquáticas

4. CONCLUSIONS

As described by Wei et al. (2024), organofunctional silicone polymers, such as PDMS, exhibit excellent dielectric properties, optical transparency, aging resistance, and gas permeability.
However, due to their low mechanical properties, it is necessary to include a reinforcing agent to improve the mechanical performance of these materials. According to Monteiro (2009), silica is often used as a reinforcing agent.
Silica is found both in solid materials and in living organisms such as algae. When incorporated into polymers such as PDMS (polydimethylsiloxane), it can significantly improve their mechanical properties, making them stronger and more durable.
As described by Kashima et al. (2012), alginate has been studied as a toxic metal sequestering agent. It can modify properties such as rheology, water-binding ability, emulsion stabilization, and film formation.
Alginate is a polysaccharide composed of two main monomers: β-D-manuronyl and α-L-guluronyl (Chin et al., 2015). In the presence of divalent cations, it forms a gel by ionic crosslinking, giving the material characteristics such as: resistance, durability and dimensional stability.

For Monteiro (2009), the process of alginate extraction involves ion exchange from the extraction of algae tissues, followed by neutralization and solubilization of alginic acid with a water-soluble alkaline compound. After separation processes, such as flocculation, centrifugation and filtration, the sodium alginate is precipitated using alcohol, calcium chloride or mineral acid and, finally, it is dried (Draget et al., 2000).
According to Wei et al. (2024), the combination and composition of these substances exhibit excellent antifouling properties. These properties demonstrate efficacy in combating protein, bacterial and microalgal fouling on submerged surfaces.
Biotechnological resources can protect against the formation of biofilm and corrosion, preventing the maintenance of naval equipment.
In addition, hydrodynamics applied in scale prevention takes into account factors such as fluid velocity, turbulence, viscosity, and rheology. These aspects are crucial for keeping equipment running efficiently and extending its lifespan.

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