THE DEVELOPMENT OF BIOFOULING ON TWO COMMERCIAL ANTIFOULING COATINGS UNDER STATIC CONDITIONS

KALOUPI M.D.[1], KOTRIKLA A.M.[1] and BATJAKAS I.E.[2]

[1]Department of Transport, Shipping and Trade, University of the Aegean, Korai 2A, Chios, Greece
[2]Department of Marine Sciences, University of the Aegean, University Hill, Lesvos, Greece
E-mail: akotr@aegean.gr

ABSTRACT

The fouling of the vessels' hull due to marine organisms is a serious problem for shipping and the environment. The attachment of marine organisms on a ship's hull increases the friction between the hull and the sea water and consequently increases fuel consumption, operational cost and air pollutant emissions. Marine biofouling also contributes to the corrosion of the ship's hull and it is a vector for the introduction of non-native species to the marine environment. In order to protect the hull of the ships from biofouling, antifouling paints are used.
In this work, the performance of two commercial antifouling products on the inhibition of the settlement of marine organisms on static panels immersed in sea water was tested. Nine polyester panels (200mm x 140mm) were immersed in the marine area near Kardamyla, north-eastern Chios. Three of them painted with an antifouling paint containing copper oxide and dichlofluanid and three painted with antifouling paint containing only dichlofluanid. There were also three control panels that received no treatment. The experiment lasted two months (29/7/2014-3/10/2014) and three samplings were taken during that time. The marine organisms attached on the surfaces were indentified and counted in the laboratory using Olympus SZ 40 stereoscope.

The results showed that the first colonizers were algae, crustaceans (mainly amphipoda) and only one mollusk (bivalve). A greater amount of mollusks (gastropods, bivalve, polyplacophora) and annelids followed the initial colonization. Eventually, during the third sampling there were the aforementioned species in greater numbers. The control panels were much more rapidly colonized by marine organisms compared to the treatments. Comparing the performance of the two biocides, it appears that the paint which contains copper oxide and dichlofluanid is much more efficient compared to the one which contains dichlofluanid only. Copper is an effective antifouling ingredient and its toxicity is strengthened when it is combined with booster biocides (herbicides or fungicides) such as dichlofluanid.

Keywords: biofouling, biocide, antifouling, copper, dichlofluanid, booster biocide, sorting, colonization by organisms, static conditions, vessel hull.

1. Introduction

Generally any solid structure, regardless the manufacture material, either static or in motion, immersed into the sea, is subjected to the settlement of marine organisms, a phenomenon that is called biofouling (Fay et al., 2007). Biofouling has different levels (sequence) of organism attachment. Bacteria and microalgae (mainly diatoms) are the first colonizers (microfouling) followed by more complex organisms such as mollusks, macroalgae (multicellular plant organism) and annelids (macrofouling). Macroalgae biofouling organisms consist of various species of red, brown and green algae.

Biofouling causes serious problems on the ships' hull. It was found that a 1-mm thick slime layer that developed on a 23-m fleet tender caused an 80% increase in skin friction coefficient, together with a 15% loss in ship's speed, compared with values obtained for the clean hull

(Casse and Swain, 2006). One of the factors that affect the extent of biofouling is the movement of the ship. Static conditions favor the growth of biofouling (Casse and Swain, 2006), because strong water flow is a factor that inhibits the organism colonization of surfaces (Saloni and Crowe, 2015).

Antifouling paints are used in any surface in order to prevent the settlement of various organisms on it (Mellouki et al., 1989). Such products have been used from the ancient times: Natural products such as wax, tar and asphalt and also copper sheathing were applied to the ships of Phoenicians and Carthaginians and later on Greeks and Romans (Almeida et al., 2007). The most effective biocide used in antifouling paints in the last decades was TBT (tributyltin) (Almeida et al., 2007). However, it was found that it has high toxicity to non-target oysters, mollusks and crustaceans and has disastrous effects on the marine environment, especially in the vicinity of dry docks and busy ports (Kotrikla, 2009). This product and its derivatives are successively being banned for environmental and bioaccumulation reasons (Almeida et al, 2007). Alternatives to TBT are mainly copper based coatings containing organic booster biocides to improve the efficacy of the formulation (Voulvoulis et al, 2001). Important booster biocides include irgarol, diuron, sea nine and dichlofluanid (Omae, 2003).

In this study, the extent of biofouling onto a polyester surface, coated with 2 types of commercial antifouling paints, was studied. The experiment resembles a condition in which a vessel is anchored to a port (static conditions). The efficiency of two antifouling paints was examined: The first contained copper oxide and dichlofluanid and the second dichlofluanid only. Finally, the sequence of organism settlement onto the polyester surfaces and the dominant biofouling species were identified.

2. Materials and methods

Two different types of self polishing antifouling paints were used, manufactured by the same company. The first product contains copper oxide (Cu_2O) and a booster organic biocide (dichlofluanid), while the second product contains dichlofluanid.

