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# Nanotechnology: A Recent Approach to Combat Marine Biofouling

V. Naganandhini[1], S. Mariappan[2] and T. Ravikumar[2]
[1]PG Research Scholar, Dept. of Fishing Technology and Fisheries Engineering
[2]Assistant Professor, Dept. of Fishing Technology and Fisheries Engineering, Fisheries College & Research Institute, Dr. J. Jayalalithaa Fisheries University, Thoothukudi, Tamil Nadu

## SUMMARY

The formation of a symbiotic population of bacteria, plants, algae, or small animals on the surfaces of objects immersed or in contact with sea water is known as biofouling. Biofouling on the hulls of ships slows them down by increasing frictional drag. More fuel is burned when there is a lot of biofouling. CO2 emissions from the maritime industry are expected to have increased by 30% by 2020, according to the International Maritime Organization (IMO). Antifouling is the process of removing or preventing marine organisms from accumulating on the surface of a vessel using mechanical cleaning, biocides, and toxic coatings. A copper-based mixture works effectively and lasts at least three years as an outstanding antifouling agent. A nanocoating prevents scratches, improves hardness, and prevents abaration and fouling on the surface.

## INTRODUCTION

The majority of marine creatures live in two states: planktonic larval form and sessile/sedentary adult form. These sedentary forms have a tendency for colonising any hard surface. Biofouling is the term used to describe the colonisation of man-made structures such as offshore platforms, ship hulls, ship machinery, coastal power plants, desalination plants. Biofouling is a biological process that involves the growth of a symbiotic community of microbes, plants, algae, or small animals on the surfaces of objects immersed or in contact with sea water.They result in both functional and structural flaws. Barnacles, macroalgae, and microbial slimes all contribute to marine biofouling. They have an impact on surfaces such as pipes, desalination devices, sensors, hulls, building materials, and filters in the marine environment. It also harms mariculture infrastructure including as pipes, cages, and other structures. Biofouling organisms have been detected in over 4000 marine species, all of which are sessile forms. Biofouling is defined by two terms or types: Micro fouling is the production of a biofilm on a surface. Macro fouling is the adhesion of organisms such as barnacles, soft corals, and seaweed to the surface of the water. A macro fouling community made up of either "soft fouling" or "hard fouling" can form and outgrow the microfouling. There are three types of marine biofoulers: primary, secondary, and tertiary colonisers. Primary colonisers are microorganisms, bacteria and microalgae that settle initially on the surface. Secondary macrofoulers, which include protozoa and macroalgae spores, contribute for a 10% increase in ship frictional drag. Hard macrofoulers known as tertiary colonisers settle on unprotected man-made surfaces after 2-3 weeks of immersion.

**Table 1. Examples of micro- and macrofouling organisms**

| | | TYPES | EXAMPLES |
|---|---|---|---|
| **Microfouling Organism** | | Sessile bacteria | *Micrococcus,pseudomonas* |
| | | Diatoms | *Amphorasp.,naviculasp.,nitchiya spp.* |
| | | Micro-fungi | |
| | | Heterotrophic flagellates | *Monosiga,pteridomonas* |
| | | Sarcodines | |
| | | Sessile ciliates | |
| **Macrofouling Organisms** | **Hard fouling** | Barnacles | *Amphibalanusamphitrite, Amphibalanusreticulatus, Balanusamphitrite.* |
| | | Bivalves | *Crassostreagigas, mytilus spp., pernacanaliculas, pernaperna* |
| | | Calcareous | *Hydroidesalbiceps,* |

| | | | |
|---|---|---|---|
| | | tube worms | *Hydroideselegans* |
| | **Soft fouling** | Algae | *Laminaria spp., Enteromorpha spp., Ulva spp.* |
| | | Anemones | *Haliplanella spp.* |
| | | Asdicians | *Didemnumvexillum* |
| | | Bryozoans | *Bugulaneritina, cryptosulapalasiana, watersiphorasubtorquata, zoobotryonpellucidum* |
| | | Corals | |
| | | Hydroids | *Obeliasp* |
| | | Sea cucumber | |
| | | Sponges | *Acantheacavernosa* |

