# The Impact of Implementing the International Convention on the Control of Harmful Anti-fouling Systems in Ships (AFS Convention) on the Marine Environment

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**<u>Abstract</u>**

Marine fouling is the settlement and growth of a variety of marine organisms, such as bacteria, diatoms, protozoa and algae spores on structures immersed in seawater, such as ship's hulls, navigation buoys, and sonar equipment. Anti-fouling refers to material or systems used to prevent the accumulation of biological material on submerged surfaces.

Bio-fouling results in higher fuel consumption and can also facilitate the transport of harmful Non-Indigenous Species (NIS). Antifouling technologies incorporating biocides (e.g., Tributyltin) have been developed to prevent fouling. Their widespread use, however, raised concerns about their toxic effects on marine communities.

The International Convention on the Control of Harmful Anti-fouling Systems in Ships (AFS Convention) is a 2001 International Maritime Organization (IMO) treaty, whereby states agree to ban the use of harmful anti-fouling paints and other anti-fouling systems that contain harmful substances. Particularly, the use of the organotin Tributyltin is prohibited, since leaching of that chemical from the hulls of ships has been shown to cause deleterious effects on some sea creatures.

Although the AFS Convention has entered into force, its full implementation has not yet been appropriately achieved. Most of the ratifying States have delegated the Classification Society to inspect their ships to ensure the implementation of the provisions of the Convention. Since painting ships takes place in dry docks, the full control falls in the hands of Classification Societies.

## 1. Introduction

Marine bio-fouling describes the community of organisms that settle and grow on the external surfaces of submerged or semi-submerged objects, both natural and artificial. Within hours of a structure's submergence, a slime layer develops, which is comprised of microscopic organisms (bacteria and algae). This layer facilitates the settlement and attachment of macro-organisms, including larvae of invertebrates such as ascidians, serpulids and barnacles, by providing biochemical cues for settlement and increasing their adherence to the lower layer. (Dafforn et al., 2011)

Bio-fouling is omnipresent in the marine environment and is a major problem for the shipping industry. Growth of organisms on a vessel hull increases frictional drag which reduces ship speed or requires increased power and fuel consumption to maintain speed. A totally fouled hull is an economic disaster because a vessel burns 40 % more fuel and fouling causes a serious risk of transport of invasive species into sensitive ecosystems. Species invasions have ecological, human health, and economic impacts. The ecological impacts include altering competition between species, predation and population dynamics in sensitive areas. Toxic species can be introduced (e.g., disease causing bacteria) adversely affect human health. Impacts on fisheries and aquaculture, infrastructure damage, impacts on tourism, and costs of management are all negative economic effects. The economic costs of hull fouling have been a driving force behind the development of Anti-Fouling (AF) technologies. (Yebra et al., 2003)

From the late 1960s effective anti-fouling started to rely widely on the use on hulls of anti-fouling paints containing organotins, such as Tributyltin (TBT), effective biocides but highly toxic chemicals. High concentrations of TBT were detected around ports and shipping routes and the use of TBT paints was found to be harmful to a range of aquatic organisms including molluscs, crustaceans and fish. Alternative methods started to be investigated, developed and implemented. (Comnap, 2006)

Researchers found, however, that TBT in the marine environment was not only killing hull-borne species, it was also killing sea life in the water. Studies revealed high concentrations of TBT in shellfish and accumulations in fish and sea mammals, causing shell deformations in oysters, sex changes and sterility in certain mollusks, and various alternative adverse effects on other marine life. There was further evidence that TBT was entering the food chain and might, therefore, adversely affect human health. (Dodd, 2008)

In November 1999, the International Maritime Organization (IMO) adopted an Assembly resolution that called for a legally-binding treaty that would address the harmful effects of anti-fouling systems used on ships. This resolution led to the Anti-Fouling Convention (AFS Convention), which was adopted by the IMO on October 5, 2001. The United States played a leading role in the negotiation of the Convention and signed it on December 12, 2002. (Dodd, 2008)

The AFS Convention was concluded in London on 5 October 2001 and entered into force on 17 September 2008. As of August 2015, it has been ratified by 71 states, which includes 69 United Nations member states plus the Cook Islands and Niue. A ratifying state agrees to enforce the prohibitions of the Convention on all ships flying its flag and on any ship that enters a port, shipyard, or offshore terminal of the state. The 71 ratifying states represent approximately 85 % of the gross tonnage of the world's merchant fleets.

