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An eco-friendly process for prevention of biofouling

G. Subramanian [a,*], S. Palanichamy [a], P. Veeramani [b]

[a] Offshore Platform & Marine Electrochemistry Centre, CSIR-CECRI Unit, Harbour Area, Tuticorin, 628004, India
[b] CSIR-Central Electrochemical Research Institute, Karaikudi, 630003, India

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ABSTRACT

In the present study an apparatus was developed for prevention of biofouling using pneumatic system. The materials used for the investigation are bare as well as painted galvanized iron (GI) pipes, mild steel structures of L shaped, I shaped, square tube configuration, ship hull model and reinforced cement concrete (RCC) cylindrical piles. Each material was studied for a period of 3–6 months in the coastal seawater of Mandapam. At the end of each experiment, no fouling was observed on the specimen tested with the present process, whereas substantial amount of fouling was noticed on the control specimen.

1. Introduction

Marine biofouling can be defined as the undesirable accumulation of microorganisms, plants, and animals on artificial surfaces immersed in sea water.

The macrofouling has serious implications in the performance of desalination and power plants. Intake structures, screens, seawater piping systems and heat exchanger tubes are the sites worst affected in the plants causing overall decline in plant efficiency at great economic cost. In the case of ships, the adverse effects caused by this biological settlement are known. They are; a) high frictional resistance, due to generated roughness, which causes increased emissions of harmful compounds, b) increase in fuel consumption can be up to 40% and in voyage overall costs as much as 77%, c) large amount of toxic wastes is also generated owing to increased frequency of dry docking, d) deterioration of the coating leads to corrosion, discolouration, and alteration of the electrical conductivity of the material [1].

There has been a significantly laudable effort in the world to understand the phenomenon of biofouling and evolve strategies for its prevention and control [2,3]. Several processes are available in the literature for the prevention and control of biofouling on marine installations, including seagoing vessels. They are: 1) sheathing with fouling resistant materials like lead and copper which rely on the leaching of the metal ions from an insoluble film to prevent fouling, 2) iron ships, 3) coatings with lime, arsenic and mercurial compounds were used until the modern chemical industry developed effective anti-fouling paints using metallic compounds, 4) coatings containing tin and copper, 5) coatings containing toxic antifouling agents such as TBT – SPC was developed based on tin copolymers (1970′s) which provided a long service life and a smooth surface. Unfortunately, tin was identified in the 1980′s as a major and persistent pollutant, and hence banned in 2003, 6) coatings with low surface energy technology (example silicone coatings) that rely on the extremely smooth surface, fast cruising speeds and constant use to prevent fouling development were in use in early 1970′s, 7) coatings containing copper and cuprous oxide, 8) coatings containing TBT free – SPC with biocides, 9) coatings containing TBT – (a) silicon coatings: the surface is so smooth that organisms can barely stick to it and fouling that does develop can easily be removed, (b) prickly coatings – prickles prevent organisms like barnacles from sticking to the ships hull, (c) solid coatings: can be effective in combination with mechanical cleaning as an alternative to toxic tin compounds, 10) coatings containing nanomaterials with copper oxide or doped zinc oxides which can reside permanently in marine coating formulations and increase the life time of the antimicrobial activity, meaning that cleaning and reapplication cycles can be extended, 11) Audible, ultrasonic (high frequencies) and infrasonic sound (low frequencies) to remove and prevent settlement of fouling species including bivalves, barna-

* Corresponding author.
E-mail addresses: cgscorr@yahoo.co.in (G. Subramanian), spscientist18@rediffmail.com (S. Palanichamy), veeramani57@gmail.com (P. Veeramani).

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cles and bacteria as well as acting as a barrier to exclude fish and crustacean from certain areas [1].

Hitherto known processes for prevention of marine fouling somehow or other adversely affect marine organisms. Frequent dry docking and re-painting; besides causing exchequer, severely pollutes the atmosphere. Environmental concerns over the potential impact of antifouling paints in the past have led to regulatory measures in the US and around the world. The International Maritime Organizations (IMO) of UN's Marine Environment Protection Committee (MEPTC) adopted a resolution that recommended restricting the use and release rate of TBT – antifouling paints. The world shipping community has indicated that current alternative antifoulants are not as effective as TBT – SPC based paints, resulting in varying degrees of fouling on ship hulls. The October 1999 OSPAR convention report reveals that the alternatives (booster biocides) for TBT antifouling paints may have unwanted environmental effects, attaining more comprehensive scientific research and evaluation. However, the other available system developed without any chemicals such as acoustic sound waves has not been found effective. Keeping in mind the economic losses caused by fouling and environmental hazards rendered by the use of antifouling paints, an apparatus has been developed for eco-friendly combating of biofouling on the surfaces of steel, RCC materials of uniform configuration and mini steel ship hull model, using pneumatic system. This work has been patented in India [4].

2. Materials and methods

In the present study a pneumatic system consisting of continuous rated 3 phase air compressor of 165 L capacity, non-return valve, timer controller and pneumatic cylinder with limiting switches and stainless steel piston rod along with brush arrangement has been installed on a platform of size 3 m × 2 m, erected in the sea, 20 m away from the shoreline of the Gulf of Mannar, Mandapam Coast (79°10′ latitude and 9°15′ longitude in India). Schematic of the fouling prevention system is shown in Fig. 1.

