TRANSNAV
http://www.transnav.eu
the International Journal
on Marine Navigation
and Safety of Sea Transportation
Volume 14
Number 3
September 2020
DOI: 10.12716/1001.14.03.24

Effect of Antifouling Paints and Nautical Tourism on the Sustainability of Marine Environment in the Case of the Village Ports of a Small Island

R. Ivče, D. Paparić, A. Zekić & M. Škapul
University of Rijeka, Rijeka, Croatia

ABSTRACT: The problem of underwater hull fouling has been mostly noticed by the pleasure boat owners when reducing the boat speed. In order to decrease the fouling of the underwater part of the hull, antifouling paints have been used. Some kinds of antifouling paints have become a serious environmental problem due to its very harmful effect on marine organisms and also, indirectly, on humans. Scientific research conducted in this domain has confirmed contamination by toxic compounds as a result of the usage of antifouling paints over long period of time. The paper is focused on underwater hull maintenance, especially when applying antifouling systems on pleasure crafts owned by tourists and local residents, in the example of the village ports of a small island. A survey was conducted among the residents who use ports to determine their knowledge regarding the harmful effects of biocidal coatings and the possible harmless maintenance of the underwater hull part. This paper aims to indicate the necessary equipment and procedures in the two small local ports in order to maintain pleasure boats in environmentally acceptable manner.

1 INTRODUCTION

All types of watercrafts are moving faster through water when their underwater part of hull is free from marine fouling. Sea animals, plants and microorganisms attach themselves to the surface of the underwater craft creating friction that decreases the speed of a boat, manoeuvrability and increases fuel consumption. Antifouling paint used for pleasure boats is a relevant source of toxic substance emission into the aquatic environment.

Nautical tourism is an important economic activity for the Republic of Croatia. With its advantageous location and natural attractions Croatia has always been an important tourist destination, especially for many EU countries in the Central and Eastern Europe. Because of its geographical position it represents the closest access to the Adriatic Sea and warm and crystal-clear sea. Croatia has a total of 1,244 islands, islets, cliffs and reefs scattered all along its coastline, which is the main rea-son why it has been attractive for a large number of pleasure boats. The coastal ecosystems are especially important for the well-being of the Adriatic Sea because they function as spawning, nursery and feeding grounds for a wide range of marine organ-isms. Also, marine environments and coastal areas are very important for human recreation and various kinds of outdoor activities. Leisure boating is a popular recreational activity on the Adriatic coast and islands. According to the data [3], Croatia has about 17,000 berths equipped for sailing boats and yachts and about 5,500 positions on dry land, boat storage.

A great number of boat owners are applying anti-fouling paints which contain biocides, primarily be-cause of the reasonable price. These paints contain

toxic heavy metals such as copper and zinc and are designed to erode. The slow process of leaching of biocidal heavy metals into the marine environment causes serious problems. High concentrations of these toxic elements have been measured in the are-as with intense boat traffic, but biocides also spread into the sea during maintenance work, when a boat's hull is just washed or scraped.

Over the history a variety of methods have been used to prevent marine fouling, e.g. pitch, tar, and copper. An early record noted a mixture in use around 412 B.C. composed of arsenic and sulphur, mixed with natural oil and applied to a ship's hull [9]. Many other examples could be noted, from the tar and wax of the ancient Greek boats to the various compositions used on the wooden sheathing in the 18th century. 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 [4]. The cost-effective anti-fouling paints using metallic com-pounds, in particular the organotin compound tributyltin (TBT), were first applied during the 1960's. The continuous use of the antifouling paints adds to the spread of harmful biocides in the coastal eco-system and increases the load of hazardous sub-stances in sediments and soils, especially in harbour areas and boatyards where the majority of the maintenance work is performed [1]. The use of toxic antifouling paints has appeared as one of the highest environmental risks to the coastal ecosystems, especially for small closed bays.

The paper is focused on underwater hull maintenance, especially when applying antifouling systems on recreational crafts owned by tourists and local residents in the example of a smaller island village. The village considered has two bays with local ports. During the summer season residents and tourists use these ports for berthing mostly recreational crafts. A survey was conducted among the residents which have had berthed boats in the port. With the help of the conducted survey authors in-tend to determine their knowledge regarding the harmful effects of biocidal coatings and their desire to maintain the underwater part of hull in a harm-less manner.