The area of the study was Paleiopirgos at Kardamila Municipality. It is located at a gulf and there is interaction with open sea. In particular the installations of Nireus Aquaculture SA were used for the experiment. The sea depth at the region ranges from 30-50 m. Temperature; pH and salinity values are typical of coastal water bodies, which are influenced of the natural processes of rainfall, evaporation and terrestrial inputs. Temperature has a normal seasonal variation during the study (25 ^oC on August, 24 ^oC on September and 21 ^oC on October sampling). Salinity was 35.1 and pH 8.12.

The experiment lasted 67 days, from 29/7/2014 to 3/10/2014. Nine polyester panels were used with dimensions 200mm X 140mm. All were smoothed with hard abrasive paper. After that, six of them were coated with an epoxy product. Then, three of the surfaces were painted with antifouling paint containing copper oxide and dichlofluanid, three of them were painted with antifouling paint containing dichlofluanid while the rest three were not painted with antifouling paint. Finally, all the surfaces were immersed into the sea at a depth of three meters using a rope.

Three samplings were performed. After sampling, each panel was placed in a bag. Then, they were transferred to the laboratory and photographed.

The substrates were washed and separation of macrobenthic organisms performed. The macrobenthic organisms were preserved in ethyl alcohol 70% and were sorted later. The organisms from each sample were identified to the level of species. They were placed in eppendorfs with ethyl alcohol 70%. Counting of each species followed in order their abundance to be recorded.

The marine organisms attached on the surfaces were indentified and counted in the laboratory using an Olympus SZ 40 stereoscope.

3. Results

The total number of organisms found on the panels from all the samplings was 3148. Specifically 252 organisms were found during the first sampling, 1006 during the second one and 1880 during the third. The identified organisms were mainly macroalgae, arthropods, molluscs, polychaetes and branchiopoda.

As it was expected, the highest abundance was observed on the panels without antifouling in all samplings (figure 1). From the panels with antifouling, the higher abundance was observed on the panels coated with antifouling containing dichlofluanid than on the panels coated with antifouling with copper oxide and dichlofluanid. Regarding the coverage of the panels by macroalgae (figure 2) the same pattern is observed: The coverage with macroalgae of the panel with no antifouling treatment was 80%, the coverage of the panel with the antifouling containing dichlofluanid was 22% and for the panel with antifouling containing copper oxide and dichlofluanid, 4%. From these results it is clear that the combination of dichlofluanid and copper is much more effective on inhibiting marine settlement compared to dichlofluanid only.

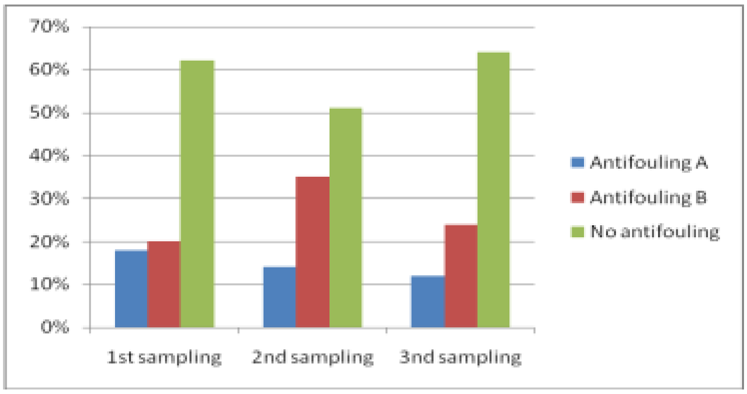


Figure 1: Distribution of species abundance (all organisms) at the three panels (treatments) in all samplings (Antifouling A: copper oxide and dichlofluanid, Antifouling B: dichlofluanid)

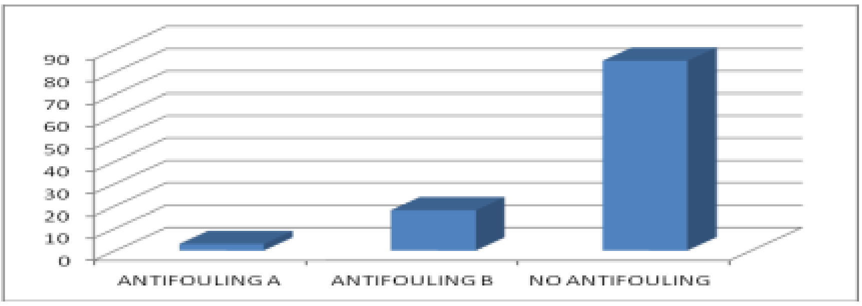
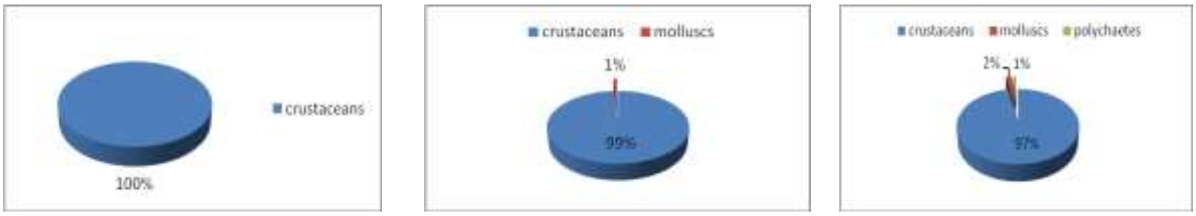