The pneumatic cylinder has been positioned to facilitate vertical displacement of the piston, over the surface of the submerged specimens (GI pipe, mild steel "I" section, mild steel "L" section, mild steel square tube and RCC cylindrical pile) mounted in the seabed, exactly below the piston. While, for mild steel ship hull model, the pneumatic cylinder has been positioned to facilitate lateral movement of the piston. The piston was designed for 1 m movement over the surface of the specimen. Below the platform the average depth of the sea was 2 m.

The paints, red oxide primer and anticorrosive Epigard HB MIO (grey) supplied by Shalimar Paints Limited, Gurgaon, Haryana, India were used for coating the test specimens. The red oxide primer (80 ± 5 μm) as under coat and Epiguard (100 ± 5 μm) as top coat were applied on the test specimens by brush and allowed to dry for 24 h between each application, with a final dry film thickness of 180 ± 5 μm. All the coated specimens were cured at room temperature for 7 days before exposure.

The following specimens such as painted and bare GI pipes (100 mm diameter), painted and bare mild steel "I" sections (Length 1.5 m and width 100 mm), painted and bare mild steel "L" section (Length 1.5 m and 75 mm × 75 mm), painted and bare mild steel square tube (Length: 1.5 m and 75 mm × 75 mm), painted mild steel ship hull model (1200 mm × 800 mm × 1100 mm with taper angle of 7° to 8°), and bare RCC cylindrical pile (Length: 1.5 m and 250 mm diameter) were experimented one after another by mounting on the seafloor. Control (allowed to foul freely) specimens of the similar materials were exposed in the sea simultaneously adjacent to the test specimens to compare the effectiveness of the process. In the case of mild steel ship hull model, the inner painted surface was treated as control and the outer surface was used for experimentation. Painted specimens were used in the study as to ensure that the movement of brush arrangement on the surface of the specimens do not cause any damage to the coating.

Brushes made of high quality soft nylon bristles have been fabricated according to the geometry of the specimen and fixed at the bottom end of the piston. This brush arrangement would move over the submerged specimen to a distance of 1 m, when the pneumatic system is operated at a vertical displacement of 0.5 m/min for 4 min in a day, for the upward and downward movement of the brush arrangement over the submerged specimen.

All the materials were experimented in submerged condition for a period of 3 months one after another, excepting the ship hull, which was experimented for 6 months in the sea. After the termination of the each experiment, the biomass was scrapped from the control specimen as well as on the experimented specimen (if any) and weighed.

3. Results and discussion

Marine biofouling is a natural process occurring in the ocean as soon as a substratum is lowered or moored underwater. Biofouling has long been considered as a great menace to the marine industries which use seawater as coolant, other marine installations like piles, piers, moorings, buoys, offshore structures and sea going vessels. Many potential solutions to fight against this problem have been proposed but none of them seems to be universally applicable. The present process describes an economically viable and environment friendly solution for the fouling menace. The specimens experimented with the present process are completely free of fouling, whereas substantial amount of fouling was noticed on the control specimens (Figs. 2–5). The fouling load on the control – bare and painted G I pipes was found to be 0.26 kg/m^2 and 1.58 kg/m^2, respectively (Fig. 2). While on the control – bare and painted mild steel "I" section the observed fouling load was 0.25 kg/m^2 and 0.28 kg/m^2, respectively. The fouling load on the control – bare (0.23 kg/m^2) and painted (0.25 kg/m^2) mild steel "L" section did not vary much. While on the control – bare and painted mild steel square tube the observed fouling load was 0.34 kg/m^2 and 0.70 kg/m^2, respectively (Fig. 3). The fouling load on the painted mild steel ship hull model was found to be 2.36 kg/m^2 (Fig. 4) and on the control bare RCC pile the observed fouling load was 2.0 kg/m^2 (Fig. 5).

The data of all the above recited examples clearly indicate that the specimens (bare and painted) experimented with the present process were free of fouling, whereas substantial amount of fouling was observed on the control specimens (bare and painted), which were allowed to foul freely. After the termination of the experiment, it was observed that the coating was intact on all the specimens experimented with the present process.

It is a well known fact that a precursor to macrofouling is the microfouling caused by bacteria, fungi and other microscopic organisms [5]. Bacterial biofilms are known to be important in the settlement process of representatives of most marine invertebrate groups including sponges, tubeworms, cnidarians, annelids, echinoderms, phoronids, bryozoans, ascidians and algae [6–8]. Antifouling research has provided insight into the development, structure, and function of biofilms [9,10], especially regarding how they adhere to surfaces [11] and how specific bacterial components of biofilms induce recruitment of some larvae [12].Thus, microfouling layer also acts as a holdfast for larvae of macrofoulers. In such cases, a mechanism which could completely remove the biofilm over the surfaces of materials in seawater would be a viable solution for prevention of macrofouling. This basic concept sparkled in our mind to prevent fouling by means of the present process. In the