The purpose of the Convention is to control the adverse effects of anti-fouling systems that have an impact on the marine environment and human health, and to encourage the continued development of anti-fouling systems that are effective and environmentally safe. It would prohibit the use of harmful organotins in anti-fouling paints and establish a mechanism to prevent the potential future use of other harmful substances in anti-fouling systems. An anti-fouling system is any surface treatment, paint, surface, or device that is used to prevent the growth of marine organisms, such as algae and barnacles, on the hull of a ship. The global ban on Tributyltin and increasing regulation of copper has prompted research and development of non-toxic paints. (Comnap, 2006)

## 2. <u>Main Provisions of the AFS Convention</u>

To mitigate the damaging impact of these anti-fouling systems, the Convention:

- Requires Parties to ban the use of anti-fouling systems containing organotin compounds acting as biocides on ships that fly their flag or operate under their authority and provides for prohibiting ships that use such systems from entering Parties' ports, shipyards, or offshore terminals;
- Requires Parties to take appropriate measures to safely collect, handle, treat, and dispose of wastes resulting from the application or removal of controlled anti-fouling system in an environmentally sound manner;
- Provides a procedure through which new, harmful anti-fouling systems can be added to the prohibited list in Annex 1 in the future, after a comprehensive and technical review process;
- Obligates Parties to take appropriate measures to promote and facilitate scientific and technical research, as well as share information, regarding anti-fouling systems; and
- Addresses the inspection of ships to determine compliance with the Convention and requires Parties to establish sanctions for violations that are adequate in severity to discourage violations of the Convention. (Dodd, 2008)

## 3. Anti-Fouling Coatings

Anti-fouling paints are applied to ships' hulls and immersed surfaces to prevent fouling. There are two main types of coatings: biocidal and non-biocidal. Biocide is released from paint film on the ship's hull creating a micro-layer of toxicity on the paint surface, preventing settling of organisms. Non-biocidal foul release coatings provide a low energy non-stick surface to which organisms can only weakly adhere. Organisms that do adhere are removed during vessel operation or mild cleaning.

In the early days of sailing ships, lime and later arsenic were used to coat ships' hulls, until the modern chemicals industry developed effective anti-fouling paints using metallic compounds. These compounds slowly leach into the sea water, killing barnacles and other marine life that have attached to the ship. Studies, however, have shown that these compounds persist in the water, killing sea-life, harming the environment and possibly entering the food chain. One of the most effective anti-fouling paints, developed in the 1960s, contains the organotin Tributyltin (TBT). (IMO, 2008)

## 4. Environmental Impacts of Anti-Fouling (AF) Paints

The widespread use of toxic biocides in Anti-Fouling (AF) paints has introduced high levels of contamination into the environment and raised concerns about their toxic effects on marine communities. Toxicity is related to the properties of the contaminant as well as its bioavailability in the marine environment. For example, organotins such as TBT are highly toxic because of their increased fat solubility compared to inorganic tin. Toxicity will increase if a contaminant is more bioavailable and this is related to local environmental conditions (e.g., temperature). (Dafforn et al., 2011)

## 5. Effects of TBT Antifouling Paint

TBT is highly toxic to various aquatic organisms. It is released into the marine environment through TBT-based antifouling paints used on ships' hulls. The use of TBT in antifouling paint in 1970 was a revolution in the approach to antifouling. Tin, the basic substance used in TBT, is effective for longer periods of time than copper, which was the normal additive in paints at that time, but is more poisonous and therefore made it possible to postpone the need to repaint. Although TBT antifouling paint was more expensive than the traditional copper paints, the economic arguments did not stop the change to occur quickly. The problem of fouling, however, was not solved, as it first seemed. In the mid-1980s, researchers from France and UK reported the alarming effects of TBT on marine organisms. Many studies from different parts of the world have also highlighted the adverse impacts of antifouling paints.

Apart from affecting marine organisms like barnacles, bacteria, tubeworms, shellfish, and algae, which cling to the hull of a ship, TBT also affects non-target marine organisms such as oysters and mussels, causing them an abnormal shell development, brittle shells, leading to poor weight gain. TBT is further found to bio-accumulate in fish, dolphins, seals, whales, and other sea mammals, and it negatively affects a range of invertebrates, causing sterility in them and sometimes, even death. Consequently, this ecological harm also indirectly affects commercial fisheries and tourism. At shipyards and harbors, where vessels are dry-docked for repairing and repainting, the risk of polluting water bodies is particularly high and demands high-quality waste management. Washing, scraping, and repainting of boat hulls may also cause harmful health effects on shipyard workers. (Gipperth, 2008)

Ecological effects of TBT on growth, development, reproduction and survival have been reported in organisms ranging from bacteria to fish and mammals. Laboratory studies indicate TBT exposure causes shell abnormalities in oysters by inhibiting calcification, and results in reduced oyster growth. Some developing countries where TBT remains unregulated have also experienced high levels of contamination.

