Planktonic:

In-water Prevention Strategy
Limited Supporting Field Data

Benthic:

In-water Prevention Strategy
No Available Supporting Field Data

Cyanobacteria contain the photosynthetic pigment chlorophyll-a along with phycobiliproteins that allow them to use light energy more efficiently than other phytoplankton. Turbidity, stratification, and water color can influence the amount of sunlight captured by the pigments. Some planktonic cyanobacteria can regulate their buoyancy and position in the euphotic zone (depth at which 1% of the sunlight can penetrate) to maximize their sunlight-capturing ability, while benthic cyanobacteria are limited by the sunlight penetration through the entire water column. Therefore, light is the major factor determining cyanobacteria distribution in the water column or attachment to benthic substrates, followed by temperature, nutrient availability, and sheer stress associated with wave action. To reduce the amount of sunlight available for photosynthesis, dyes may be added to ponds and small lakes to physically filter sunlight with the goal of reducing cyanobacteria growth. Light-attenuating dyes do not destroy cell structure or kill cyanobacteria.

A commercial dye product can be added to the shoreline of ponds or small lakes beginning in spring and periodically during the growing season to reduce the potential for and severity of HCBs. These nontoxic dyes naturally disperse and can filter out certain light spectra, reducing light penetration and shading the water body. Dyes are available in blue, black, and other colors. Testing suggests that dyes are likely to be most effective on aquatic plants, algae, and cyanobacteria at least 2 feet below the surface (NYSFOLA 2009). Commercial dyes for this application have been available in the marketplace for decades, but there is limited published scientific demonstration of their effectiveness.

Application rates will vary by dye manufacturer, but dosing rates of commonly used dyes are in the range of 1–2 gallons of dye solution per million gallons of water (Madsen et al. 1999). After initial dye dosing, periodic re-doses are necessary to maintain the shade color and light-filtering properties and counter dye fading and dilution from inflowing water (Ludwig, Perschbacher, and Edziyie 2010).

If the pond or small lake is deeper than 2 feet and has a history of repeated cyanobacterial blooms, the dye light filtering and shading approach may be a prevention technology to consider, either alone or in conjunction with other technologies. Method practicality and costs largely hinge on the volume of the water body and the dilution caused by clear-water inflows from streams, springs, etc.; the larger the volume and dilution, the more dye you will need to add. While eutrophic waters are the most likely candidates for the approach, there are no established specific trophic state or mixing regime requirements. Using dye shading to limit photosynthesis may affect growth of some cyanobacterial species more than others, depending on light sensitivity and their relative position in the water column. As a result, you may change the species of algae and cyanobacteria that predominate (NYSFOLA 2009, Suski et al. 2018).

Floating plastic balls have been suggested as another shading option to reduce planktonic cyanobacteria, but they have not been used in HCB control (see Abridged Strategies).

Other forms of shading, especially in smaller rivers and streams, include promoting riparian vegetation canopy cover. However, there are few applied studies that show shading may be an effective management strategy (Lehmann et al. 2015, Read et al. 2014) for controlling benthic cyanobacteria in riverine systems.

PLANKTONIC	BENTHIC
EFFECTIVENESS • Water body types: Pond, lake/reservoir with little to no outflow and rivers • Surface area: Small • Any depth • Trophic state: Eutrophic • Any mixing regime • Water body uses: Recreation, livestock watering, irrigation	**EFFECTIVENESS** • Water body types: Pond, lake/reservoir with little to no outflow and rivers • Surface area: Small • Depths greater than 2 feet • Trophic state: Oligotrophic to eutrophic • Any mixing regime • Water body uses: Recreation, livestock watering, irrigation

