ABSTRACT

In the middle of the 19th century antifouling paints were developed to prevent marine growth on ship hulls. Due to fouling, there is an increase in fuel consumption, reduction in vessel speed, increase in greenhouse emissions, acceleration of corrosion and propagation of invasive species. Today, ships are required to be dry-docked every 5 years when the bottom hull is cleaned of fouling growth and painted with fresh coats of antifouling paint. Hull fouling takes place in marine environment in varying degrees. Density of marine organisms is higher in coastal water and since run-off from the land brings a wealth of food on which plankton exists, boats moored in harbours and estuaries are heavily fouled as paint depletion is low.

There is an ongoing effort to improve the antifouling paint quality which can reduce fouling growth on hull surface and increase the gap in dry-docking schedules. But with this effort towards improving paint quality, it has been observed that paint components can be toxic causing ecological harm to ocean environment. Hence extensive research is being done in Natural Product Antifoulants (NPA). Natural product derivatives such as marine organisms like corals, sponges and seaweeds protect their body surfaces with several biochemical substances. Similarly, a wide array of terrestrial plants possess several natural compounds such as terpenes, acetylenes, polycyclic compounds, steroids, phenols, isothiocyanates, nitrogen containing compounds, glycerol derivatives, higher fatty acids and enzymes that are perhaps suitable as antifouling agents.

Due to their availability and physio-chemical properties, Pongamia pinnata (Karanj) seed oil and Azadirachta indica (Neem) seed oil have been studied in the work for their potential use as antifouling agents. The bioassay studies against barnacle larvae reveal that Azadirachtin (Neem bioactive) has acute toxicity against barnacle
larvae, percent motility inhibition being 64.78±3.95 at 0.5 μg.ml⁻¹, 81.24±8.23 at 1.0 μg.ml⁻¹ and 100 at 5.0 μg.ml⁻¹ in 24 hrs. Karanjin (Karanj bioactive) which also showed positive results against barnacle larvae at higher concentration, percent motility inhibition being 29.2±5.4 at 20 μg.ml⁻¹, 57.3±23.9 at 50 μg.ml⁻¹ and 85±25.9 at 100 μg.ml⁻¹ in 4 hrs. The results of Neem toxicity also agrees with what was previously reported about Neem oil toxicity against *L. Fortunei* (Pereyra et.al., 2011) and Karanj oil has been used indigenously with Chandrus (a plant resin from members of the family Dipterocarpaceae) and lime in wooden boats to protect against termites (Santhakumaran et.al., 1982).

Marine exposure trials were conducted to find out the efficacy of Neem oil and Karanj oil in marine environment and these investigations on biocidal antifouling compositions were carried out at two sites at Visakhapatnam harbour. Environmental parameters such as temperature, salinity, pH and dissolved oxygen were monitored at the two stations. The seasonal pattern didn’t vary much during the field trials. The analyses of variances followed by post hoc tests of biofoulers recruitment both in terms of their numerical abundance and quantitative spread over the metal test plates from different points of view clearly demonstrated the usefulness of treatments in controlling biofouling formations at two sites at Visakhapatnam harbour despite spatial and temporal variations in the quality and quantity of biofouling on planted coupons. Analysis of variance conducted on the recruitment of *Amphibalanus amphitrite amphitrite* during various months as well as treatments at Visakhapatnam Fishing Harbour divulged no significant difference in the abundance of this fouling barnacle species among various months (*p*=0.06), but projected very highly significant difference among various treatments given to the test plates (*p = 4.78x10⁻⁸*) signifying the effect of treatments over controls in curtailing the balanid recruitment. Thus, the overall
assessment of performance of the bioactives of Karanj and Neem during the field exposure at the two sites in Visakhapatnam harbour in the backdrop of the performance of the Controls and Commercial antifoulant reveals that Neem bioactive is marginally better than Karanj bioactive and formulations incorporating still higher doses than the ones employed during the present investigation are required to achieve desired outcome of total prevention of biofouling on metal surfaces.

Also, in order to significantly minimize fouling, antifouling (AF) painting schemes must also take into account the uneven hydrodynamic forces at the water-hull interface. If a correlation between wall shear stress at all locations on the vessels hull with rate of antifouling paint depletion is known, then the appropriate AF scheme could be applied. To obtain such a correlation the “Drum-Test” apparatus was devised, designed, manufactured and utilized. The results of paint film depletion of three self-polishing copolymer (SPC) antifouling paints versus time for various speeds of the drum indicated that Paint 3 which was TBT free SPC antifouling paint with Cuprous oxide and organic biocides as active ingredients had maximum polishing rates while in Paint 1 which was TBT free SPC antifouling paint based on Copper acrylate, the polishing action was minimum. This implies that that Paint 1 could be coated for high speed high activity vessels such as ocean going vessels while Paint 3 would be an option for low speed low activity vessels such as harbour crafts, motor launch etc.

This is expected to help in reducing the proportion of antifoulant in the proposed formulations paving way both for the development of eco-benign and cost-effective antifouling formulations.

Key words: fouling, paint depletion, Natural product antifoulants, marine, terrestrial, bioactives, Commercial antifoulants, antifouling
(AF) painting schemes, wall shear stress, Drum test apparatus, Self-polishing Copolymer (SPC).