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MEMORANDUM

To: Mark Sandoval – Marine Recreation Association Board of Directors

From: Shelly Anghera, Ph.D. and Bryce Corlett, Ph.D.

Date: July 29, 2020

Re: Review of Non-copper-based Alternative Antifouling Paints to Support Discussion on Implementation Strategies for Reducing Copper by Boat-Paint Conversions

Boat owners, marina operators, marina owners, cities, counties, and other stakeholders have been advised to replace copper-based antifouling paints (AFPs) with non-copper nontoxic (i.e., non-biocidal) AFP to meet water quality objectives. These discussions have been ongoing in Marina del Rey, Newport Bay, and Shelter Island. The Marine Recreation Association (MRA) and other stakeholders have maintained concerns from boaters that alternative nontoxic boat paints are not yet proven to be dependable alternatives. However, Regional Water Quality Control Board (RWQCB) staff continue to assert that alternative nontoxic AFP are readily available (Los Angeles RWQCB 2015; San Diego RWQCB 2005; Santa Ana RWQCB 2018).

In response to the claims of readily-available non-biocidal paints, as well as the potential use of alternative biocidal AFPs, this memorandum reviews the findings of five studies commissioned by the USEPA, CalEPA Department of Toxic Substances Control (DTSC), and Washington State Department of Ecology (Ecology) over the past decade. Together, these studies demonstrate continued concerns regarding the availability, proven effectiveness, and safety of alternative AFP. These concerns include the following:

1. **No Single Alternative AFP will Work.** One paint does not fit all vessel types, all environments (temperature ranges, seasons, types of fouling organisms), and all boat owner needs/uses. The studies presented here suggest AFP effectiveness can vary from boat to boat, year to year, and place to place. The most supported non-biocidal paints currently available are Intersleek 900 (now Intersleek 1100SR) and Hempasil X3. However, these soft-non-biocidal paints may not be suitable for recreational boaters, as they were developed for large commercial vessels which operate at high speeds for long durations to slough off fouling organisms. Very few recreational boaters use their vessels at the frequency required to have the paints perform optimally. In addition, soft-non-biocidal paints are prone to damage and typically require professional application, making these paints expensive to apply and to care for.

2. **Boat Paint Formulations Are Constantly Changing.** AFP brands and formulations are constantly changing, which contributes to the difficulty in gaining boater confidence in alternative AFPs. Not only are the formulas constantly changing, but new paints are

constantly added to the market and old paints are frequently discontinued. Out of the six alternative AFPs recommended in the reviewed studies, only one has not been discontinued or modified.

3. **Non-Biocidal Paint Safety Has Not Been Confirmed.** All AFP contain hazardous chemicals, and their safety to human health or other receptors in the environment has not been confirmed. The environmental safety of AFP formulations are currently difficult to determine, as AFP ingredients and safety information are often not disclosed due to proprietary rights, and inactive ingredients (which may have detrimental environmental effects) are not listed in mandatory disclosures. Furthermore, these paints are not regulated as biocides and, therefore, have not been tested to determine if high usage of these paints in enclosed waterbodies will result in water quality related impacts. Several of the best performing non-biocidal AFPs provide immediate concern as they contain a slime-resistant coating composed of fluoropolymers (e.g., Intersleek 1100SR). These compounds can bioaccumulate, and several are known to the State of California to cause reproductive toxicity in humans[1]. However, the leach rates and environmental impacts of fluoropolymer (e.g., PFOA/PFAS) compounds in the marine environment are unknown.

4. **The State of Washington Has Delayed Halting Copper-Based AFP Because No Feasible, Reasonable and Readily-Available Alternative Paint Exists.** Due to findings of several studies, Ecology recommended the Washington State Legislature delay halting copper-based AFP until January 1, 2026, to allow for "feasible, reasonable, and readily-available" alternatives to copper-based AFP (SSB 6210); this recommendation was accepted on June 30, 2020.