**Formation and development of Biofilm**

Biofilm includes groups of microorganisms composed of cells that attach to each other and also to a surface.Marine organisms congregate on surfaces by a five-stage process:

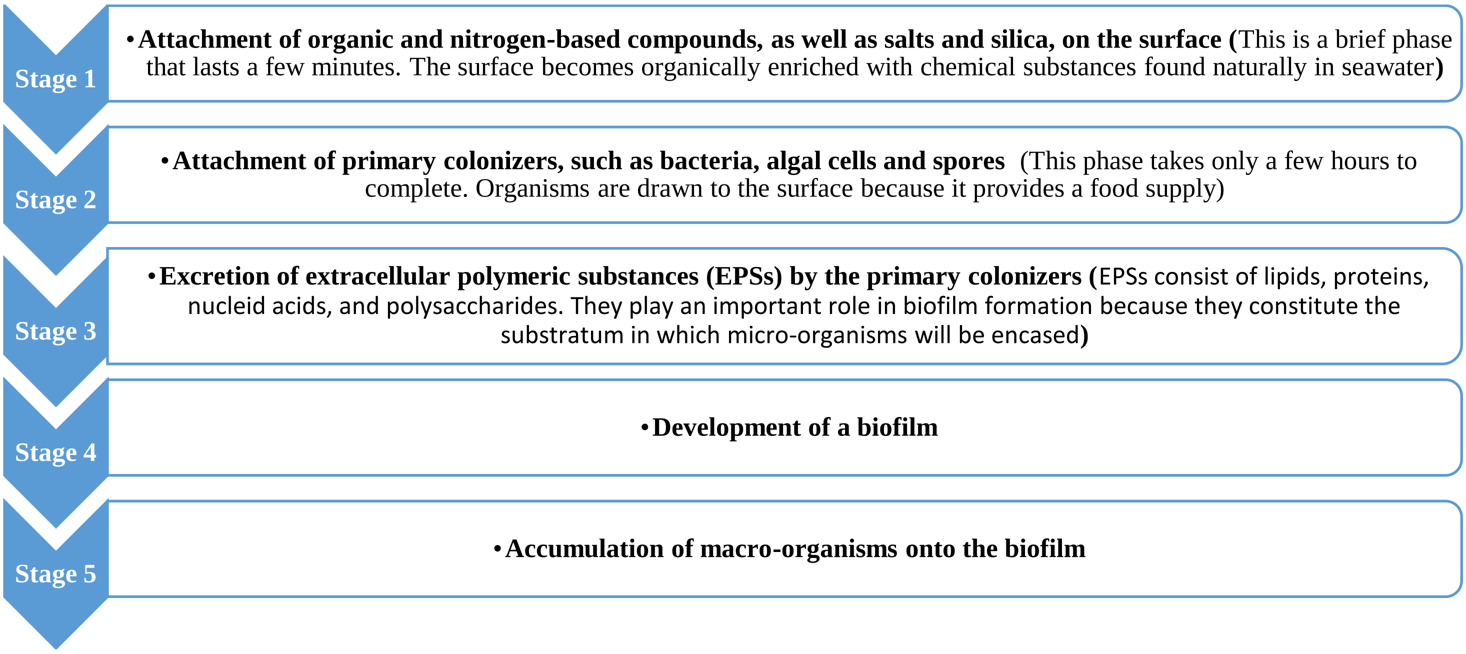


**Fig 1.Stages in the mechanism of biofilm formation**

Cell divisions produce the biofilm matrix, which takes a few days to a month to form. It is made up of a variety of bacteria, protozoa, larvae, algal cells like diatoms, and spores that are separated by water-filled interstitial gaps. This structure is also known as'microfouling' or'slime,' and it can be up to 500 metres thick. The nature and number of EPSs affect the biofilm's internal cohesiveness as well as its adherence to the colonised surface. It's worth noting that when cells are structured in a biofilm, they're less vulnerable to biocides than when they're planktonic. The reason for this is that the EPS matrix serves as a physical barrier that keeps biofouling communities at away. The biofilm also serves as a substrate for macroorganism adhesion.Barnacles, mussels, and tube worms are frequent fouling species found on the lower parts of the ship's submerged body, whereas algae is abundant on the upper parts. Algal growth is influenced by the amount of light available and the amount of space available.

