The Importance of Antifouling Application Monitoring on Leisure Boats

Renato Ivče, Đani Šabalja, Srđan Žuškin
University of Rijeka, Faculty of Maritime Studies, Studentska ulica 2, Rijeka, Croatia
rivce@pfri.hr

***Abstract* - Underwater part of ship's and boat's hull is affected by marine biofouling which are adhering on it. Fouling of underwater part of hull is huge problem in shipping causing speed reduction and higher maintenance cost. Adhering of marine biofouling organisms can be reduced or eliminated applying antifouling coatings, but the release of hazardous substances also causes serious problems to the environment. This paper gives a brief overview of the international law and conventions relating application of anti-fouling paints. One of the most effective anti-fouling paints, developed in the 1960s, contains the organotin tributyltin (TBT) was banned 2001. by IMO International Convention on the Control of Harmful Anti-fouling Systems on Ships. Alternative antifouling coatings also may contain toxic elements causing problems to the environment. The paper indicates on possible environmental effects of using biocide antifouling at leisure boats on Croatian coast. Also authors suggest that anti-fouling paints application at marinas and also other small local ports should be adequately supervised and also boaters should be provided by anti-fouling educational materials.**

Keywords *– Marine biofouling, antifouling paints, leisure boats, aquatic environment.*

I. INTRODUCTION

All kinds of ships and boats sail faster through water and consume less fuel when their hulls are clean and smooth - free from fouling organisms. Marine animals, plants and microorganisms generally adhere to surface of underwater part of ship's hull which is common called biofouling. It is huge problem in shipping causing economic loss due to speed reduction and higher costs for both fuel and for hull maintenance. Roughly it can be estimated that 5% surface area of marine biofouling costs 10% increase of the fuel consumption.

The most efficient protection system of ship's hulls against marine biofouling is still studying. Antifouling coatings are generally some kind of biocides which prevent marine fouling organisms from attaching to the boat. Marine biofouling can be reduced or eliminated applying antifouling paints, but on the opposite release of hazardous substances also causes serious problems to the environment. High concentrations of these toxic elements will be measured in areas with intense boat traffic.

Over the long history of fouling prevention a variety of methods have been used, e.g. pitch, tar, and copper. In the early days of sailing ships, lime and later arsenical and mercurial compounds and pesticides were used to coat ship's hulls to act as anti-fouling systems. The first antifouling paints emerged in the mid 19th century and were based on the idea of dispersing a powerful toxicant in a polymeric binder. These were followed by other paints with binders based on different bituminous products and natural resins, whose dilution was achieved with turpentine spirit, benzene or naphtha.[1] During the 1960s the chemicals industry developed efficacious and cost-effective anti-fouling paints using metallic compounds, in particular the organotin compound tributyltin (TBT). By the 1970s, most seagoing vessels had TBT painted on their hulls.

The toxicity of anti-fouling paints has been debated for decades and attention has generally focused on the active substances. Focused studies in this area aimed to determine and compare the potential toxic effects of common anti-fouling paints used on ships and leisure boats. Environmental studies provided evidence that organotin compounds persist in the water and in sediments. Specifically, TBT was shown to cause genetic affects in marine species.[1]

In 1988, the problem with TBT was brought to the attention of the Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO), the United Nations Agency concerned with the safety of shipping and the prevention of marine pollution.

In October 2001, IMO adopted a new International Convention on the Control of Harmful Anti-fouling Systems on Ships, which will prohibit the use of harmful organotins in antifouling paints used on ships.

Copper-based antifouling paint is currently dominated on the market and its ions at low concentration may have influence on the health of animals and plants through the enrichment effect of food chain, causing damage to the ecological balance.[2]

Croatia has been attracting a larger number of leisure boats which sail mainly in a summer season. The aquatic environment may be threatened by high concentrations of toxic elements from antifouling paints. This paper aims is to point out this problem.