[1] The California Safe Drinking Water and Toxics Enforcement Act of 1986, codified at Health and Safety Code Section 25249.5 et seq., and often referred to as Proposition 65.

Available Non-copper AFP Options

There are a wide range of boat hull coatings available for recreational boaters to prevent the attachment of marine organisms, known as fouling. Non-copper AFP can be classified in the following categories (CalEPA 2011):

Containing no biocides:

- **Hard non-biocidal paint**: This paint contains no biocides, but instead contains epoxy and sometimes ceramic to prevent organisms from fouling the hull. Ceramic coatings use hard minerals such as quartz to create a hard-protective coating that is also smooth.
- **Soft non-biocidal paint**: This paint contains no biocides and is based on silicone compounds, fluoropolymers, and wax-like polymers. These types of paint do not function by releasing toxic chemicals to prevent organisms from attaching to the boat hull, but rather as a non-stick surface that makes it more difficult for fouling organisms to attach and easier to remove fouling organisms that have attached on the surface. The coatings are soft, and vigorous cleaning (or scratching) may damage the antifouling coating, resulting in ineffectiveness. (Northwest Green Chemistry 2017).
- **Photoactive non-biocidal coating**: This coating is designed to interact with water and light to produce hydrogen peroxide at the hull surface, thereby deterring fouling. These paints usually contain zinc-oxide; the zinc acts as a catalyst in the formation of hydrogen peroxide. Zinc-oxide is not regulated as a biocide (Northwest Green Chemistry 2017).

Containing biocide:

- **Zinc biocidal paint**: This paint usually contains zinc pyrithione as a zinc biocide and often contains zinc-oxide, which functions as an adjuvant or a material that aids in the effect of another component.
- **Organic biocidal paint**: This paint often contains Tralopyril/Econea, an organic biocide that has emerged in the last several years and generally contains zinc-oxide.
- **Zinc/organic biocide combination paint**: This paint often contains Cybutryne/Irgarol 1051, a “booster” biocide that is currently prohibited for sale or use within the European Union (EU 2018), or DCOIT/Sea-Nine, a “broad spectrum” biocide designed to be used in combination with another biocide.

Evaluations of Non-copper AFPs

Non-copper AFPs were evaluated as alternatives to copper-based paint in a series of five studies commissioned by the USEPA, CalEPA DTSC, and Ecology over the past decade. First, a USEPA study (**1**) was conducted in collaboration with the Port of San Diego (2011). This study evaluated 46 paints, including copper and zinc biocidal AFP and non-biocidal AFP. A CalEPA 2011 study (**2**) immediately followed, comparing newly-developed non-biocidal AFP to the USEPA-recommended non-biocidal AFPs. Based on the USEPA and CalEPA studies, Ecology (2014) commissioned a study to further evaluate six potential paints and compare their performance and risks to copper-based AFP (**3**). After these studies were published, a multi-stakeholder alternatives assessment study was conducted and published in 2017 by Northwest Green Chemistry (a nonprofit organization) in collaboration with Ecology (**4**). Following the publication of the 2017 Northwest Green Chemistry report, Ecology (2019) was directed by the Washington State Legislature to further review recent AFP risk assessments and scientific studies; the resulting Ecology AFP report was published in 2019 (**5**).

Most of these studies included evaluations of non-copper biocidal AFPs (e.g., zinc-based paints); however, this memorandum only includes the findings for non-biocidal AFPs, as the RWQCB is expected to recommend the use of non-biocidal coatings (Santa Ana RWQCB 2018). Findings from each of the five studies are summarized below.

1. USEPA 2011 Study: *Safer Alternatives to Copper Antifouling Paints for Marine Vessels*

The Institute for Research and Technical Assistance (IRTA), in collaboration with Port of San Diego, evaluated potential alternative antifouling paints (USEPA 2011). The study was funded by USEPA.

