R8-1 Hull paint and the sea

What does hull paint release into the sea, how far is this known, and what limits does the method of fixing a substance to the surface have?

Readers	Ship owners, shipyards and repair companies, people who handle paint or parts, local government staff and others. It can be read without specialist knowledge. For those who want to know what hull paint releases into the sea, and the limits of a method other than paint.
Takeaways	1. Most hull paints work by slowly releasing into the sea a substance that keeps living things away (a biocide). Of the 363 antifouling methods registered with the Japan Paint Manufacturers Association, 273 contain a copper compound (cuprous oxide). The guidelines of the International Maritime Organization (IMO) say that cleaning a hull may release biocides, metals, pigments, microplastics (fine particles of plastic) and other things. 2. Coatings that do not use biocides are also already on sale. However, limits have been pointed out, such as fouling attaching easily while the ship is stationary and the coating being easily damaged, and a separate concern has been raised about substances that contain fluorine. The IMO's 2023 guidelines do not treat methods that use biocides as better or worse than methods that do not (this paper's reading). 3. The company uses a method of treating the surface of a material to fix a fluorine-based antifouling active substance to it. It does not use biocides such as copper or silver. This method also has limits. In the research of the company's technical supervisor, after 5 months of use on a boat's propeller, part of the substance came off, and barnacles attached there. What happens in the sea to the substance that came off has not been measured.
After reading	For the paint on your own ship, check the type (self-polishing, foul-release and so on) and the names of the biocides it contains, in the paint maker's documents. When cleaning, also check whether the method suits that coating.

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This is an English translation. The Japanese edition is the authoritative text.

1. Key points

- Most hull paints work by slowly releasing into the sea a substance that keeps living things away (a biocide). Of the 363 antifouling methods registered with the Japan Paint Manufacturers Association, 273 contain a copper compound (cuprous oxide). [S4] The guidelines of the International Maritime Organization (IMO) say that cleaning a hull may release biocides, metals, pigments, microplastics (fine particles of plastic) and other things. [S1]
- Coatings that do not use biocides are also already on sale. However, limits have been pointed out, such as fouling attaching easily while the ship is stationary and the coating being easily damaged, and a separate concern has been raised about substances that contain fluorine. [S5, S6, S7] The IMO's 2023 guidelines do not treat methods that use biocides as better or worse than methods that do not (this paper's reading). [S1]
- The company uses a method of treating the surface of a material to fix a fluorine-based antifouling active substance to it. It does not use biocides such as copper or silver. This method also has limits. In the research

of the company's technical supervisor, after 5 months of use on a boat's propeller, part of the substance came off, and barnacles attached there. What happens in the sea to the substance that came off has not been measured. [S13]

2. How paint works, and what it releases into the sea

Working while releasing a substance

Barnacles, shellfish and algae attach to the bottom of a ship. When they attach, the resistance of the water increases and the ship uses extra fuel (for details, see R1 "The burden of biofouling at sea"). Antifouling paint is what is applied to prevent this.

Many antifouling paints contain a biocide and prevent fouling by slowly releasing it into the seawater. The report of GloFouling, an international project of the IMO and others, describes paints that release biocides as the most widely used method, and one that is also advantageous in terms of cost. [S6] There are 363 antifouling methods registered with the Japan Paint Manufacturers Association (as of 23 October 2026), of which 273 contain cuprous oxide (a copper compound). [S4]

In paints of the type called self-polishing, the surface dissolves little by little and keeps exposing a new surface. The IMO's guidance on in-water cleaning (2025) writes that the self-polishing type can release biocides as its surface dissolves. [S1]

What cleaning releases

Attached organisms are sometimes removed by cleaning the hull in the water. The IMO's biofouling management guidelines (2023) divide what is released by cleaning into dissolved matter and particles, and define it as possibly including biocides, metals, organic matter, removed fouling, pigments, microplastics and so on. They also write that cleaning can damage the coating, shorten its life and release harmful substances. [S1]

The 2025 guidance lists, as the main risks, the release of biocides, plastics and microplastics into the surrounding water. According to the guidance, even when cleaning is done while capturing the debris, a portion that cannot be fully captured may remain. [S1]

Examples of copper thought to come from paint being found in the seabed, and the results of tests and calculations showing that the leaching of copper increases after cleaning, are summarised in chapter 3 of R1.