Long range passive transport has exposed organisms not inhabiting point source areas to TBT. The effects of TBT contamination also have the potential to extend to higher organisms through consumption. Both mammals and seabirds have been found to harbor high TBT concentrations. Tributyltin in human blood and liver has raised concerns about the transfer of TBT via human consumption of seafood.

Since the introduction of TBT restrictions, there is some evidence of recovery in marine ecosystems. For example, oyster populations have recovered from TBT contamination in Australia and in France. However, despite restrictions, TBT contamination in the water column remains high. Even a brief exposure to TBT can result in shell deformities and significant bioaccumulation in oysters. (Dafforn et al., 2011)

As TBT began to be widely used in anti-fouling paints increasingly high concentrations of TBT were detected in areas with high concentrations of boats and ships, such as marinas, ports and harbours. In the open seas and oceanic waters, TBT contamination was seen as less of a problem, although later studies showed evidence of TBT accumulation in fish and mammals.

While TBT is only moderately to slightly toxic to mammals, it is extremely toxic to a number of marine species, including crustaceans. In the 1970s-1980s, high concentrations of TBT were detected in shellfish on the coast of France causing the collapse of commercial shellfisheries in at least one area. In south-west England, TBT poisoning was linked to the decline of the population of the dog-whelk in the 1980s. Studies showed that female dog-whelks develop the condition known as "imposex" in response to TBT poisoning, where females develop male sexual organs and can become sterile.

TBT has been described as the most toxic substance ever deliberately introduced into the marine environment and has been confirmed to be harmful to a range of aquatic organisms, including microalgae, molluscs and crustaceans, fish and some invertebrates. (Comnap, 2006)

## 6. Alternative Anti-Fouling Systems

Many traditional antifouling systems are paints. Paint is a comprehensive term covering a variety of materials: enamels, lacquers, varnishes, undercoats, primers, sealers, fillers, stoppers and many others. Anti-foulants are one of many additives usually incorporated within the topcoat paint of a marine protective coating system. Most antifouling coatings are organic and consist of a primer and a topcoat both of which can include anticorrosive functions, however, the top-coat is often porous. Since the initial phasing out of TBT from the antifouling industry in 2001, alternatives have been available including biocide-free antifouling coatings. (Chambers et al., 2006)

The coatings industry has developed alternatives that do not contain TBT. Some of these coatings are silicone-based. They are super slick coatings that prevent any organisms from attaching to the hull when the ship is moving. Because they have a lower tension surface, a side benefit is that the silicone-based coatings make the ship more fuel efficient. Some ships may choose to first remove the existing coating that contains TBT before applying a coating that is TBT-free, but it is more likely that ships will first apply a sealant to the existing coating to prevent leaching of the harmful compounds into the water and then apply a TBT-free coating, which is an alternative provided for in the Anti-Fouling Convention. (Dodd, 2008)

The development of alternative, less harmful anti-fouling systems has been encouraged with a number of different directions followed. A number of alternative active biocide substances have been identified and their use in anti-fouling paints explored. Approximately 30 different active biocide substances are used in a variety of anti-fouling products. TBT-free self-polishing free-association coatings can achieve a 60 month performance whereas conventional paints reach a maximum of 36 months.

Some non-stick coatings do not contain any biocide and rely on an extremely slippery surface to minimise the chance of fouling occurring and facilitate cleaning when it does occur. Periodic cleaning of hull is most appropriate for ships operating in both sea and fresh water and in areas where few organisms attach to the hull. In-water cleaning of merchant ships typically involves divers using rotating brushes or high-pressure hoses. Creating a difference in electrical charge between the hull and sea water can unleash a chemical process which prevents fouling. This technology has been shown to be more effective than tin-free paint in preventing fouling, but systems can be easily damaged and expensive. It also creates increased corrosion risk and higher energy consumption. (Comnap, 2006)

## 7. Best Management Practices for the Prevention of Pollutionby TBT Wastes

The first step for an integrated management scheme is to identify processes that have the potential to generate wastes containing TBT. Knowing the processes helps to characterize the content of the wastes in order to employ pollution prevention options such as source reduction and treatment. Source reduction is the best alternative for pollution prevention and it benefits the marine yards by reducing raw material demands and disposal costs, and lowering the liabilities associated with hazardous waste disposal.

Various methods like process changes, efficient rinse systems, substitution of toxic chemicals, and reduction of material inputs are viable processes. In the waste management hierarchy of the Pollution Prevention Act of 1990, if source reduction is not feasible, the next alternative is recycling of the wastes, followed by energy recovery and waste treatment. The application of protective coatings on the ship's hull requires a substrate that is free of rust, paint, salt and bio-fouling. Various methods are available to prepare metal surfaces for painting.