**Biofouling of ships and potential impacts**

The entire economic balance of the Indian fishing sector is now affected by marine biodeterioration, which is dependent on the efficient functioning of its fishing fleet. A considerable money is spent annually on the maintenance of ships in the fleet, in addition to a large investment for industrial improvement.Biofouling creates a serious operating risk in a variety of marine systems around the world. The amount of money spent to combat biofouling is staggering. According to reports, the cost of shutting down a 235 MW (e) power plant due to fouling is 170 lakhs per day (at Rs. 3.00 per kw/h).The growth of biofouling on the ship's hulls reduces speed by increasing frictional drag. With significant biofouling, more fuel is burned. This can result in diminished manoeuvrability, increased weight, and slower speeds, all of which can lead to higher fuel consumption and costs. The increased fuel consumption caused by biofouling has been estimated to be as high as 40%. Currently, shipping emissions account for 2.5 percent of global CO2 emissions per year, and are expected to rise by 50 percent to 250 percent by 2050 (EU Commission, 2017). The International Maritime Organization (IMO) estimates that CO2 emissions from the maritime sector will have increased by 30% by 2020.Biofouling on the hull below the waterline can increase the boat's frictional resistance, resulting in higher fuel consumption and a slower speed.The growth of biofouling in probes, sensors, and oceanographic instruments has an impact on data quality and instrument performance. High levels of biofouling activity can result in more dry-docking operations and deterioration in the ship hull's overall integrity.Although biofouling may create an equal or even larger risk of species transmission than ballast water, other studies have revealed that ballast water is the most common vector. Organisms are still detected on ships despite the use of antifouling coatings. They accumulate in nooks and crannies, as well as on surfaces where the coating is damaged, degraded, or applied improperly.Biocorrosion is accelerated by marine biofouling because it maintains a continual metal/organism interaction, which can lead to the deterioration of particular ship structures.

**Biofouling control measures**

Antifouling is the process of eliminating or preventing the accumulation of marine organisms on the surface by mechanical cleaning, biocides, toxic coatings. Marine antifouling paints can be described as 'highly specialised coatings that protect ship hulls from biofouling by releasing active compounds in a controlled manner'.This coating is used to inhibit the growth of barnacles, slime, algae, and weed, among other marine creatures. Biocides including lead, arsenic mercury, and their chemical compounds were once used as antifoulants. However, these were outlawed due to risk they posed to the environment. The antifoulanttributyltin (TBT), a pioneering self-polishing copolymer technology that used a similar heavy metal toxic effect to discourage marine species, has also been prohibited.Indeed, the use of organotins in antifouling paints was prohibited in 2008.Since 2008, ships have been treated with two types of antifouling coatings: those that contain hazardous agents and those that do not.Non-toxic paints may have a shorter lifespan than organotin paints, requiring more frequent application.They might be less effective at preventing biofouling and also another disadvantage of biocide-free coatings is that they may not be durable enough for some deep-sea vessels.Researchers looking for innovative coating ideas are also inspired by natural antifouling surfaces.Sponge and corals are examples of marine invertebrates that are relatively free of fouling organisms. Anti-fouling compounds generated from sponges have been discovered to prevent barnacle larvae from settling.

**Nanotechnology as an Antifouling Method**

Short-term, a copper-based mixture works well and acts as an excellent antifouling agent for at least three years following application. Other organisms are affected by copper-based antifouling formulations in addition to fouling organisms. Organotins like tributyltin (TBT) are also prohibited due to their harmful impact on the environment.When copper is employed at a nanoscale, the environmental impact is significantly reduced. Scientific researchers have discovered that the nanocoating reduces biofilm formation, bacterial adhesion, and macro fouler attachment. Nanocoating is the process of applying a thin layer of nanoparticles (chemical structures) on an object at a nanoscale thickness. Paints using nanoparticles are commonly used to cover surfaces such as cu, $zno_2$, $sio_2$. A superhydrophobic coating is a water-repellent thin surface layer. It's made of materials that are superhydrophobic (ultrahydrophobicity). Droplets that come into contact with this type of coating can fully rebound. A nanocoating protects the surface from scratches, improves hardness, avoids abaration and fouling, and makes it bacterium resistant. Because of their unique morphological traits and size-dependent, self-cleaning qualities, metallic nanoparticles and their oxides have also been extensively studied.

