Toxicity of copper

It is well established that copper is toxic to many different marine organisms above a certain concentration (USEPA, 2016). The U.S Environmental Protection Agency has determined the toxicity threshold for copper which is given as two separate values. A chronic value which is the toxic threshold during continuous exposure and an acute value which is deemed to be toxic if an organism is exposed to this concentration for more than 1 hour a day (USEPA, 2016). These two values are the primary benchmarks when evaluating the abundance of copper in the environment and if it has accumulated to toxic levels.

Environmental accumulation of copper

Several studies have shown that accumulated copper levels in the environment often increase above the chronic and acute toxicity levels as set by the EPA. This is primarily observed in water bodies with a low water flow such as marinas and estuaries. Examples are presented below:

Example 1: A 2009 report by the California Department of Pesticide regulation found that the dissolved copper concentrations in more than half the water samples taken from salt and brackish water marinas exceeded the U.S. Environmental Protection Agency (U.S. EPA) California Toxics Rule chronic water quality standard for copper, a criterion intended to protect aquatic life. In addition, about one-third of the water samples exceeded the acute water quality standard for copper. California Department of Pesticide regulation also observed toxicity to aquatic test organisms in some marina samples that was likely caused by high dissolved copper concentrations (ref: California DPR, Monitoring for Indicators of Antifouling Paint Pollution in California Marinas).

Example 2: The Washington state department detected copper concentrations exceeding acute and chronic water quality levels (as set by the EPA) in two of two harbours tested in Puget Sound. In the inner parts of the marinas, dissolved copper concentrations exceeded the acute and chronic criteria by factors of 2–4 (https://apps.ecology.wa.gov/publications/documents/0703037.pdf).

Example 3: Similar observations have been made in harbours in Sweden (Kylin & Haglund, 2010; Lagerström et al., 2020) and Finland (Lagerström et al., 2020) with copper concentrations exceeding the Environmental Quality Standards set by the EU.

Origin of environmental copper

Today, approx. 80-90% of the world's vessels are coated with antifouling paint containing copper. Many studies have shown that copper leaching form the antifouling paint is a large contributor to copper accumulation in the environment, especially in water bodies with a lot of boats and a low water flow such as marinas and estuaries. For example, a California regional water quality control board investigation of the dissolved copper concentrations in the Shelter Island Yacht Basin (SIYB) in San Diego concluded that approximately 98 percent of the total copper in the SIYB originates from copper-based antifouling paints applied to the hulls of recreational vessels moored in SIYB marinas. Of this total, 93 percent is attributable to copper entering the water column through passive leaching of copper from antifouling paints. The remaining five percent enters the water column during periodic underwater hull cleaning of recreational vessel hulls in the marinas (California regional water quality control board, 2005).

Legislation to prevent environmental copper accumulation

To prevent further accumulation of copper in the environment, several environmental agencies have implemented legislation to either ban or restrict the use of copper based antifouling products in both freshwater and marine environment. For example:

Example 1 – Washinton state, U.S: Originally proposed to ban the use of copper by 2021, but due to a lack of alternative products with a proven superior environmental profile, this ban has been delayed to 2026.
Example 2 – Sweden: Implemented restrictions on leaching rates depending on the regional salinity and fouling pressure. In the northern part of the Baltic Sea (the Bothnian Bay) and in freshwaters, no copper is allowed
Example 3 – Netherlands: Implemented restrictions on copper content in antifouling paints using for recreational boats.
Example 4 – California state, US: Implemented restrictions on copper leaching rates for antifouling paints used for recreational boats.

Lack of alternatives

Extensive work commissioned by the Washinton State department of Ecology have shown that there is currently no alternative to copper based antifouling paints that are less harmful to both people and the environment while retaining the antifouling efficiency (Report, 2017; *Report to the Legislature on Non-Copper Antifouling Paints for Recreational Vessels In*, 2017; State, 2019). This was supported by a report from ToxServices LLC which found that there are currently ***zero*** commercially available non-Cu based antifouling products that are safer and perform as well as Cu antifouling products (Whittaker, 2018).

The lack of alternative "green" biocides for use in antifouling is also evident when examining the EU chemicals agency article 95 which is a list of biocides approved for use in antifouling products. This list currently has 11 different chemicals, with only a single new addition since the list was generated in 2014. (https://echa.europa.eu/documents/10162/5604808/art_95_list_en.pdf/c752c5ae-358c-e84b-652a-fb98106dfe8e?t=1635331888300).

Lastly, not using any antifouling coating is not an option either:
If no biocide is added to the bottom coating, unwanted organisms can attach to the hull, increasing the ship's water resistance, which in turn decreases speed and increases fuel usage and shipping costs significantly (Lindholdt et al., 2015). For example, biofouling increased shipping costs by 77 percent for a ship sailing from San Francisco to Yokohoma, Japan (Abbott et al., 2000). Beyond the economic consequences, the increase in fuel usage also has an environmental cost, since it increases the emission of harmful gasses such as CO_2 (Tian et al., 2021). The use of paint without biocides will also increase the risk of the ship transmitting invasive species from one ecosystem to another (Lehtiniemi & Outinen, 2021). Clearly, it is neither economically nor environmentally favorable to eliminate biocides from antifouling paint.

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