The dry abrasive blasting is a widely used method since the 1950s and produces solid wastes contaminated with TBT-paint chips. The most common abrasive material is silica sand, which is naturally occurring, readily available, economical to use and effective. However, silica sand has inherent limitations and disadvantages. It is an expendable abrasive, as the breakdown rate after one use is considerable. Moreover, the quantity of airborne dust generated is high. It contains free crystalline silica, which has long been associated with silicosis. Silicosis is an incurable and irreversible lung disease that progresses even when exposure to the sand stops. Alternatives to sand, like metal slag, steel shot or grit, and ground glass and plastic media, are being evaluated and used increasingly. Whereas steel shot and grit require a high initial capital, they could be used 50 times or more compared to slags and sands that can only be used a couple of times. Metal slags, however, may contain heavy metals that would affect the health of the workers and the environment. (Kotrikla, 2008)

## 8. Preventive Measures Used on Ships

There are 4 main types of combating bio-fouling on ships.

### 8.1. Electrolytic system

The electrolytic system is the most commonly used system to fight bio-fouling on ships. Through the use of copper and aluminium, an electric current is passed throughout the whole piping network. These copper ions in the seawater prevent marine organisms from settling down and multiplying on the surface of the pipes.

### 8.2. Chemical dosing

Chemical dosing is also a common method which is used to prevent marine growth in piping network. Anti-fouling chemical such as ferrous chloride is used to dose sea water boxes. The chemical coats the pipework with a protective ferrous layer to prevent corrosion.

### 8.3. Ultrasonic system

High frequency waves are also used as a method to prevent marine growth in piping systems. A reduction in bio-fouling of as much as 80% is claimed by this method. In the ultrasonic method, a wave generator produces and sends electrical impulses at high frequency. The main advantage of this system is that it is non-invasive and no parts are in contact with sea water. Moreover, no toxic substances are produced.


### 8.4. Electro-chlorination

Electro-chlorination is a method in which chlorine is generated to produce sodium hypochlorite, which is used to prevent fouling.10pp chlorine in sea-water would kill all marine life quickly, whereas 1 PPM (Parts per Million) will prevent fouling. This can be tested on board. It is to note that this system is designed to be used only in sea water and not in fresh water.

## 9. Conclusion

Decisions regarding the use and regulation of AF paints in the marine environment are complex and require the integration of information regarding the economic and ecological costs and benefits of different strategies. Bans on TBT were primarily based on the economic costs to the oyster industry, but also because of ecological impacts on non-commercial species, bioaccumulation by a range of organisms, and potential human health risks. Still, the subsequent shift to copper paints containing booster biocides may result in environmental impacts, toxicity to non-target marine organisms and the spread of NIS.

An ideal situation would allow the complete elimination of toxic biocides from AF paints; however, in reality this poses the question of what could replace them. Currently, there is not a viable option for widespread replacement of copper in AF paints although foul-release and natural compounds show some potential. Without an effective replacement, the ecological costs of increased bio-invasions and the economic costs of increased drag may outweigh the impacts of current AF strategies. It is advisable, therefore, to allow time for the development and implementation of more environmentally-friendly alternatives. (Dafforn et al., 2011)

After the prohibition of the use of TBT in small boats, the major pollution burden in coastal marine areas is located near ports and shipyards. The forthcoming phasing out of TBT will result in huge amount of wastes near ports and shipyards. However, there is a possibility that TBT will continue to be used in antifouling paints at some parts of the world and its regular use in agriculture and other industries will continue to produce wastes.

In the shipyards, a careful design and management of all processes and operations would result in the reduction of pollution. Available options include the recycling of the abrasive materials (sand and metal slag), use of cleaner abrasive materials, re-use of spent abrasive materials in public works, substitution of hydro-blasting by vacuum blasting or containment or ultra-high-pressure water blasting and confinement of pollution by enclosure and containment systems. All the above methods are applicable after the prohibition of TBT, irrespective of the biocide used in antifouling paints.
The adoption of wastewater treatment techniques would further reduce pollution. The conventional wastewater treatment plants are probably not suitable due to the toxicity of TBT in the micro-organisms of the activated sludge. (Kotrikla, 2008)

## 10. Recommendations

- Ratifying States should consider using the above-mentioned modern preventive measures to avoid the harmful impacts of anti-fouling paints.
- States should ensure the implementation of the Convention on ships flying their flag.
- The delegation allotted to the Classification Society is a work delegation; not one of responsibility. Thus, States must fulfill their duties and responsibilities.
- States are to undertake periodic inspections of ships in their ports and take samples of ship paints to make sure that they are in line with the provisions of the Convention.

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