Forty-six non-copper AFPs were evaluated for performance, longevity, and cost via two phases: 1) panel testing; and 2) boat hull testing. The paints tested included 16 zinc biocide paints and four organic biocides, two zinc-oxide paints, and 24 non-biocidal paints such as epoxies and silicone paints. The panel testing was to evaluate whether test paints were effective in repelling or preventing growth, and ease of cleaning. The panel testing identified 21 top performing test paints, including five non-biocide paints, 14 zinc paints, and two organic biocide paints.

Among the top 21, 11 were screened further with the priority on non-biocidal paints for the boat hull testing. The 11 paints included six non-biocide paints, two zinc-oxide paints, two active zinc biocide paints, and one organic-biocide paint. The 11 selected paints were applied to boat hulls and evaluated for approximately 20 months for fouling growth (the amount of fouling present, its location on the boat hulls, and the types of fouling), cleaning effort (the level of effort required to clean the hulls), and test paint condition (test paint integrity). The top performing test paints included two non-

biocidal products (Intersleek 900 and Hempasil X3) and two zinc-biocide products (Ecominder and Seaguard HMF). See Table 1 for a summary the evaluation of the 8 non-biocidal paints.

The study concluded that Intersleek 900 and Hempasil X3 were the best alternative paints tested in the study. Both soft non-biocidal paints ranked high in the performance evaluation of the hull testing, were cost effective over the long-term, and were available on the retail market. Note that both Intersleek 900 and Hempasil X3 are multi-component coating systems. Application of these products requires both a tie coat (to bind paint to the hull) and a primer (to be applied prior to the application of a topcoat). The Intersleek 900 coating tested in the study consisted of Intersleek 970 White Part A as top-coat and Veridian Tie Coat as tie coat (CalEPA 2011). Since the study was completed, the manufacturer of Intersleek 900 has changed formulations and Veridian Tie Coat is no longer available in the U.S. market. The currently-available alternative, Intersleek 1100SR, consists of multiple Intersleek products, some of which were not available at the time of the study.[2]

These products were designed for larger oceangoing vessels. A representative from the boat paint manufacturer for Interlux Paint Company testified at the Los Angeles Water Board hearing in February 2014 that soft non-biocidal paints, such as Intersleek 900 and Hempasil X3, are designed for oceangoing commercial vessels (e.g., container ships) that continuously move through the oceans at high speeds, providing the needed self-cleaning effect, and are not designed for small recreational vessels, which may remain docked for months at a time.

Table 1. Evaluation of Paint Performance Conducted in the Hull Testing Phase of the USEPA 2011 Study

Type	Paint	Hull testing	Recommended as an Alternative by the Study	Currently Available for Sale
Non-biocidal	Hempasil X3 (87500)	Yes	Yes[1]	Yes[2]
	Intersleek 900	Yes	Yes[1]	Yes, but formulation changed[3]
	Klear N' Klean XP-A100	Yes	No	-
	Phase Coat Bare Bottom	No[4]	No	-
	PropSpeed	No[4]	No	-
	VC Performance Epoxy	Yes	No	-
Non-biocidal zinc-oxide	Sunwave	Yes	No	-
	EP-21	Yes	No	-

Notes:

- *Indicates that the current availability for sale has not been confirmed since the studies (USEPA 2011, CalEPA 2011, and Ecology 2014)*

[2] For more details regarding Intersleek 1100SR, see https://www.international-marine.com/product/intersleek-1100sr

[1] *Designed for oceangoing commercial vessels, such as container ships, that continuously move through the oceans at high speeds, providing the needed self-cleaning effect and not designed for small recreational vessels*

[2] *Available for purchase from Hempel (USA), Inc. as of July 23, 2020*

[3] *The exact Intersleek 900 tested in the study is no longer available because the manufacture changed formulations. Intersleek 1100SR is available for purchase from International Paint Company, LLC. as of July 23, 2020. For more details regarding Intersleek 1100SR see https://www.international-marine.com/product/intersleek-1100sr*

[4] *Boat removed from study due to ineffectiveness of product as applied to the boat or delaminating from hull*

2. CalEPA 2011 Study: *Safer Alternatives to Copper Antifouling Paints: Non-biocidal Paint Options*

Sponsored by USEPA Region IX and CalEPA's DTSC, the CalEPA 2011 study further investigated the performance of non-biocidal paints via panel and boat testing. The study conducted panel testing of newly developed non-biocidal paints in addition to those tested in the USEPA 2011 study, including seven soft non-biocidal paints, six hard non-biocidal paints, and four other non-biocidal paints (Table 2). Panel testing involved inspecting panels with non-biocidal paints for the level of fouling, the ease of cleaning, and the overall paint condition.