The authors of this paper indicate the necessary equipment for the two small local ports with boat wash area, which is designed to collect and adequately process all the wash water of the underwater part of a boat. The additional reason for this re-search is the need to better inform boat owners and other stakeholders about potentially safer alternatives for conventional antifouling systems. Safer alternatives will help preserve environment. The authors also try to point out the procedures to raise the level of environmental protection.

2 MARINE BIOFOULING AND PROTECTION

When an artificial structure is placed in seawater, fouling starts to occur very soon and vegetal and animal species start causing grave technical and economic problems [10]. In the case of pleasure boats biofouling produces high frictional resistance and when combined with additional weight and all things mentioned, it has great impact on speed and manoeuvrability and increases fuel consumption by up to 40%. Pleasure boats are moored most of the time and only in use for short periods. On the other hand, long mooring periods result in more fouling than when they are in regular use and this may in-crease the need for antifouling treatment.

The International Maritime Organization (IMO) uses the phrasing 'antifouling system', which is de-fined as 'a coating, paint, surface treatment, surface or device that is used on a ship to control or prevent attachment of unwanted organisms' [8]. The most widely used protective method for the prevention of marine biofouling on boats is antifouling paint. Biofouling has been recognized as a problem for more than 2,000 years and in the beginning of the protection of the underwater hull of a boat lime and later arsenic were used to provide anti-fouling. Since the use of the first simple antifouling coatings many kinds of antifouling methods have been investigated. The early Phoenicians were the first to use lead and copper sheets to prevent biofouling on their wooden boats. By the late 18th and into the 19th century coatings containing copper, arsenic and mercury were applied to protect the underwater hull of a boat. Since the late 20th century organotin compounds and their derivatives have been widely used as antifouling coatings because of their effectiveness [6]. Figure 1 gives a general view of the types of antifouling systems which may be ap-plied for the protection of the hull of a boat.

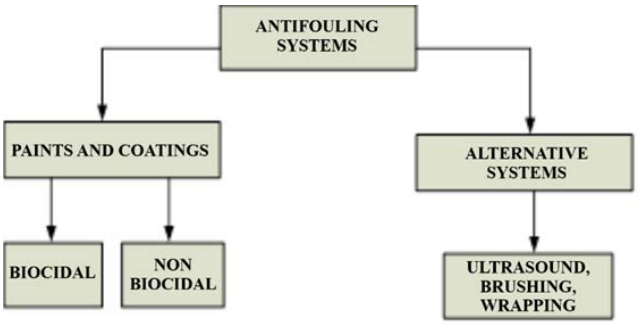

Figure 1. A general view of the types of antifouling systems for the hull of a boat

This overview shows that a variety of alternative antifouling systems are available for pleasure boats. A number of these are expected to be safer than biocidal self-polishing paints. These are:

- various types of hard foul release coatings,
- foul release coatings,
- liquid surface technology,
- ultrasound systems,
- other alternative antifouling systems.

Hard coatings are generally made of epoxies, polyesters, vinyl esters or ceramic-epoxy com-pounds, sometimes reinforced with glass flakes. In general, these coatings are intended to be used in conjunction with routine cleaning, using either high-pressure washing in a dry dock or underwater cleaning with the boat still afloat. Routine and timely

cleaning keeps fouling to a minimum and the hull operating optimally. These coatings are advertised as 'extremely hard' and they should have much greater longevity than conventional silicone coatings – possibly up to ten years.

Foul release coatings do not contain biocides for antifouling purposes. They have a smooth surface, which does not dissolve in water. The characteristic of this coating is that organisms just fall down when a boat moves through water at appropriate speed being unable to attach or it can easily be re-moved when the boat is lifted out of the water. Most foul release coatings are based on silicone elastomer, fluoropolymers or a combination of the two. Silicone coatings have an ultra-smooth surface which has slippery and hydrophobic surface [5].

Liquid surface technology is the basis for a newly developed coating, based on nano-/micro-structured porous material infused with a lubricating fluid. This creates a thin, ultra-smooth and slippery liquid layer that prevents the attachment of organisms.