Figure 2: Coverage (%) of macroalgae on the three panels (2^{nd} sampling) (Antifouling A:copper oxide and dichlofluanid, Antifouling B: dichlofluanid)



Antifouling A Antifouling B No antifouling

Figure 3: The abundance (%) of different taxonomic groups on the three panels (3^{rd} sampling) (Antifouling A: copper oxide and dichlofluanid, Antifouling B: dichlofluanid).

Regarding the abundance of different groups of animal species on the panels, it was found (figure 3) that the paint containing dichlofluanid was effective on polychaetes while the one with copper oxide and dichlofluanid was effective on both polychaetes and mollusks. Crustaceans were abundant in all treatments and that can be explained either with the resistance of this group to the chemicals used and/or the fact that crustaceans are usually found on the macroalgae attached on the panel and not on the panel itself, therefore they are less exposed to the biocodes that leach to the water microlayer near the panel surface.
The colonization of the panels is illustrated on figure 4, where it is shown that even the most effective antifouling does not prevent the colonization of the surface to some extend under static conditions. Regarding the succession of the organisms, the first organisms that colonized the panels were macroalgae, followed by crustaceans and finally, mollusks and annelids.

Copper oxide and dichlofluanid | Dichlofluanid | No antifouling

Figure 4: Appearance of test panels after static immersion for 45 days (second sampling)

The results of this experiment are consistent with other studies that examine the succession of organisms onto various surfaces without antifouling coatings. For example, mussels and annelids were the dominant macrofouling organisms in a study that took place in a tropical coast (Satheesh and Wesley, 2011). Madin et al (2009) found mainly arthropods, molluscs and polychaetes. Crustaceans had the highest abundance while molluscs and polychaetes followed. In addition, amphipods have higher percentage of abundance compared with isopods.

4. Conclusions

In conclusion, the antifouling paint containing copper and dichlofluanid is more effective to prevent the colonization of static surfaces with marine organisms compared to antifouling paint containing dichlofluanid only. However, during the period of 67 days of the experiment, some organisms succeed to colonize the protected surfaces. This is probably due to the static conditions of the experiment that favor the settlement of the organisms. The identified organisms were mainly macroalgae (at first), followed by crustaceans and finally by mollusks and annelids. Dichlofluanid was effective on polychaetes while the combination of copper oxide and dichlofluanid was effective on both polychaetes and mollusks. Crustaceans were abundant in all treatments.

ACKNOWLEDGMENTS

The authors would like to acknowledge Nireus Aquaculture SA for helping deploying the panels in their facilities and for providing the abiotic parameter’s measurements.

REFERENCES

1. Almeida E., Diamantino C.T. and Sousa O. (2007), Marine paints: The particular case of antifouling paints. Progress in organic coatings 59, 2-20
2. Candries M. (2000), Paint systems for the marine industry, Notes to Complement the External Seminar on Antifoulings, Department of Marine Technology, University of Newcastle-upon-Tyne
3. Casse F. and Swain W.G. (2006), The development of microfouling on four commercial antifouling coatings under static and dynamic immersion. International Biodeterioration 57, 179-185
4. Fay F., Linossier I., Peron J., Langlois V. and Vall´ee-Rehel K, (2007), Antifouling activity of marine paints: Study of erosion. Progress in organic coatings 60, 194-206
5. Kotrikla, A. (2009), Environmental management aspects for TBT antifouling wastes from the shipyards. Journal of Environmental Management, 90, S77-S85.
6. Kotrikla A. (2014), Maritime Environmental Management, Lecture Notes, Department of Shipping, Transport and Trade, University of the Aegean
7. Madin J., Chong C.V and Basri B. (2009), Development and short-term dynamics of macrofouling assemblages on fish-cage nettings in a tropical estuary. Estuarine, coastal and shelf science 83, 19-29
8. Mellouki A., Bianchi A., Perichaud A. and Sauvet G. (1989), Evaluation of Antifouling Properties of Non-Toxic Marine Paints. Marine Pollution Buletin 20, 612-615
9. Saloni S. and Crowe P.T. (2015), Impacts of multiple stressors during the establishment of fouling assemblages. Marine Pollution Bulletin 91, 211-221
10. Satheesh S. and Wesley G.S., Influence of submersion season on the development of test panel biofouling communities in a tropical coast. Estuarine, Coastal and Shelf Science, 94, 155-163
11. Omae I. (2003), General Aspects of Tin-Free Antifouling Paints. Research Laboratories, 103, 3431-3448
12. Voulvoulis N., Scrimshaw D.M. and Lester N.J. (2001), Comparative environmental assessment of biocides used in antifouling paints. Chemosphere 47, 789–795