The study concluded that soft non-biocidal paints performed better than the hard non-biocidal paints and other non-biocidal paints (Table 2) primarily because they were much easier to clean. The performance of the hard non-biocidal paints and the other non-biocidal paints in the panel testing is difficult to evaluate and compare because hard non-biocidal paints require periodic or routine cleaning with a power tool and are not effectively cleaned with hand tools underwater. The additional costs associated with the required haul out for cleaning make these paints less desirable than other alternatives.

Seven non-biocidal paints were tested on ten boats, including the top three performing paints from the panel testing of the study (Klear N' Klean XP-A101, Hempasil XA 278, and Sher-Release), one paint that had been included in the panel testing but not in the boat testing in the USEPA 2011 study (BottomSpeed), two of the top performing paints evaluated in the USEPA 2011 study (Intersleek 900 and Hempasil X3), and one additional emerging paint that had not been tested on panels (XZM 480). The boat testing indicated that Klear N' Klean XP-A101, XA 278, BottomSpeed, and Sher-Release performed better than other emerging non-biocidal paints. XZM 480 did not adhere to the hull properly for hull protection. Note that Klear N' Klean XP-A101 had been applied only 2 months before the study was completed, which was not long enough to confirm the performance of XP-A101.

Out of the six highest-performing paints of the study, only Hempasil X3 is currently available in the same form. Intersleek 900 has changed formulations; the current form is offered for sale as Intersleek 1100SR. XP-A101 contains an ingredient that has since been removed from the market (USEPA 2011), so it cannot be offered for sale. XA 278, BottomSpeed, and Sher-Release have since been removed from the market as well.

Table 2. Paints Evaluated in the CalEPA 2011 Study

Category	Paint	Panel Tested	Hull Tested	Recommended as an Alternative	Currently Available for Sale
Soft non-biocidal	Klear N' Klean XP-A100	Yes	No	No	-
	Klear N' Klean Plus XP-A101	Yes	Yes	Yes	No
	Sher-Release (or Surface Coat Part A-Black)	Yes	Yes	Yes	No
	XZM 480	No	Yes	No	-
	Hempasil XA 278	Yes	Yes	Yes	No
	Hempasil XA 284	Yes	No	No	-
	XQQ075	Yes	No	No	-
	Intersleek 900	No	Yes	Yes[1]	Yes, but formulation changed[2]
	Hempasil X3	No	Yes	Yes[1]	Yes[3]
	BottomSpeed Top Coat Clear and BottomSpeed TC Base Coat	No	Yes	Yes	No
Hard non-biocidal	HullSpeed 3075	Yes	No	No	-
	HabraCoat	Yes	No	No	-
	Easy On Bottom Wax	Yes	No	No	-
	HullSpeed 3080	Yes	No	No	-
	Oxilane	Yes	No	No	-
	Crystal Marine Pro	Yes	No	No	-
Other non-biocidal[4]	W.A.V.E.	Yes	No	No	No
	SmartBottom	Yes	No	No	No
	Seashell SK9	Yes	No	No	No
	Seashell SK9-S	Yes	No	No	No

Notes:

- *Indicates that the current availability for sale has not been confirmed since the studies (USEPA 2011, CalEPA 2011, and Ecology 2014)*

[1] *Intersleek 900 and Hempasil X3 were reviewed positively in the study but were not explicitly named in the discussion, which was limited to recently developed (or "emerging") non-biocidal paints. For this review, the positive findings were implied as recommended.*