II. LEGISLATION

Conducted researches have shown that toxic elements from anti-fouling paints persist in the water and bottom sediment, killing sea-life, harming the environment and entering the food chain. This huge problem has requested to carry out measures under relevant legal instruments to prevent further damages to aquatic environment. One of the most effective anti-fouling paints, developed in the 1960s, contains the organotin tributyltin (TBT), which has been proven to cause deformations in oysters and sex changes in whelks. The pollution problems caused by TBT in anti-fouling paints were

first raised at IMO's Marine Environment Protection Committee (MEPC) in 1988. MEPC requested to carry out measures under relevant legal instruments to restrict the use of TBT compounds on seagoing vessels.

In 1990, on 30th session, the MEPC adopted Resolution MEPC 46(30) Measures to Control Potential Adverse Impacts Associated with Use of Tributyltin Compounds in Antifouling paints. This resolution recommends that Governments adopt measures to eliminate the use of antifouling paint containing TBT on non-aluminium hulled vessels of less than 25 meters in length and eliminate the use of anti-fouling paints with an average leaching rate of more than 4 micrograms of TBT per cm^2 per day.

In October 2001, IMO adopted a new International Convention on the Control of Harmful Antifouling Systems on Ships, which will prohibit the use of harmful organotin in antifouling coatings used on ships and will establish a mechanism to prevent the potential future use of other harmful substances in antifouling system. The Convention are required to prohibit and/or restrict the use of harmful antifouling systems on ships flying their flag, as well as ships not entitled to fly their flag but which operate under their authority and all ships that enter a port, shipyard or offshore terminal of a Party.[3]

Ships of above 400 gross tonnage engaged in international voyages (excluding fixed or floating platforms and its supported ships) will be required to undergo an initial survey before the ship is put into service or before the International Anti-fouling System Certificate is issued for the first time; and a survey when the anti-fouling systems are changed or replaced. Ships of 24 metres or more in length but less than 400 gross tonnage engaged in international voyages (excluding fixed or floating platforms and its supported ships) will have to carry a Declaration on Anti-fouling Systems.

Tributylin (TBT) has been banned to use in anti-fouling coatings on ships length of less than 25 m in EU, and Directive 2002/62/ European Commission (prohibits their sale and use in all ships, boats, vessels and floating structures, underwater facilities.

Permissible concentrations of TBT and other harmful components in anti-fouling coatings have not been specifically regulated in laws and regulations of the Republic of Croatia. Only Circular letter marks QC-T-177 (Anti-fouling Systems - AFS) was sent to Croatian shipowners and shipyard regarding new International Convention on the Control of Harmful Anti-fouling Systems on Ships application. Mentioned Circular letter also states Directive 2002/62 of European Commission which TBT and other harmful components in anti-fouling coatings have been banned to use in anti-fouling paints on ships length of less than 25 m in EU. [4]

On Croatia's Adriatic coastal water there have not been carried systematical monitoring of state of the environment (biological indicators) and concentrations of TBT and other harmful components. Some researches carried on positions near by Rovinj and Kaštelanski zaljev showned devastating results.

III. THE IMPORTANCE OF UNDERWATER HULL PROTECTING

In the beginning of sea trade, lime and later arsenic were used as coat of ships' hulls to provide anti-fouling protection. Today the modern chemicals industry developed effective biocide anti-fouling paints often using metallic compounds. These compounds slowly "leach" into the sea water, killing marine fouling organisms that have attached to the underwater part of ship's hull. Vessels and boats in the water required maintenance due to corrosion protection and removing marine fouling. Unprotected surfaces of underwater part of ship's hull immersed in sea water, after a relatively short immersion time ship hulls become fouled with numerous marine organisms.[5] The intensively and degree of fouling generally depends:

- how long the ship remains in port or its cruising speed at sea,
- on the nature of the water (salinity, temperature, pH, dissolved salts and oxygen concentration).

Attached organisms on underwater part of ship's hull can significantly reduce the vessel's speed. Just a small amount of fouling can lead to an increase of fuel consumption of up to 40%, and possibly as much as 50%, since the resistance to movement will be increased. A clean ship can sail faster and with less energy. The need to protect ship hulls from marine fouling is as old as man’s use of ships for sailing. It is mandatory that protective painting systems for underwater ship parts include an anticorrosive primer and an antifouling topcoat. Sometimes a suitable tie coat is applied between the primer and the antifouling paint, especially when the anticorrosive primer contains components that may negatively affect the adhesion of the antifouling coat. [6] Besides assuring the necessary protection and mechanical strength, antifouling coat must prevent or strongly reduce the fouling of the hull, which occurs above all in port or when sailing at low speed.