Stationary ships

How well a paint works changes with how the ship is used. The IMO guidelines write that each antifouling method is designed for a particular speed, and that fouling can increase while a ship is not moving. [S1] The 2025 guidance also says that a coating cannot always protect every surface, and gives as examples the cases where a product unsuited to the ship is chosen, where the ship stays stopped for a long time, and where the ship is used differently from what was assumed. [S1]

The amount is not known

As far as the company has examined, it found no source showing how much microplastic is released from hull coatings in a year.

3. The course of regulation

Two banned substances

The international convention that sets the rules for the antifouling methods of ships (the AFS Convention) was adopted in 2001 and entered into force on 17 September 2008. The Convention bans two substances. [S2]

- Organotin compounds (biocides that contain tin) could no longer be newly applied from 1 January 2003. From 1 January 2008, they must either not be left on the hull or be covered over with a coating so that they do not leach out.
- Cybutryne (a biocide that acts on algae) could no longer be newly applied from 1 January 2023. The handling of what remains is described in chapter 4 of R1.

Japan implements this Convention through a ministerial ordinance under the Ship Safety Act. The ordinance defines an "antifouling method" as a method that uses a coating, a paint, a surface treatment or a device to control or prevent the attachment of living things to a ship. Not only paint but also surface treatment is included. [S3]

No division by whether there are biocides or not

The IMO's 2023 guidelines do not treat methods that use biocides as better or worse than methods that do not (this paper's reading). What they ask for is that the effects of the release of harmful substances be considered, that a cleaning method suited to the coating be chosen, and that the makers of coatings disclose the biocides and the type of coating. [S1]

Moves to make it mandatory

The IMO's guidelines and guidance on biofouling management are both voluntary. At its session in April–May 2026, the IMO's Marine Environment Protection Committee agreed to develop a stand-alone international instrument that makes biofouling management mandatory. The scope of consideration includes responding to the release of harmful substances and microplastics. The target for completing the work is 2029. [S8]

The dates of the regulations for each substance, and the moves in the EU and the United States, are summarised in chapters 3 and 4 of R1.

4. Coatings that do not use biocides

Already on sale

Coatings that contain no biocides are already on sale. The typical example is the coating called a foul-release coating, which does not prevent attachment itself but weakens the hold of the organisms that have attached, so that they are removed by the force of the water as the ship moves forward or by gentle cleaning. [S7] Its development began in the 1970s. [S6] According to a report (2024) by Washington State in the United States, the resin that forms the coating is usually silicone-based or fluoropolymer-based. [S5] Coatings for propellers that contain no biocides are also on sale.

Of the 363 registrations in Japan, 22 have "no biocide" written as their type (the 23 in R1 is the number of registrations in which no biocide is listed). [S4] Not every coating whose name includes "foul-release" is free of biocides. The IMO guidance also writes that some foul-release coatings contain biocides and some do not. [S1]

Limits

Public documents and papers list the limits of foul-release coatings as follows.

- Foul-release coatings are said to be best suited to ships that are fast and move often. A 2011 review article (a paper that summarises research) writes that they are less suited to ships that stay in port for long periods and to slow ships. [S6, S7]
- The same review article says that silicone-based foul-release coatings do not last as long as other coatings and are easily damaged. [S7] Washington State cites fouling while the vessel is stationary and the weakness of the coating film as the main weaknesses. [S5]
- In recesses where there is little flow of water, the performance of foul-release coatings can fall greatly. [S6]

Test results are divided. There are examples in which much fouling attached to foul-release coatings in a test in which they were placed in calm sea, and examples in which products that contain no biocides performed well in a 12-month test (chapter 3 of R1).