[2] *The exact Intersleek 900 tested in the study is no longer available because the manufacture changed formulations. Intersleek 1100SR is available for purchase from International Paint Company, LLC. as of July 23, 2020. For more details regarding Intersleek 1100SR see https://www.international-marine.com/product/intersleek-1100sr*

[3] *Hempasil X3 is available for purchase from Hempel (USA) Inc. as of July 23, 2020*

[4] *All non-biocidal paints in "other" category are no longer for sale, and information on ingredients or antifouling mechanisms is not available. CalEPA 2011 study contains no further information on these paints*

3. Ecology 2014 Study: *Assessing Alternatives to Copper Antifouling Paint: Piloting the Interstate Chemicals Clearinghouse (IC2) Alternatives Assessment Guide*

Ecology commissioned a study (Ecology 2014) to evaluate non-biocidal paints using the Interstate Chemicals Clearinghouse (IC2) Guide. The IC2 Guide was an alternative assessment tool developed by a team consisting of state and federal health and environmental agencies, including CalEPA DTSC. USEPA and Ecology funded the development of the IC2 Guide, which was intended to be "a set of tools that manufacturers, product designers, businesses, governments, and other interested parties can use to make better, more informed decisions about the use of toxic chemicals in their products or processes" (IC2 2013). The IC2 Guide uses four different assessments to evaluate alternatives: 1) hazard assessment: human health, environmental, and physical hazards posed by individual chemicals in alternatives; 2) performance assessment; 3) cost and availability assessment; and 4) exposure assessment: potential exposure pathways to environment and potential risk based on physical-chemical properties of chemicals in alternatives.

In the Ecology 2014 study, six soft non-biocidal paints were selected based on their performance in the USEPA 2011 and CalEPA 2011 studies and compared to one copper-based paint as a control (Table 3). Three different groups of assessors conducted the evaluation of these seven paints via one of three alternative assessment frameworks (sequential, simultaneous, and hybrid); each assessment was conducted independently. Although the three frameworks do not differ in their fundamental approaches, the IC2 Guide contains limited decision-making guidance. The three groups of assessors applied different approaches when handling issues related to the elimination of paints and data gaps in the hazard evaluations. As a result, selected preferable alternatives differ among the three frameworks.

A summary of the alternative evaluation conducted for all three IC2 Guide frameworks is presented in Figure 3 of Ecology (2014). Overall, three non-biocidal paints, Intersleek 900, BottomSpeed TC Base Coat/Top Coat Clear, and Surface Coat Part A – Black, were determined to be preferred by at least one of three frameworks in the IC2 Guide evaluations.[3] A summary of all evaluated paints is provided in Table 3.

Despite selecting three preferred non-biocidal paints, the study concluded that the safety of the test paints was uncertain and none of the tested non-biocidal paints were ideal alternatives to copper-based paint. As discussed in the hazard assessment in detail, all formulations contain hazardous chemicals that pose human health and/or

[3] BottomSpeed and Surface Coat Part A are no longer available.

environmental risks and are categorized to be avoided.[4] Furthermore, the hazard assessment was limited and incomplete due to the undisclosed chemicals in the primers and the paints. As stated in Ecology (2014; pg. i):

> *"Although the assessors were able to select preferred alternatives, results indicated that none of them was a good alternative to copper antifouling paint. Some appeared to be slightly preferable to the copper antifouling paint in terms of hazard, but they all contained chemicals that posed human health and environmental concerns. Therefore, the selection of preferred alternatives does not constitute an endorsement because significant reservations remain. Data gaps due to minimal disclosure of chemicals coupled with the difference in decision rules resulted in uncertainty."*