NATURE OF HCB • Subsurface HCBs • Toxic and nontoxic HCBs • Prevention strategy	NATURE OF HCB • Benthic HCBs • Toxic and nontoxic HCBs • Prevention strategy
ADVANTAGES • Unlikely carryover after bloom dissipation • Low potential for adverse impacts • Available and relatively inexpensive • Minimal technical expertise, manpower, electricity, or specialized equipment needed for application • Shading dyes are nontoxic to aquatic life when applied at recommended dosage (USEPA 2005, WA Ecology 2016)	**ADVANTAGES** • Low potential for adverse impacts • Available and relatively inexpensive • Minimal technical expertise, manpower, electricity, or specialized equipment needed for application • Shading dyes are nontoxic to aquatic life when applied at recommended dosage (USEPA 2005, WA Ecology 2016)
LIMITATIONS • Cost-effective only for small lakes with longer residence time • Inhibits photosynthesis of all algae, not just cyanobacteria • Can interfere with pigment analyses used to characterize blooms (Buglewicz and Hergenrader 1977) • May alter lake ecology, changing dominant plant, algae, and fish species (NYSFOLA 2009, Suski et al. 2018) • Typically proprietary blends of nontoxic dyes (WA Ecology 2016); most shading products are not labeled as registered pesticides, and full chemical composition may not be given with product • Limited proof of effectiveness, and blooms may return • Permit may be required	• **LIMITATIONS** Cost-effective only for small lakes with longer residence time • Inhibits photosynthesis of all algae, not just cyanobacteria • Low light–adapted cyanobacteria may not be affected by shading • May alter lake ecology, changing dominant plant, algae, and fish species (NYSFOLA 2009, Suski et al. 2018) • Typically proprietary blends of nontoxic dyes (WA Ecology 2016); most shading products are not labeled as registered pesticides, and full chemical composition may not be given with product • Limited proof of effectiveness, and blooms may return • Permit may be required

This aquatic growth control technology dates back at least 73 years (Eicher 1947), and commercial dye products for this purpose have been available for at least 40 years. Researchers have found that at least one shading dye does not significantly reduce visibility in water for swimmers and other recreators (Madsen et al. 1999). Dyes may be used in conjunction with other cyanobacteria preventive or control technologies such as herbicides. Perhaps most importantly, you might find that dyes have little to no effect on reducing cyanobacteria bloom frequency or severity. Some laboratory experiments and field-scale pilot studies conducted in 2- to 3-foot water depths showed that prescribed concentrations of a leading pond dye had little to no effect on algal growth rates or phytoplankton communities (Boyd, Hanapi, and Noor 1982, Ludwig, Perschbacher, and Edziyie 2010, Spencer 1984).

COST ANALYSIS

Shading with dyes has a low seasonal cost for ponds or small lakes with limited flowthrough and longer retention time.

Relative cost per growing season: Shading with dyes (light filtering)

ITEM	RELATIVE COST PER GROWING SEASON
Material	$$
Equipment	$$
Labor	$
OVERALL	**$$**

REGULATORY AND POLICY CONSIDERATIONS

Commercially available, nontoxic dyes are suitable for use in waters used for swimming and other recreational purposes, livestock water, irrigation, or fish consumption; however, dyes should not be applied to water that will be used for human consumption (USEPA 2020). A permit from the state herbicide or pesticide control agency may be required prior to use. Check with the state's environmental regulatory agency before moving ahead (NYSFOLA 2009).

The dyes will impart a new and unnatural color to the water that may not be appealing to some. Furthermore, the public may view the technique as adding a manmade "chemical" to the environment to engineer the disruption of a naturally occurring, albeit undesirable, aquatic phenomenon (NYSFOLA 2009). Before applying dyes to community waters, solicit input from stakeholders to ensure that there is public consensus for intervention.

CASE STUDY EXAMPLE

Teton Pond, Dunbar, Nebraska, U.S.: Buglewicz and Hergenrader (1977) performed a field-scale pilot study on a 2.4-acre pond west of Dunbar, Nebraska, ~5.2 feet deep, and fed by a 147-acre watershed of fertilized farmland during the April to September growing season.

Six isolation test box enclosures were constructed within the pond. No dye was added to one box, which served as the test control, and no dye was added to the pond outside of the enclosures.

Alizanine blue dye was added to three enclosures at three different concentrations that reduced Secchi disc visibility from 10 feet to just 12, 6, and 4 inches, respectively. Secchi depths eventually stabilized to 12 inches in all blue-dyed boxes.

Sandolan dark brown dye was added to two enclosures at two different concentrations that reduced Secchi disc visibility from 10 feet to 24 and 12 inches, respectively. Secchi depths eventually stabilized to 18 inches in all brown-dyed boxes.

Cyanobacteria were eliminated from both Sandolan dark brown-dyed boxes and from one of the three enclosures dyed with Alizanine blue.

Cyanobacteria algal volumetric share increased substantially in the treated box, even though the cyanobacteria share remained steady in untreated control boxes.

Cyanobacteria treatment effectiveness results were mixed despite reducing light penetration. It is possible the test may not have fairly evaluated dyes as a preventive technology since cyanobacteria were already a sizable fraction of the total algal volume before the test was initiated.

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