Metal-based antifouling paints have recently been introduced, with heavy metals including copperoxide, titanium oxide, and zinc oxide being taken in nanosize and put into the paints. The fouling inhibition behaviour differed significantly. Anti-microbial and anti-fouling capabilities are found in nanoZnO. Nano ZnO rods were used to increase the shape, hydrophilicity, and biofouling resistance of the polyethersulfone membrane. Because of its low toxicity and environmental friendliness, nano SiO2 and ZnO are deemed safe. Microorganisms were repelled by Nano ZnO'sphotocatalytic activity, which resulted in the formation of an OH radical (OH) when it reacted with water. Many bulk parameters important to antifouling, "non-stick" surfaces, such as surface energy, charge, conductivity, porosity, roughness, permeability, friction, physical and chemical reactivity, are controlled by nano-structuring of a coating.

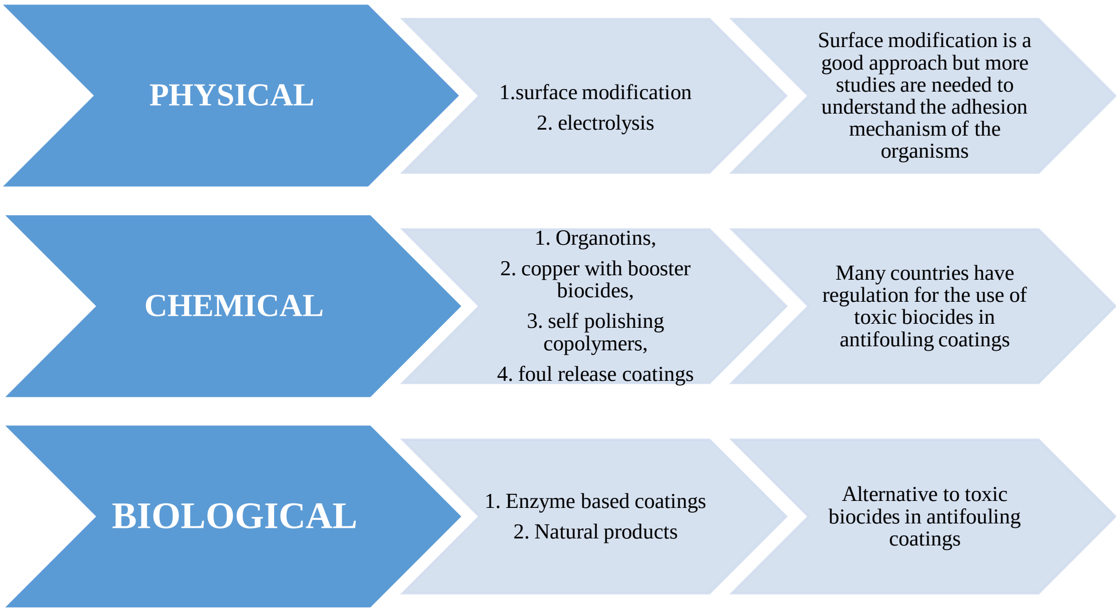


**Fig 2. Different types of anti-fouling methods**

## CONCLUSION

The antifouling coating industry could benefit from nanotechnology in biofouling. Nanoparticles improve corrosion resistance, chemical characteristics, and mechanical properties considerably. The nanocoatings performed well against *Pseudomonas fluorescens*, a freshwater bacterium, lowering initial attachment and biofilm formation, as well as the adhesion strength of attached bacterial cells.It has a great future in the maritime industry, particularly in terms of biofouling control. In the shipping sector in several regions of the world, nanocoating of metals with antifouling capabilities has demonstrated promising results for effective fouling control.

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