Table 3. Paints Evaluated in the Ecology 2014 Study

Type	Paint	Recommended as Preferred Alternative by the Study	Currently Available for Sale
Soft non-biocidal paints	Surface Coat Part A – Black (Sher-Release)	Yes[1,2]	No
	Intersleek 900	Yes[1,3]	Yes, but formulation changed[4]
	BottomSpeed TC Base Coat/Top Coat Clear	Yes[1,5]	No
	XZM480 International	No	-
	Hempasil XA278	No	No
	Klear N' Klean Plus XP-A101 White Topcoat	No	-
Copper-based paint	Pettit Marine Paint Trinidad Pro Antifouling Bottom Paint 1082 Blue	Control for comparison	-

- Indicates that the current availability for sale has not been confirmed since the studies (USEPA 2011, CalEPA 2011, and Ecology 2014)

[1] All three paints identified as preferred contain hazardous chemicals that pose human health and/or environmental risks and are categorized to be avoided. From Ecology (2014; pg. i), "the selection of preferred alternatives does not constitute an endorsement because significant reservations remain"

[2] The hybrid framework concluded that Surface Coat Part A-Black contains a chemical with equivalent hazard concern as the copper control

[3] The simultaneous framework concluded that Intersleek 900 could be either similar or worse than the copper control for the hazard

[4] The exact Intersleek 900 tested in the study is no longer available because the manufacture changed formulations. Intersleek 1100SR is available for purchase from International Paint Company, LLC. as of July 23, 2020. For more details regarding Intersleek 1100SR see https://www.international-marine.com/product/intersleek-1100sr

[5] The simultaneous framework concluded that it was uncertain whether BottomSpeed was better or worse than the copper control for the hazard

[4] These are chemicals that have a combination of either high persistence in environment, high bioaccumulation potential, and high human toxicity or ecotoxicity, and are recommended to avoid.

4. Northwest Green Chemistry 2017 Study: *Washington State Antifouling Boat Paint Alternatives Assessment Report*

Ecology engaged the team of TechLaw, Inc. and Northwest Green Chemistry to identify and evaluate alternatives to copper antifouling boat paints. In the resulting alternatives assessment study, the stakeholder team assessed 17 AFP coatings for boats, including 13 biocidal and four non-biocidal coatings (Coval Marine and Hull Coat, CeRam-Kote 54 SST, Aurora Marine VS721, and ePaint EP-21). The alternatives assessment considered hazards to human and environmental health impacts, exposure to workers (do-it-yourself boat maintenance) and exposure to marine environment, paint performance (the likelihood it will be used by boaters), and cost and availability of the paints.

The alternatives analysis determined paint performance by using information previously collected as part of the USEPA 2011 study (Study #1 discussed above) and a Practical Sailor panel and hull test (Practical Sailor 2017). To support the objectives of this memorandum, only the findings on performance of the non-biocidal AFPs are discussed here. Of the four non-biocidal paints evaluated in the Northwest Green Chemistry analysis, only ePaint EP-21 was field-tested (Practical Sailor 2017 and USEPA 2011). This paint performed poorly in the USEPA (2011) study, coming off the vessel at the waterline in 7 months[5] (Table 1).

The alternatives assessment confirmed that less hazardous alternatives to copper AFPs are available, but the report did not recommend any particular paint because of the diversity of boater needs. In addition, three of the non-biocide paints were found to have data gaps, with no available data to assess performance, and one paint (EP-21) was found to have mixed results (Table 4).

[5] It is acknowledged that the formula may have changed since this study in 2010.

Table 4. Summary of Alternatives Assessment Results for the Non-biocide Products

Product	Anti-fouling Mechanism	Ingredient Disclosure[1]	Chronic Human (CMRDE[2])	Neuro/ Resp	Biocide	Boatyard COCs (Zinc)	35' boat over 5 years	Overall Recommended[3]	Manufacturer Longevity (year)
Coval Marine & Hull Coat	Foul release ceramic/ quartz	Full	0%	0%	none	0%	$4,035	Data Gap	5
ePaint (EP-21)	Photoactive foul release	Full	15% to 17%	15%	none	16% to 48%	$11,127	Borderline results[4]	1
CeRam-Kote (54 SST)	Foul release ceramic	SDS	26% to 53%	0%	none	0%	$3,887	Data Gap	5
Aurora Marine (VT721)	Foul release polymer/ wax	SDS	0%	0%	none	0%	$12,979	Data Gap	1