What is released

Substances are released from coatings that contain no biocides as well. The Washington State report writes that silicone oils, components that did not fully react and other substances can be released from foul-release coatings, and that particles of the coating can become microplastics. It then says that there is not enough information to reach a conclusion on the toxicity of foul-release coatings and their effects on the environment. [S5]

The same report also touches on the fluorine-based substances used in paints that contain no biocides. These are a group of compounds that contain fluorine, called PFAS. The report describes PFAS as pollutants of great concern in the marine environment, and writes that using them in place of copper cannot be supported. [S5]

5. The method of fixing a substance to the surface

From here on, we describe the method of the publisher of this paper (SeatecHIROSHIMA Ltd.) and its limits.

The company's method

The company treats the surface of a material and fixes a fluorine-based antifouling active substance to that surface. It does not use biocides such as copper or silver. [S14] There is no record, in published materials, of a measurement of how hard it is for the substance to come away.

This method is based on research led as principal investigator by the company's technical supervisor, Kensuke Kuroda (Representative, Nagoya Surface Technology; Specially Appointed Professor, Institute of Innovation for Future Society, Nagoya University). The research was funded by a national research grant (a KAKEN grant), with the number 22K04725, and its period was fiscal 2022–2024. Kuroda supervises the company's technology as an individual. What follows is what is written in the published research results report and in the reports for each fiscal year. These are not the results of the company's own tests. [S13, S14]

- According to the report for fiscal 2022, surfaces to which silver, copper or zinc had been applied became less likely to have shellfish attach in the laboratory, but in the sea the surfaces were worn away by waves, and no effect was seen. In the laboratory test in the final report, zinc was almost the same as no treatment. Polyethylene plates with silver ions fixed to them came to look the same as untreated plates within 3 months of being hung in the sea.

- The research then switched to a method of fixing a "CF-based substance", which is highly water-repellent. The report does not give the name of the substance.
- A vinylon (a synthetic fibre) rope 16 mm in diameter was still, judging by eye, in a state of little fouling even after 10 months in the sea. The figure shows one rope for each condition.
- For a high-density polyethylene float (about 150 mm in diameter), 1 year after it was put in place, kelp and other seaweeds were growing thickly on the rope that held it, but no shellfish or algae were attached to the float. The report does not state the number of floats. The figure shows one treated float for each point in time. For the untreated float, there is only one photograph, at 5 months, and there is no photograph at 1 year.
- A brass propeller was fitted to a boat and run almost every day. After 5 months of use, part of the CF-based substance came off, and barnacles attached where the brass was exposed. The report says that improving durability is an issue to be addressed. No comparison was made with an untreated propeller.
- In fiscal 2023, rope 2 mm in diameter for nori nets was tried on 4 frames 1 m square. Possibly because the rope was not fastened well enough, the treated materials were washed away into the sea, and the effect could not be confirmed. The report says that recovery and evaluation were not carried out.

In its conclusions, the report writes that in harsh environments such as the sea some surface modifications have problems with durability, and that further research is needed to maintain durability and persistence. [S13] No papers or conference presentations from this research are registered in the database of KAKEN grants (KAKEN). [S13]

The limit of size

The equipment the company uses now can treat objects up to about the size of a football. It cannot treat the hull of a large ship as it is; that would require the development of different equipment. The company's intention is to start with small parts that foul easily, such as propellers.

What becomes of the substance that came off

The concern of Washington State seen in chapter 4 is one that could also be directed at the company's method, in that it uses a fluorine-based substance.

In the research of the company's technical supervisor, it was not measured where the substance that came off the propeller in 5 months went, or how much of it there was. [S13] Separately from the research, the company has a policy of not leaving treated items abandoned in the sea.