Ultrasound waves can be used for fouling control. A small transmitter is placed on the inside of the boat's hull and it transmits ultrasonic waves (≈23 kHz). These waves continuously pass through the boat hull and act as a soundboard, causing microscopic vibrations.

Other promising alternative antifouling systems are still being researched and developed, such as UV light and natural, readily degradable biocides that stay inside the coating. The antifouling action happens because of the UV irradiation and causes DNA damage to marine organisms, thereby preventing biofilm to continue growing up on boat's hull.

The ecosystems of enclosed and shallow seas are most exposed to contamination of antifouling paints. Toxic elements enter the water column and remain there for some time after. They are removed from the water column by the sea tides, wind and local currents and settle on the bottom. The problem is significantly increased by the development of nautical tourism, which is one of the most profit-able selective forms of tourist offer and which, considering the market, can be expected to lead to an increase in vessel mooring. Therefore, the im-portance of preventive measurements should also be emphasized in the case of smaller ports.

3 POSSIBLE ANTIFOULING POLLUTION BY PLEASURE BOATS IN THE EXAMPLE OF TWO SMALLER LOCAL PORTS

With its indented coast and numerous bays and beaches the island of Rab has attracted a large number of pleasure boats. Only 12 kilometres away from the town of Rab lies the village of Lopar, otherwise known as the Sandy Paradise due to numerous natural sandy beaches. Surrounded by numerous small islands and islets, Lopar has a lot to offer to nautical tourists. It has two ports, which lie in two beautiful bays. Both ports have been used for berthing mainly pleasure boats owned by the local residents and tourists. Pleasure boats owned or hired by tourists sail mainly in summer. Some of the mentioned boats are permanently berthed in ports entire year, but most of them have a permanent berth in other marinas. Also, some of them are brought on a trailer to the ports from where they set out to the sea and are driven home on a trailer at the end of the holiday. Pleasure boats owned by the local residents are usually dry docked for maintenance once a year. The total number of the leisure boats on permanent berth in ports located in the village of Lopar is 338. Boats are divided according to size in certain categories and are shown in Table 1. Information regarding boats was collected and sorted out by the authors.

Table 1. Approximate leaching of toxic elements from Biocide Antifouling Paints (Copper) for boats permanently berthed in 2019 in the Village of Lopar (both ports).

Boat Category (Length in m)	Number of Boats	Approximate underwater area (cm2)	Average flux rate of dissolved Copper (4 μg/cm2/day)	Approximate total leaching per Boat Category (g/day)
<3	6	126,000	4	0.504
3-5	115	3,450,000	4	13.8
5-7	170	7,990,000	4	31.96
7-9	35	3,150,000	4	12.6
9-11	10	1,380,000	4	5.52
11-13	0		4	
13-15	2	500,000	4	2
Total				66.384

In this case permanently berthed boats are boats which are berthed in one of the ports in the Village of Lopar throughout the year. The categories of boats considered pollute aquatic environment with the antifouling toxic elements which slowly leach in the surrounding water and after that fall down to the bottom and enter the sediment.

Table 1 shows the number of leisure boats which have been permanently berthed in the ports of Lopar, their approximate underwater hull surface and the approximate release of toxic elements. It is assumed that the underwater part of the boats is protected by antifouling paints containing copper. Toxic element leaching was calculated by the average flux rates of dissolved copper for the hard vinyl and modified epoxy paints (approximately 4 μg/cm2/day) [7]. Also, toxic elements have remained in the sediment of nearby boats. The soil re-search which was done in similar ports show high concentrations of Cu and Zn. The measured Pb concentrations were generally lower than Cu and Zn because most frequent antifouling paints currently used contain Cu and Zn. Since the total ban of TBT (tributyltin) in the EU in 2003, Cu has been the main biocide added to antifouling paints. Heavy metals are not degradable and their concentration increases over time. The increasing number of pleasure boats on berth may lead to additional over-load of sediment with heavy metals from antifouling paints.

The underwater hull of pleasure boats is usually maintained once a year when they are dry docked or hauled out and stored at plateau near the sea. Usual maintenance includes removing any marine growth that has attached to the boat and reapplying the antifouling paint. Most leisure boats owned by the

local residents are dry docked or hauled out in the late autumn or at the beginning of spring. Having been applied with a fresh coat of antifouling paint and with the maintenance carried out, boats are then berthed in the port. Pleasure boats owned by the tourists who resided in Lopar are dry docked or hauled out and after that cleaned at the end of holiday. Most of them are brought on a trailer by the owners or left on land at dry marina. For the next holiday they will set out to the sea again with a fresh coat of antifouling paint.