Notes:
CMRDE - Carcinogenicity, mutagenicity, reproductive/developmental toxicity, and endocrine disruptors
COCs – Contaminants of Concern
SDS – Safety Data Sheet only

1 *The level of disclosure provided to the reviewers for product assessment. There is more certainty in results for fully disclosed products than for partially disclosed products. Full disclosure is preferred over SDS*

2 *This is the percent of the product made of chemicals that are carcinogens, mutagens, reproductive/ development toxicants, and/or endocrine disruptors. A chemical is considered a CMRDE if it contains any or all of the hazards in the CMRDE group. Its concentration is the concentration of the chemical in the product and is not based on the number of hazards in the CMRDE group*

3 *Evaluation based on San Diego report on copper free marine coatings (USEPA 2011) and Practical Sailor's panel testing results (2017)*

4 *Defined as uncertain if this product will or will not meet manufacturers' claims. Available evidence was mixed or consistently mediocre*

5. Ecology 2019 Study: *Antifouling Paints in Washington State: Report and Recommendations*

Ecology was directed by the Washington State Legislature to review recent risk assessments and scientific literature regarding alternatives to copper-based AFPs. Unlike previously-discussed assessments, the Ecology 2019 report focused on the toxicity and availability of *types* of alternative AFPs rather than specific products. The report included assessments of biocidal and non-biocidal AFPs, as well as non-coating antifouling measures. However, to support the objectives of this memorandum, only findings related to the safety and performance of non-biocidal AFPs are discussed here.

Recent studies and risk assessments of non-biocidal AFPs have primarily focused on silicone- and/or fluorine-based (e.g., Teflon) coatings. Ecology (2019) found that silicone-based coatings are most effective at limiting biofouling; however, these coatings do not prevent the growth of diatom-based brown slimes (RVIM 2018). Silicone-based coatings also damage easily and require professional application. Recent studies have also suggested that silicone-based coatings leach silicone compounds into the surrounding water. Silicone is a persistent chemical in the environment (Ecology 2017 and 2019), yet the environmental implications of silicone leaching have not been examined.

Fluorinated polymer-based coatings, which use PTFE (Teflon), PFOA, and PFAS compounds, have similar data gaps. Studies have shown that these compounds are stable despite changes in pH, salinity, temperature, and sunlight. However, these compounds can be bioaccumulative, and the leach rates and environmental impacts of PFOA/PFAS compounds in the marine environment are unknown (Ecology 2019).

Ecology was unable to recommend either silicone- or fluorine-based non-biocidal coatings due to continuing research regarding the environmental impacts of these compounds in marine environments. Consequently, recent recommendations regarding copper AFPs have emphasized non-coating alternatives (such as routine brushings, floating docks, and out-of-water storage) rather than non-copper AFPs, and have encouraged the delay of restrictions on copper-based AFPs for further development and toxicity studies of viable alternatives.

Summary of Alternative AFP Evaluations

In response to the claims of readily-available nontoxic (i.e., non-biocidal) paints and the potential use of alternative biocidal AFPs, a summary of the findings from five studies commissioned by the USEPA, CalEPA, and Ecology were reviewed.