Rules on substances that contain fluorine

Japan has a law that regulates the manufacture and import of chemical substances (the Chemical Substances Control Law). Among substances that contain fluorine, the manufacture and import of PFOS, PFOA and PFHxS, and of the substances related to PFOA and PFHxS, are in principle prohibited by this law. Long-chain PFCAs with 9 to 21 carbon atoms and their related substances were also added from 22 November 2026. Among the chemicals used by bonding them to a surface (silane agents), some fluorine-based ones have been subject to the prohibition since January 2025, as substances related to PFOA. Fluoropolymers such as PTFE, which is used for things such as the coating of frying pans, are not included in this designation. [S9] Not being included in the designation does not mean that safety has been confirmed.

In the EU, a proposal to restrict PFAS as a whole, including fluoropolymers, is under consideration. The proposal covers substances that have one or more fully fluorinated carbons (CF3 or CF2), and it also includes those contained in products. Five countries submitted the proposal in January 2023. At the European Chemicals Agency, the committee that looks at the risks to health and the environment adopted its final opinion in March 2026. The Agency announced on 19 November 2026 that the committee that looks at the effects on society and

the economy has also adopted its final opinion. The opinion is to be finalised within the coming weeks, sent to the European Commission and published on the Agency's website. After this, the European Commission will draw up a proposal, and the member states will vote on it. The European Commission's proposal is reported to be expected in early 2027. No schedule is given for the vote. [S10]

The summary of the proposal does not name antifouling coatings for ships, fishing nets, ropes or aquaculture materials (fishing line is listed as a consumer item). However, it says that ships come under the transport sector, and that uses that are not named are also dealt with in one sector or another. [S10]

Public debate on fluoropolymers

Fluoropolymers hardly break down in the environment. On this point, the side calling for regulation and the industry side agree. [S10, S11] Where they differ is in how to view the fact that fluoropolymers do not break down. A paper whose authors are mainly from industry says that fluoropolymers are stable, are not easily taken up into the body, and should be treated separately from other PFAS. A paper whose authors are mainly from universities and government says that, when the auxiliary chemicals used in making them, the small molecules that remain in products, and the stage after use are included, the concern cannot be said to be low. [S11]

Research has shown that particles of fluoropolymer are released from the damaged coatings of cookware (the numbers of particles are estimates). There is also a report of fluoropolymer being found in plastic swallowed by fish in the Mediterranean. [S12] Where the particles found in the fish came from is not known.

For the following, as far as the company has examined, it found no study that measured them.

- How much substance and how many particles are released into seawater from fluorine-based antifouling paints and surface treatments
- How fast fluoropolymers break up and break down in seawater
- How particles of fluoropolymer affect living things in the sea

6. Means of looking at the sea itself

To know what happens in the sea to what has been released from paints and surfaces, a means of measuring the sea itself is needed. As R1 shows, the materials that measured antifouling active substances in the seawater and the seabed of Hiroshima Bay are mainly from the 2000s, and the present state is not known.

The company is also working on a system that finds oyster rafts on the sea in satellite images (R5-1 "Collisions between boats and fishing gear"). Satellites can photograph wide areas of the sea again and again. However, as far as the company has examined, it found no example of something dissolved in water at very low concentrations, like the substances in paint, being measured from satellite images. For now, the means of checking the relationship between paint and the sea is surveys that take samples of water and of mud from the seabed and measure them.

7. Reliability and the publisher's position

What is not known is written in chapters 2, 5 and 6.

The dates and provisions of the regulations were checked on 12 November 2026 against the convention, IMO resolutions, Japanese laws and regulations, and materials of the EU authorities. The materials of the European Chemicals Agency were checked using archived copies, because the Agency's website could not be opened. On 25 November 2026, we checked again only the coming into force of Japan's rule on long-chain PFCAs and the

adoption by the EU committee. The EU committee's adoption rests on three articles that report the announcement the European Chemicals Agency made on 19 November 2026. The EU's proposed restriction and the IMO's work on making biofouling management mandatory are still in progress.

Most of the figures for the performance of coatings that do not use biocides are claims by their makers. This paper does not use them. We found no material that compares paints and the company's method under the same conditions. For this reason, this paper does not compare which is better.

The results of the research in chapter 5 are the researchers' own reports, and not papers that have been reviewed by other researchers (peer review). [S13] For the tests in the sea, either the number is not stated, or the figure shows one for each condition.

