Planktonic:

In-water Intervention and Prevention Strategy
Substantial Supporting Field Data

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Copper algaecides have been used to treat problematic algae and cyanobacteria for more than a century due to their effectiveness (Moore and Kellerman 1905). As such, copper algaecides have been extensively evaluated, and numerous peer-reviewed publications have increased our understanding of copper algaecide efficacy, copper fate, and potential off-target aquatic life impacts (Calomeni, Rodgers, and Kinley-Baird 2014, Fitzgerald and Faust 1963, Gibson 1972, Iwinski et al. 2017, Kinley et al. 2017, Murray-Gulde et al. 2002). Cyanobacterial responses to copper algaecides are concentration dependent. At effective concentrations of copper algaecides, respiration and photosynthesis rates can be decreased, leading to a decrease in cell density (Calomeni, Rodgers, and Kinley-Baird 2014). At higher concentrations, copper algaecides impact cell integrity, causing cell lysis and decreased viability (Gibson 1972, Iwinski et al. 2016).

There are a variety of forms of copper algaecides, and cyanobacterial responses to these algaecides range as a function of innate cyanobacterial sensitivities (Calomeni, Rodgers, and Kinley-Baird 2014, Iwinski et al. 2017), abundances (Calomeni et al. 2018, Kinley et al. 2017), exposure durations (Calomeni et al. 2018), site characteristics (water hardness, alkalinity, conductivity, pH), and the copper-based algaecide applied (Fitzgerald and Faust 1963, Murray-Gulde et al. 2002). Copper algaecides include copper sulfate, acidified copper products, and chelated copper algaecides (copper ethanolamine, copper citrate, and copper gluconate). Copper algaecides have different trade names and are registered with the U.S. Environmental Protection Agency (USEPA) for treatment of excessive algae and cyanobacteria. The product's label specifies how the compounds may be applied in lakes, reservoirs, ponds, irrigation canals, and other water bodies. To be effective, a treatment manager should closely follow the label instructions provided. The algaecide must be applied so that the active ingredient contacts the problematic alga or cyanobacterium. When selecting a copper product to use for the treatment of harmful benthic blooms a product that can effectively reach the population should be selected. Anderson et al. (2019) found that the copper product with the highest density was most effective at treating benthic *Lyngbya wollei* populations, largely because of the increased interaction it had with the benthic mats. Granular copper sulfate of large size has also been found to be effective in reaching benthic mats before it dissolves in the water column (McGuire et al. 1984). Benthic cyanobacteria mats often have thick mucilage protecting the cells, and copper products with surfactants degrade the mucilage, making cells susceptible to the copper (Wood et al. 2020). Following an effective algaecide application, cell and population responses can be measured in as little as one day after treatment (Bishop and Rodgers 2011, Isaacs et al. 2013).

Copper algaecides are often applied when harmful algae and cyanobacteria achieve high densities, produce cyanotoxins, or produce taste and odor compounds that pose risks or interfere with the uses of water resources. The timing of algaecide treatments is often important to ensure treatment success and may limit potential adverse impacts of the cyanobacteria. A detailed management plan that includes monitoring of the cyanobacteria issue and explicit triggers for treatments with respect to a measured cyanobacterial cell density, cyanotoxin concentration, or taste and odor compound concentration (Calomeni et al. 2017) is useful for ensuring well-timed treatments for sites that experience recurring HCB issues.

PLANKTONIC AND BENTHIC
EFFECTIVENESS • Any water body type • Any depth • Surface area: Algaecide labels may specify applicable area (for example, maximum of half of the surface area of the water body can be treated at one time) • Any trophic state • Any mixing regime • Water body uses: Algaecide labels will specify applicable uses

NATURE OF HCB • Single or repeating HCBs • Algal or cyanobacterial sensitivities to copper algaecides vary, but cyanobacteria are often more sensitive to copper algaecides than green algae • Intervention and prevention strategy
ADVANTAGES • Rapid • More than a century of use and effectiveness in the United States • Scalable • Can be used to target specific problematic algal or cyanobacterial species
LIMITATIONS • Because copper is a USEPA priority pollutant with national water quality standards, National Pollutant Discharge Elimination System (NPDES) permits or state/territory/tribe-specific equivalent permits are required for treatment in waters of the United States. There also may be location-specific requirements on use or nonuse. • Care is required when treating algae or cyanobacteria in soft waters due to the sensitivities of off-target species; copper algaecides can cause toxicity to some fish and invertebrates under certain conditions. • Frequent application can lead to copper accumulation in sediments and potential adverse effects. • Dissolved oxygen reduction may result from decomposing algae. • Toxin release from lysed cells.