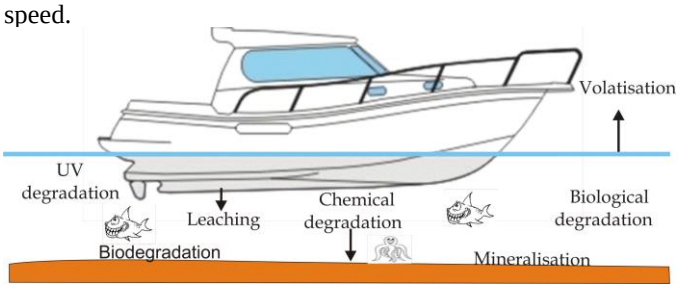

FIG 1. EFFECT OF ANTI-FOULING LEACHING

Uncontrollable hull fouling will lead to potential corrosion and safety hazard. Some of the new alternative antifouling systems claim to be equally effective as organotin-based systems allowing dry docking intervals of up to five years. Other systems will require increased frequency of dry-docking, perhaps every 2.5 or three years. But for many ships this could fit in with routine surveys or general maintenance. Paint manufacturers are likely to increase research efforts to produce efficient organotin-free systems with the prospect of a ban antifouling paints contain toxic elements. Yacht and other pleasure boats, including other kinds of small boats are usually dry docked every year.

Cooper and other metals have been used in underwater part of ship's hull for many decades. Antifouling coatings work by slow release of toxic elements (biocides) from the paint applied on the underwater hull. The fouling organisms have been all time exposed to biocides. Such toxic element discourages fouling organisms and also slowly leaches in the surrounding water and after that fall to the sediment. New alternatives to copper based antifouling coatings have been developed to increase water quality. Alternative antifouling coatings generally can be classified in two main categories:

- biocide antifouling coatings,
- non biocide antifouling coatings.

Biocide antifouling coatings contain slowly release toxic substances such as zinc, fluorine, chlorine and various organic biocides. Non biocide coatings can be further classified as soft or hard. Soft antifouling biocides usually contain silicon which may produce slick surface making it difficult for organisms to attach. Hard non-biocide coatings have ceramic or epoxy base which have same behaviour on ship's underwater hull as soft non biocide antifouling coatings. Non biocide products generally last longer than copper based or zinc oxide paints. [7]

Monthly average flux rates of dissolved copper for the hard vinyl and modified epoxy coatings were 3.7 and 4.3 $\mu g/cm^2/day$, respectively; while flux rates for the biocide free coating was 0.2$\mu g/cm^2/day$. Biocide free coatings are still more expensive than biocide. International community must take all necessary measure on developing non biocide antifouling coatings. Gradually this kind of antifouling coatings should complete replace biocide antifouling. Research and development of low toxicity and effective marine antifouling paints based on nano-materials whose are usually designed to substitute for hazardous substances in antifouling paints must be imperative.[8]

IV. Possible Antifouling Pollution in Croatian Waters by Lesiure Boats

Croatia with its indented coast and of the numerous islands has been attracting a larger number of leisure boats. These types of crafts sail mainly in a summer season. In mentioned period of year besides boats permanently berthed in Croatian marinas, many boats, flying flags of different nations and having a permanent berth in other Mediterranean countries, are brought on a trailer to the marinas from where they set to sea, while a number of others are sailing in transit. The total number of the leisure boats (at permanent berth and transit) covering period from the 2010. to 2014. are shown on graph Fig 2.

Data were taken out of the database of the Bureau of statistics and included leisure boat ports in all Croatian counties With the years, the number of the leisure craft ports has increased and on 2014. were available total 112 leisure boat ports.