The publisher of this paper (SeatecHIROSHIMA Ltd.) runs a business that controls biofouling by surface treatment of materials, and is in a position that may compete with the paints covered in this paper. It is also considering use in combination with paints.

8. Sources

Chapters 2–5 are based on research in which a separate researcher opened and checked the sources on 12 November 2026. Reliability: A = conventions, laws and regulations, and materials of international organisations and of national and state governments; B = papers, and reports of research institutions and international projects; C = materials of organisations, and the company's pages.

ID	Source (publisher, year)	Type	Reliability	Chapters used
S1	IMO: biofouling management guidelines MEPC.378(80) (2023); guidance on in-water cleaning MEPC.1/Circ.918 (2025)	Guidelines	A	Chapters 1–4
S2	AFS Convention: IMO explanatory page; authentic text of the Convention (2001); amendment banning cybutryne MEPC.331(76) (2021)	Convention	A	Chapter 3
S3	Ordinance for Enforcement of the Ship Safety Act (in Japanese) (Articles 19 and 65)	Law	A	Chapter 3
S4	List of registered antifouling methods (Japan Paint Manufacturers Association, October 2026; the counts were made by the researcher)	Organisation	C	Chapters 1, 2, 4
S5	Antifouling paints: third report to the Legislature (Washington State Department of Ecology, USA, 2024)	State	A	Chapters 1, 4
S6	GloFouling: report on fuel consumption and greenhouse gases (a joint work of an IMO project and an industry body, funded by members of the industry body, 2022)	Report	B	Chapters 1, 2, 4
S7	Callow and Callow: trends in marine biofouling and antifouling (Nature Communications, 2011)	Paper	B	Chapters 1, 4
S8	IMO Marine Environment Protection Committee, 84th session: report; Addendum 3 (2026; copies published by the Maritime and Port Authority of Singapore)	Report	A	Chapter 3
S9	Japan's regulation of PFAS: Order for Enforcement of the Chemical Substances Control Law; PFAS handbook (Ministry of the Environment, December 2025); ministerial ordinance specifying the substances related to PFOA (Ordinance of the Ministry of Health, Labour and Welfare, the Ministry of Economy, Trade and Industry and the Ministry of the Environment No. 4 of 2024 (Reiwa 6)) (in Japanese)	Law	A	Chapter 5

ID	Source (publisher, year)	Type	Reliability	Chapters used
S10	The EU's proposed PFAS restriction: summary by the authorities of the five countries (2025); announcement of the European Chemicals Agency (26 March 2026); report in a trade magazine (European Coatings, 20 November 2026); CGTN article (source AFP, 22 November 2026); article reporting the announcement (2eu.brussels, 20 November 2026)	Authority	A	Chapter 5
S11	Assessments of fluoropolymers: Lohmann et al. (2020); Henry et al. (2018, abstract only checked; the authors are mainly affiliated with industry)	Paper	B	Chapter 5
S12	Fluoropolymer particles: Luo et al. (Science of the Total Environment, vol. 851, 2022, abstract only checked); Capillo et al. (Marine Pollution Bulletin, vol. 150, 2020, abstract only checked)	Paper	B	Chapter 5
S13	KAKEN grant 22K04725 (principal investigator Kensuke Kuroda): project page; research results report (as of 14 May 2025); progress reports for fiscal 2022 and fiscal 2023 (in Japanese)	Report	B	Chapters 1, 5, 7
S14	The company's page: Surface technology (in Japanese) (SeatecHIROSHIMA Ltd., 2026)	Company	C	Chapter 5

Related materials

- R1 "The burden of biofouling at sea": the fuel and labour that fouling adds, today's measures and their limits, and the dates of regulations
- R5-1 "Collisions between boats and fishing gear": the work on finding oyster rafts in satellite images
- R8-2 "Arrangements for returning nutrients to the sea": a proposal to use the same surface technology in the "Help it take hold" direction
- C2 "Solving the problems of the sea in combination": how the company intends to use this method