Today most boat owners use high pressure water sprayers to save time and make cleaning more efficient. They rinse the salt water off and quickly remove dirt and any marine growth on the boat. Anti-fouling paint can be washed off in the process as well. The washed water contains not only dirt and marine organisms but also metallic and toxic anti-fouling compounds and that results in the higher levels of pollutants, which exceed the approved levels. Because of the short boating season boats owned by tourists have significant amounts of anti-fouling paint still on them at the end of the season. Both ports in Lopar do not have a proper plateau for cleaning boats and the polluted wash water is often directly run back into the water or soaks into the ground at the plateau location. The disturbing fact is that the metallic and toxic antifouling compounds can be rinsed by heavy rainwater or washed by extremely high water and through this process end up in the bottom of the surrounding sea. This area has been typically contaminated by significant levels of metals, mostly Cu and Zn. Paint particles were clearly visible on the ground at both plateaus at ports in Lopar.

4 ANTIFOULING PAINTS AND SUSTAINABILITY OF THE MARINE ENVIRONMENT

The life quality in an island village, fishing and many tourist activities depend on the long-term sustainability of marine resources and the ecological health of their supporting ecosystems. The reduction of potential antifouling pollutants is a significant step in the protection of the marine environment. Pleasure boats owned by the village residents or tourists that cruise the island's coast should sail and be maintained without adverse impact on the marine environment. Boat repair and maintenance have been done at their current locations for many years. Boat owners are, however, often unaware of the environmental risks posed by their practices and the wastes that they generate, in particular the harm caused by the toxic antifouling paint chips, paint residues containing heavy metals, acids, oil, hydro-carbons and other substances with adverse effects on the marine environment.

The contaminated wash water, which contains antifouling toxic substances, is often allowed to run back into the water or soak into the ground at the plateau where the boat is located on land. This results in the significant levels of toxic substances being discharged into the water and the groundwater harming the marine environment. Gradually, the discharge of boat bottom wash water (antifouling paint-contaminated wash water) should be regulated at the considered ports. The antifouling paint-contaminated wash water should be required to be collected in the facility until it can be treated. Wash water should be collected in a closed holding tank or container and left standing so that suspended pa-ticles can settle and be physically separated from the water. Treatment of the mentioned water will reduce the amount of antifouling toxic substances. Treated wastewater meeting required standards may be disposed of through a sanitary sewer system with authorization. The contaminated sediment which was separated from the wash water should be accepted by a licensed organization for treatment or safe disposal. In the absence of a licensing facilities for treatments and disposal, contaminated sediment should be directed to a landfill lined with an im-permeable liner to prevent leaching of waste materials into the ground [2].

Using high pressure washer to clean the underwater part the hull of a boat has the potential to create environmental harm. High-pressure water blasting presents containment problems caused by the wide dispersion of biological and toxic substances removed from the boat hull during the cleaning process. Boats which are not heavily fouled can be wiped off with a sponge or a scrub pad when hauled out, which reduces any fouling that happens above the antifouling paint. Also, boats can be allowed to dry when hauled out and then sanded prior to the application of new antifouling paint. In this case it is recommended to use vacuum blast cleaning ma-chines with abrasive blast nozzle inside a shroud that is in tight contact with the work surface. Dust and abrasives are immediately vacuumed by a powerful suction unit and piped into a blast material collection and treatment chamber. It is easier to control and collect paint particles and dust, but it is very important to handle the dust carefully and dis-pose of it properly.

Both local ports need to install a wash water col-lection area and a treatment system to collect all the boat antifouling wash water and treat it to prevent or reduce the amount of antifouling paint residue being discharged in the environment. Installation of the collection and treatment systems in the two small ports in the village of Lopar will present a significant capital expense for the local community and it will be supported by the Port Authority. This investment will be of great importance in the preservation of the marine environment.