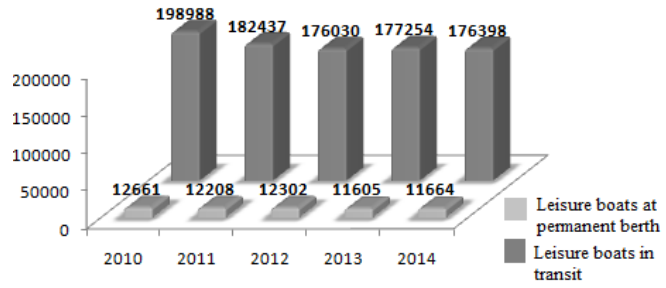

Fig 2. Leisure boats on permanent berth and in transit

The number of leisure crafts in transit includes boats which are registered in every port of arrival. Permanently berthed boats are boats which are berthed in one the same leisure craft port during a year. The percentage of leisure crafts at a permanent berth varies up to 7 percent out of the total number of leisure boats. Both categories of boats pollute aquatic environment with the antifouling toxic elements which slowly leach in the surrounding water and after that fall to the sediment.

The table I shows the number of leisure boats at a permanent berth on 2014. at Croatian leisure boat ports, their approximately underwater hull surface, and comparison of release toxic elements for coper basis and biocide free paints. Toxic elements leaching were calculated on average flux rates of dissolved copper for the hard vinyl and modified epoxy paints (approximately 4 $\mu g/cm^2/day$) and flux rates for the biocide free paints (0.2 $\mu g/cm^2/day$).[9]

The comparison of potential toxic effects of coper anti-fouling and biocide free paints used on leisure boats on daily basis is enabled by data in table. Regulations regarding biocide antifouling paints to be strengthened for boats under 24 m because these paints may pose a risk to the aquatic environment in consider of mentioned boats number. Antifouling paints which are leaching excessive Cu or other toxic elements must be gradually prohibited for use on leisure boats and replaced by non-biocide paints as acceptable in the Adriatic sea as sensible aquatic environment.

Table I Approximately leaching toxic elements from biocide and non- biocide antifouling paints

Number of boats at permanent berth (m)	Approximately underwater area (cm2)	Average flux rates of dissolved copper Kg/day	Average flux rates of biocide free coatingKg/day
206	80000	0,07	0,003
862	150000	0,52	0,03
2 108	230000	1,94	0,10
3 392	450000	6,11	0,31
3 449	750000	10,35	0,52
1 292	1250000	6,46	0,32
11309	2910000	131,64	6,58

Anti-fouling paints application at marinas and also other small ports shall be supervised by Harbor Master Office along Croatian coast. The rationale for the restriction of biocide paints is protecting coastal areas. These are the most important recruiting areas for a number of organisms and may be harmed by the spread of anti-fouling agents from the leisure boats that mainly traffic these areas.

Mentioned boats besides sailing in Croatian coastal waters, some of them are maintained underwater hull at marinas or small local ports. Boats are dry docked or hauled out of the water to be maintained on regular basis. Usually maintenance includes removing any marine growth that has attached to the boat and reapplying the antifouling paint. Most leisure boats are dry docked or hauled out in the autumn. Some of them launched after maintenance was carried out with a fresh coat of antifouling paint and berthed in marina. Other leisure boats were cleaned and marine growth removed. After that were brought on a trailer by owner or left on land at marina. Most of them set again to the sea in the spring with a fresh coat of antifouling paint.

Because of our short boating season, boats that are hauled out for annual servicing often have significant amounts of antifouling paint still on them. Typically, boatyards and marinas will use high pressure water sprayers rinse the salt water off and quickly remove dirt and any marine growth on the boat. Along with the dirt and marine growth, antifouling paint can also be washed off, resulting in wash water containing not only dirt, marine organisms but pesticides as well. When antifouling paint is washed off, antifouling paint compounds are concentrated in the wash water resulting in levels of toxic pollutants in the wash water that is much higher than the levels approved. The polluted wash water is often directly run back into the water or soaks into the ground at the location where the boat is hauled. Surrounding aquatic and ground has been contaminated by significant levels of biocides potentially harming the marine environment.