1. **In the USEPA 2011 study, only two paints were found to be effective in replacing copper-based paints: Intersleek 900 and Hempasil X3. Neither was designed for small, and mostly stationary, recreational vessels.** Since the study was completed, the manufacturer of Intersleek 900, International Paint Company, LLC, has changed formulations and the exact Intersleek 900 that was tested is no longer available in the U.S. market. At the time of the study, the manufacturer did not recommend the Intersleek paint for recreational vessels because the product is designed for oceangoing commercial vessels, such as tanker or container ships, that continuously move through oceans at high speeds, providing the needed self-cleaning effect. This limitation also applies to Hempasil X3, the other soft non-biocidal paint recommended in the study.
2. **Only one of the best-performing non-biocidal paints in the CalEPA 2011 study, Hempasil X3, is currently available in the same form.**
3. **The Ecology 2014 study concluded that the safety of the test paints was uncertain, and none of the tested non-biocidal paints were ideal alternatives to copper-based paint.** One non-biocidal paint, Intersleek 900, showed somewhat positive results. However, a hazard assessment conducted as a part of the same study revealed that all tested formulations contained hazardous chemicals that could pose human health and/or environmental risks as a result of their use. Furthermore, the hazard assessment was limited and incomplete due to undisclosed chemicals in the primers and paints.
4. **The Northwest Green Chemistry 2017 alternatives assessment did not recommend any particular paint because of the diversity of boater needs.** The report confirmed that less hazardous alternatives to copper AFPs are available, but sufficient information was not available for the four evaluated non-biocidal coatings to determine the performance of these paints. Furthermore, Ecology (2017) acknowledged that there is little data to show how the few available non-biocidal AFP affect aquatic life or water quality.
5. **The Ecology 2019 review found that adequate information regarding the environmental safety of non-biocidal alternatives is not currently available**; in addition, many of the available alternatives to copper-based AFP may cause greater environmental harm.

Following the recommendations of Ecology (2017 and 2019), the **Washington State Legislature has delayed halting copper-based AFPs until January 1, 2026**, pending "feasible, reasonable, and readily-available" alternatives to copper-based AFPs by June 30, 2024 (SSB 6210).

Concerns Regarding Alternative AFP Availability and Safety

This review demonstrates continued concerns regarding the availability and proven effectiveness and safety of alternative AFP. There are only two non-biocidal paints tested in these studies that are still available (Table 5) and were recommended in one or more studies. Only one of these paints is still available with the tested formulation. Both paints are designed for commercial vessels and must be applied by professionals. Even though the paints are recommended as alternatives to copper, Ecology (2014, 2017, and 2019) maintains concerns over hazardous chemicals within the paints that could pose risks to humans and the marine environment. These concerns extend to many of the paints evaluated, which do not have full disclosure of ingredients because of proprietary rights and use compounds which have not been tested for use in marine systems.

Table 5. Summary of Non-biocidal Paints Recommended in USEPA (2011), CalEPA (2011), or Ecology (2014), and Available as of July 23, 2020

Paint	Reference
Hempel (USA), Inc.'s Hempasil X3 (87500)	USEPA 2011, CalEPA 2011
International Paint LLC's Intersleek 900 (*currently 1100SR*)	USEPA 2011, CalEPA 2011, Ecology 2014

Use of Commercial Paint on Recreational Vessels

Concerns regarding the applicability of these paints (which were designed for commercial use) to the recreational boating industry remain. These paints were designed to be self-cleaning, and manufacturers assume the vessels are underway a significant portion of the time and at specified speeds. These paints are soft coatings that will be damaged by bumping and scratching, which will limit their effectiveness at sloughing organisms.

Furthermore, these paints have not been assessed to determine impacts of high concentration of use on vessels in enclosed areas. The same processes that are leading to the buildup of copper in the water column could lead to a buildup of lesser-understood chemicals. It is the opinion of the authors that these compounds are likely not a concern for commercial vessels that are continuously moving across large waterbodies. However, it could be an environmental concern if a large number of vessels that reside in a specific area use the same AFP that has not been tested for impacts in a recreational harbor. The fluoropolymer paints serve as an example. Though not evaluated in the Northwest Green Chemistry 2017 study, the report discusses specialized coatings that include highly fluorinated compounds (e.g., Intersleek). The report states that highly fluorinated compounds tend to be extraordinarily persistent in the environment. It is believed most of the highly fluorinated compounds are bound up in the polymer matrix, but residual monomers may be free to leach. The potential for new contaminants of concern in enclosed marinas has not been fully studied and, therefore, advocates for specific paints should be cautious until more studies can demonstrate they are truly safe for human and environmental resources.

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