Boat owners should avoid scrubbing or cleaning the bottom of their boat while in the water because it can result in discharges of pollutants similar to bottom wash water. When the opportunity arises, wiping off the water line of a boat by a sponge or a scrub pad will reduce any fouling that happens above the antifouling paint. Tipping engine out of the water in case a boat is equipped with outboard engine is also recommended.

Boat owners as well as local port authorities should be encouraged to become knowledgeable about antifouling paints and characteristics of non-biocide antifouling paints or alternative systems. They need to be educated on the use, advantages and disadvantages of biocide-free and biocide-containing antifouling paints. Also, antifouling system with

minimum environmental impact should be recommended. Boat owners with more fouling problems should be advised how to use low-release copper paint or biocide-free antifouling paints. Efforts should be made to make environmentally friendly products available at local paint shops.

A survey was conducted among the local residents who use the ports to determine their knowledge of the harmful effects of biocidal coatings and the harmless maintenance of the underwater hull.

5 ANALYSIS OF THE CONDUCTED SURVEY AMONG BOAT OWNERS

The data used for this research was collected in a questionnaire survey conducted on 50 residents that have boats sized between 3 and 15 meters. The questionnaire contained questions about the respondents' sex, age, profession, level of education, size of boat owned, questions regarding how the respondents maintain their boat and the knowledge of the respondents regarding the antifouling paint types. In the end the respondents were asked if they were willing to help improve taking care of the antifouling paint.

The survey shows that the majority of the boats in the mentioned local ports are owned by men (98%) and just 2% by women. Figure 2 shows the age and the level of education of the respondents. Most of the respondents finished high school and they are around 36 years old or older.

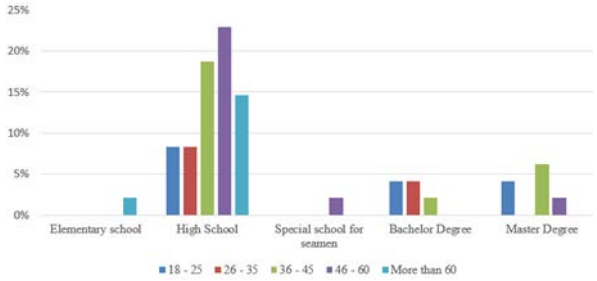

Figure 2. Age and level of education of the respondents

After the general questions, the questions were more oriented towards the way the respondents maintained the boat. The survey showed that 64% of the respondents maintain their boats by them-selves and 23% of them outsource the maintenance to third parties but under their supervision. The other 13% of boats are maintained by third parties without the supervision of the boat owners. Figure 3 shows how often the respondents take their boats out for maintenance and at which location the respondents accommodated their boats for antifouling paint removal. Most of the respondents answered that they had taken their boats out for maintenance within 1 year. About (49%) of the respondents dry docked their boats between 6 and 12 months, 33% less than 6 months while just 14% of the respondents answered that their boats were dry docked for maintenance between 12 and 18 months. About 4% of the respondents did that in the periods which exceed 18 months. The last part of the chart 2 shows the locations where the respondents maintained their boats. Because of the fact that the nautical tourism occurs mostly during the summer season pleasure boats are mostly taken out of the sea and are stored on some location on the land at the end of the season. That explained why 41% of the respondents answered that they maintain their boats away from the sea. Many local fishermen on the is-land need their boats in the water during the whole year. They take their boats outside on a plateau by the sea for a quick maintenance and to repaint the antifouling paint and they can be counted in the group of about 39% of the respondents who answered that their boats were maintained on a plateau near the sea. The last group of about 20% of the respondents answered that their boats were accommodated on some location near the sea for maintenance. The local residents who were usually per-forming maintenance between two weeks and one month are also part of this group.

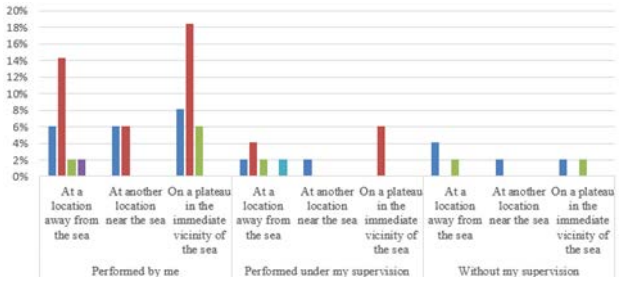

Figure 3. Manner of maintenance and location

The main part of the survey shows how the respondents are informed about the antifouling paint and its toxic components. The most of the respondents (59%) replied that they did not pay attention. Then, the respondents were asked if they were aware of the fact that certain antifouling paints contain elements that are not biodegradable and are as such deposited in the sediment. On this question about 66% of the respondents answered positively.