Gradually the discharge of boat bottom wash water (antifouling paint contaminated wash water) has been regulated at marinas. Boatyards and marinas are required to collect and treat all antifouling paint contaminated wash water before it can be discharged to the surface water. Treatment of the boat bottom wash water will reduce the amount of pollutants going into the surface water by significant percent. Also we as authors recommended that anti-fouling educational materials to commercial and recreational boaters to be provided by Government.

V. CONCLUSION

Underwater part of ship's hull is affected by marine animals, plants and microorganisms which are adhere to surface of underwater part of ship's hull. Fouling on underwater part of ship's hull produce additional resistance and has great impact to speed reduction and hull maintenance. The intensively and degree of fouling generally depends how long is ship's stay period, its cruising speed at sea and nature of the water. Underwater part of ship's hull has been protected by anti-fouling paints which generally can be classified as biocide antifouling coatings and non-biocide antifouling coatings. Biocides are slowly release from the paint applied on the underwater hull and the fouling organisms have been all time exposed to biocides. Such biocides prevent fouling organisms to adhere on hull and they are also slowly leaching in the surrounding water and after that fall to the sediment.

One of the most effective anti-fouling paints, developed in the 1960s, contains the organotin tributyltin (TBT) was banned 2001. by IMO International Convention on the Control of Harmful Anti-fouling Systems on Ships. Metals such as cooper and zinc have been used in antifouling paints for a long time. Monthly average flux rates of dissolved copper for the hard vinyl and modified epoxy coatings were 3.7 and 4.3 $\mu g/cm^2/day$. Flux rates for the biocide free coating was 0.2 $\mu g/cm^2/day$.

Croatia has been attracting a larger number of leisure boats which sail mainly in a summer season. At the end of 2014 in Croatia there were 112 leisure boat ports with 11664 boats on permanent berth and 176398 leisure boats in transit. The potential toxic effects of coper anti-fouling paints and biocide free paints were determined and compared at the basis of leisure boats on permanent berth.

Anti-fouling paints application at marinas and also other small ports should be adequately supervised and paints leaching excessive Cu or other toxic element should be gradually prohibited for use on leisure boats and replaced by non–biocide paints. The special supervision should be carried out in boatyards and marinas to collect all contaminated wash water contain antifouling toxic elements. It must be appropriate treated before it can be discharged to the sea. On this manner amount of pollutants going into the surface water by significant percent will be reduced. Boaters should be provided by anti-fouling educational materials.

REFERENCES

[1] OECD Environmental Health and Safety Publications" Emission scenario documents on antifouling product" http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf, accessed 08.03.2015. 6

[2] K. Schiff, D. Diehl, A. Valkirs," Copper emissions from antifouling paint on recreational vessels" Elsevier, Marine Pollution Bulletin 48 (2004) 371–377. 5

[3] International Maritime Organization", Anti-foulingsystems, http: //www.imo.org/OurWork/Environment/Anti-fouling Systems,
accessed 08.03.2015.

[4] Croatian Registar of shipping" Cirkular letter AFS" http://www.crs.hr/Portals/0/docs/hrv/tehnicke_okruznice/QC-T-221,%20v.00.pdf. accessed 08.03.2015.

[5] D. M. Yebra, S. Kiil∗ , K. Dam-Johansen, "Antifouling technology—past, present and future steps towards efficient and environmentally friendly antifouling coatings" Elevier, Progress in Organic Coatings 50 (2004) 75–104.

[6] E. Almeida, T. C. Diamantino, O. Sousa," Marine paints: The particular case of antifouling paints" Elsevier Progress in Organic Coatings 59 (2007) 2–20. 3

[7] D. Carteaua, K. Vallée-Réhela, I. Linossiera ad others, Development of environmentally friendly antifouling paints using biodegradable polymer and lower toxic substances" Elsvier, Progress in Organic Coatings February 2014, Volume 77, Issue 2, Pages 485–493.

[8] X. Zhao, W. Fan, J. Duan" Studies on nano-additive for the substitution of hazardous chemical" Pak J Pharm Sci. 2014 Jul;27(4 Suppl):1117-22.

J. Karlsson, E. Ytreberg, B. Eklund " Toxicity of anti-fouling paints for use on ships and leisure boats to non-target," Elsevier Environmental Pollution 158 (2010) 681–687