Copper algaecides have been applied in water bodies across the United States when problematic algae and cyanobacteria interfere with critical water resource uses and have mitigated nuisance bloom impacts to designated uses. Sites where copper algaecides have been effective range widely in terms of designated water resource uses, problematic algae or cyanobacteria, size (small ponds to thousands of hectare reservoirs), and trophic status. Copper algaecide applications can be scaled to the appropriate size for the water body but should be staged to reduce harmful side effects of the treatment.

There are a wide range of copper algaecides on the market. Many are designed to specifically eliminate a target group of algae, cyanobacteria, or aquatic plants. While copper is a micronutrient and naturally present in many waters, copper applications can affect aquatic life, including fish and macroinvertebrates, under certain conditions (USEPA 1984). Copper may also accumulate in the bottom sediments over time (Hanson and Stefan 1984, Paul, Cruz-Rivera, and Thacker 2001), where there is potential for direct interaction with benthic organisms or for the copper to become solubilized into the water (Hanson and Stefan 1984, MacDonald, Ingersoll, and Berger 2000). Soldo and Behra (2000) found that long-term exposure of benthic communities to copper caused a dominance shift from cyanobacteria to green algae (Chlorophytes). Copper treatments can also lead to reduced dissolved oxygen due to decomposition from dying algae. It is important to follow the manufacturer’s label. You should also have a good understanding of your local water and sediment chemistry, as well as any previous cyanobacteria control efforts, when considering the use of copper algaecides. Pre- and post-application monitoring should be part of your management plan to assist you with evaluation of treatment success and potential adverse effects.

COST ANALYSIS

The cost of a treatment is a function of the area treated, labor, product used, and severity of the problematic algal or cyanobacterial issue. One previous study in New York had a $933/acre treatment cost (See Appendix C.2 in ITRC 2021) (ITRC 2021).

Relative cost per growing season: Copper algaecides

ITEM	RELATIVE COST PER GROWING SEASON
Material	$
Personal Protective Equipment	$$
Equipment	$$

Machinery	$
Tools	$
Labor	$$
OVERALL	**$**

REGULATORY AND POLICY CONSIDERATIONS

Copper algaecides require NPDES permits and are also regulated under the Federal Insecticide, Fungicide, and Rodenticide Act. States may have additional restrictions for water bodies with specific uses and require state permits to apply copper-based treatments. The use of a certified pesticide applicator or lake management company is often required. Post-application monitoring may also be required.

CASE STUDY EXAMPLES

Planktonic

Hartwell Lake, Anderson, South Carolina, U.S.: A chelated copper algaecide and a peroxide compound were used to treat problematic algae, cyanobacteria, and their resulting taste and odor compounds, which had generated customer complaints associated with drinking water sourced from Hartwell Lake.

An adaptive water resource management approach was used to develop an effective treatment plan at the site. The approach included identification of the source of taste and odor compounds and small-scale laboratory studies to determine which algaecide should be used for treatment. A pilot treatment was applied initially, followed by three full-scale treatments during the growth season of the problematic species.

The adaptive water resource management approach and chelated copper algaecide and peroxide treatments eliminated customer complaints. This approach also resulted in a 50% cost savings relative to the previous year, when powder-activated carbon was used in-plant to manage taste and odor in potable water.

More information on this case study can be found in Huddleston et al. (2016).

Benthic

Three reservoirs in central Alabama, U.S.: Lay Lake, Jordan Lake, and Lake Mitchell

A long-term adaptive management program using multiple treatment strategies on *Lyngbya wollei* benthic mats was implemented to reduce populations impeding critical water resource uses.

Algaecides investigated included a variety of copper formulations. A double-chelated copper algaecide with surfactants and emulsifiers was found to be the most effective at reducing acres requiring treatment due to *L. wollei*.

More information on this case study can be found in Huddleston et al. (2016).

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