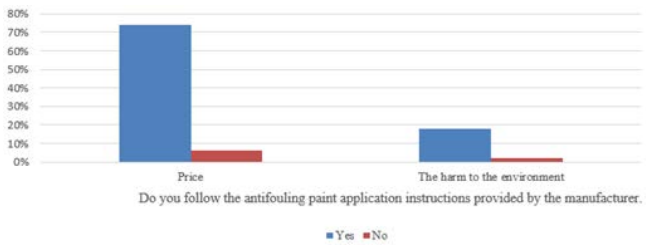

Figure 4. The antifouling paint chosen in relation to the price and the application of paint according to manufacturer's instructions

Figure 4 above shows the respondents usually buy the cheapest antifouling. Also, the same graph leads to the conclusion that the respondents who buy the antifouling paint based on price (the cheapest) are not following the instructions given by paint manufacturer.

At the end of the survey the respondents were asked if they were willing to help to improve the standards regarding antifouling treatment by positive behaviour, if they support setting up education-al panels in the port area and if they support the initiative to build up the necessary infrastructure for boat maintenance in the environmentally acceptable

manner. There were more than 95% of positive answers to these three questions.

The authors suggest that boat owners should be provided with anti-fouling educational materials because, as the survey shows, they have not been aware of the environmental impact of certain anti-fouling paints. The authors also recommend setting up posters with educational materials in the ports. Figure 5 shows a poster which will be positioned at a few places in the ports.

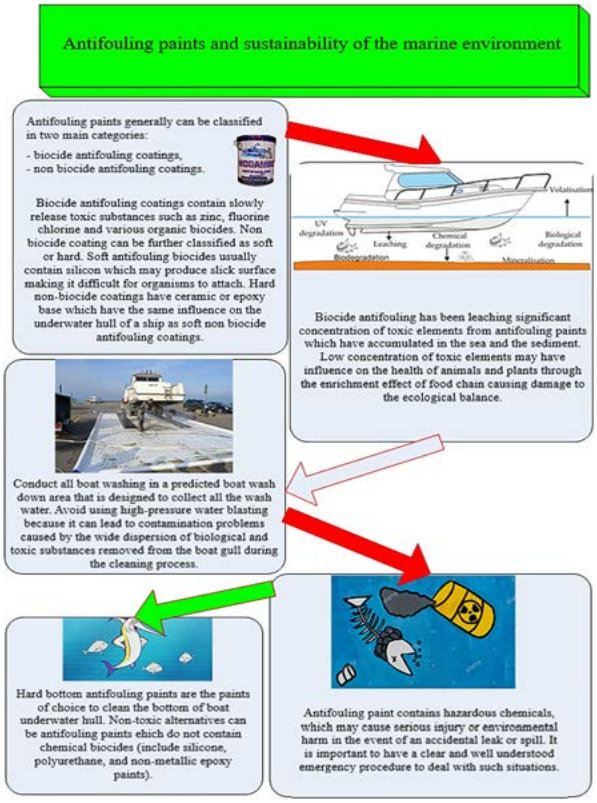

Figure 5. Antifouling paints and sustainability of marine environment poster

6 CONCLUSION

The Republic of Croatia has been a very popular tourist destination and it has been attracting a large number of pleasure boats. There are about 17,000 equipped berths along the coastline and islands. The underwater part of the hull of a boat is protected by antifouling paints which may contain biocides, which are slowly leaching into the marine environment causing serious problems. The ecosystems in the ports and marinas are exposed to the contamination by antifouling paints the most due to intense boat traffic and berthed boats. Biocides also spread into the sea and settle on the bottom during maintenance work when the hull of a boat is just washed or scraped.

The questionnaire survey was carried out among boat owners to determine their knowledge regarding the harmful effects of biocidal coatings in the smaller local ports of the island of Rab. It was con-ducted on the sample of 50 residents which have boats berthed in the local ports in the village of Lo-par. Surveyed residents have boats whose length spans between 3 and 15 meters. Most respondents (64%) maintain the boat (including the underwater part of boat) without outside help. Boats are mainly maintained near the sea. The marine growth on the underwater part of ship and the remains of antifouling paints are removed by water pressure sprayers in most cases. The washed water contains both marine organisms and toxic antifouling compounds. As the conducted survey shows, most of the respondents have taken their boats out for maintenance within 1 year and they have significant amounts of antifouling paint still on them. Both ports considered do not have a proper plateau for cleaning boats and the polluted wash water is often directly run back into the water or soaks into the ground at the plateau location and after that indirectly reaches the surrounding sea. The aquatic area and the seabed have been contaminated with metals, mostly Cu and Zn.

Gradually, the wash water contaminated with antifouling paint should be regulated in the considered ports. Contaminated water will be required to be collected in the facility until it can be treated. Wash water should be collected in a closed holding tank or container and left standing so that the suspended particles can settle and be physically separated from the water. Because of the aforementioned rea-son, both local ports will need to have a wash water collection area installed, as well as a treatment system which will provide a smaller amount of anti-fouling paint residue that is being discharged into the environment.

According to the conducted survey only 55% the of respondents have been familiarized with the harmful effects of biocidal antifouling and the process of decreasing marine biodiversity has been noticed by not more than 14%. Biocidal antifouling contains no biodegradable elements, which are de-posited in the sediment. 66% of the respondents have been familiar with this fact. It is very important to emphasize that the respondents usually buy the cheapest antifouling and the survey also shows that the respondents who buy the antifouling paint based on price were not following the instructions and the paint was applied based on their previous experience.

The last question in the conducted survey shows that almost all respondents are willing to help to improve the level of marine environment protections through positive behaviour, setting up educational panels and supporting the initiative to build the necessary infrastructure. The answers to the last three questions were positive for more than 95% of the respondents. Therefore, the authors recommend that the boat owners be provided with antifouling educational materials to improve the level of marine environment protection because, as it is evident from the survey, they have not been aware of the environmental impact of certain antifouling paints.

REFERENCES

[1] Amara, I., Miled, W., Slama, R. B., Ladhar, N. 2018. Antifouling processes and toxicity effects of antifouling paints on marine environment. Environmental Toxicology and Pharmacology, 57, pp. 115–13.

[2] Buskens, P., Wouters, M., Rentrop, C., Vroon, Z. 2013. A brief review of environmentally benign antifouling and

foul-release coatings for marine applications. Journal of Coatings Technology and Research, 10(1), pp. 29-36.
[3] Croatian Bureau of Statistics, First Release data, Nautical tourism, Capacity and Turnover of Ports, 2018, Year: LV., No: 4.3.4.
[4] International Maritime Organization, Anti-fouling systems,http://www.imo.org/en/OurWork/Environment/Anti-foulingSystems/Documents/FOULING2003.pdf foulingSystems/PageWs/Default.aspx
[5] Karlsson, J., Ytreberg, E., Eklund, B. 2010. Toxicity of anti-fouling paints for use on ships and leisure boats to non-target. Environmental Pollution, 158, pp. 681–687.
[6] Lagerström, M., Norling, M., Eklund, B. 2016. Metal contamination at recreational boatyards linked to the use of antifouling paints—investigation of soil and sediment with a field portable XRF. Environmental Science and Pollution Research, 23, pp. 10146-10157.
[7] Lončar, G., Tudor, M., Beg Plakar, G., Oreščanin, V. 2015. Numerička analiza koncentracije bakra u akvatoriju Puntarskog zaljeva. Hrvatske vode, 92, pp. 93-110.
[8] OECD Environmental Health and Safety Publications, Series on Emission Scenario Documents No. 13, Emission scenario documents on antifouling products, https://www.oecd.org/env/ehs/risk-management/47703240.pdf
[9] Slišković, M., Jelić, G. 2002. Problem obrastanja mreža u akvakulturi. Croatian Journal of Fisheries, 60(3), pp. 105-115.
[10] Woods Hole Oceanographic Institution [WHOI]. 1952. Marine fouling and its prevention. Annapolis, MD: United States Naval Institute.