Access the Cyanobacteria Management Criteria Tool

Resolving and preventing cyanobacterial blooms and their potential toxicity is the ultimate goal of any HCB management strategy; however, this can be a daunting task given the large number of potential remediation technologies and the unique characteristics of the water body and cyanobacteria, which can diminish intervention effectiveness. The intent of this section is to consolidate and evaluate established and emerging treatment techniques currently being used to combat HCBs. The Management Criteria Tool makes a distinction between planktonic cyanobacteria and benthic cyanobacteria as their individual ecologies can greatly affect the treatment approach used and potential consequences of different treatments. For both planktonic and benthic, the presentation of each strategy contains an assessment of the approach's effectiveness, advantages, limitations, and estimated relative cost, as well as information to help guide you to effectively implement the strategy in your water body.

Technology to treat, prevent, and manage HCBs is constantly evolving. Strategies and associated literature and case studies for managing benthic cyanobacteria are extremely limited due to the complex nature of benthic cyanobacteria ecological dynamics. The strategies presented in this section are not intended to be all-encompassing, and our goal is not to provide specific guidance for all water bodies and water body types; each water body is unique in its ecology and uses. This document does not provide details about specific products or tradenames or an endorsement for any specific technique or application strategy. The active ingredient may not be apparent by tradename. The information presented for each strategy represents the typical application scenario; there are additional scenarios that may not have been considered. Check with and notify all required officials and stakeholders before implementing any management strategy. No treatment is guaranteed to provide total prevention or remediation. Blooms may return, and, if improperly implemented, some management strategies can aggravate the situation or create harmful unintended consequences. Not all treatments are appropriate for both planktonic and benthic cyanobacteria blooms, and some treatments may cause the worsening of one type of bloom or the other.

When treatment strategies are implemented, evaluation of current conditions and decisions about next steps are needed to ensure that the proper effect is achieved, and that there are not unintended consequences. There are several adaptive management models that could be implemented for this purpose. One example, for benthic cyanobacteria, is from the New Zealand Ministries for the Environment and for Health, where an alert level framework is described (Ministry for the Environment and Ministry for Health 2009). This includes a description of conditions that can trigger an alert and a description of actions that should follow, such as frequency of monitoring, additional treatment, or activation of public warnings and communication. Implementing a management model appropriate for a site is recommended.

Any intervention strategy that uses algaecides to manage HCB events (for example, peroxide, ozone, permanganate, or any product that kills cells) has the potential to release dissolved, toxic by-products into the water column and shift population assemblages. Monitoring for these toxic by-products is important, particularly with respect to drinking water supplies and recreational use water bodies. At elevated levels, these dissolved cyanotoxins can represent a threat to human health. This is primarily a concern for drinking water treatment facilities. Elevated levels of toxic by-products may overwhelm or complicate this process. Recreational water users can also be at risk if significant levels of cyanotoxins remain in the water after an in-water HCB treatment. Therefore, all algaecides and coagulation compounds should be used at their minimum effective doses and preferably in the early stages of HCB development. It is important to work closely with vendors and other experts while planning in-water treatments.

Treatment strategies can be categorized broadly as prevention or direct intervention approaches, with some strategies capable of being applied as both. The goal of prevention strategies is to prohibit cyanobacteria from dominating the natural community later in the year and avoid future blooms. This is accomplished by controlling or manipulating conditions that favor cyanobacteria or by adding compounds that may directly inhibit their growth and accumulation. Intervention strategies are used when a bloom has already begun and typically act directly on the cyanobacteria to reduce or remove them—and sometimes their cyanotoxins (if present)—from the system.

Each treatment strategy heading in Table 4-1 summarizes data supporting the strategy as substantial, limited, emerging, or unavailable supporting field data. Substantial supporting data reflect a strategy that has been used in many water body types, numerous case studies are available, and impacts of long-term use are well understood. Limited supporting data reflect a strategy that has been used in only a few water body types, only a few case studies are available, and impacts of long-term use are not well understood. Emerging supporting data reflect a strategy that has been proven at bench scale or microcosm scale, case studies in the field are singular or nonexistent, and impacts of long-term use are not known. Benthic HCBs are understudied compared to planktonic HABs, so many of the treatment strategies reviewed for benthic cyanobacteria mats fall into the category of supporting field data unavailable. In some cases, an educated guess can be made regarding the efficacy of a strategy based on ecological knowledge of mats, but this does not replace case studies. We encourage practitioners to publish case studies and share their experience regarding treatment of benthic HCBs (Section 6).

Treatments are also grouped by their applicability to specific water body types. Both planktonic and benthic cyanobacteria can be found in lakes, reservoirs, ponds, bays, estuaries, and rivers. For benthic cyanobacteria in particular, water body type can have a significant influence on treatment applicability, advantages, limitations, and efficacy. Benthic populations in rivers or other flowing waters tend to grow on stable surfaces such as rocks. Benthic populations in reservoirs, lakes, and ponds do not have to contend with flowing waters and can grow on stable substrates and less stable substrates such as mud or sand. For more information on surfaces and substrates for growth, see Section 1.3.2. Flowing waters often make it difficult to treat mats by chemical means because contact time with the organisms is often required for the treatment to be effective. This can also present a problem in lakes where the chemical may dissolve in the surface waters and never have contact with mat populations. In some instances, the large granular size of the chemical may be effective at reaching mats before dissolving, enhancing contact time.

Treatments can also be grouped into their application type, whether they are chemical, mechanical, or biological alterations or some combination thereof. Depending on the size of the water body and the bloom, some treatments can be deployed with little infrastructure. Other technologies require significant capital investment to implement or deploy, as well as annual maintenance costs, which can vary by scale of the deployment, region, and goals of the treatment.

Phytoplankton populations and benthic populations represent two groups of primary producers in aquatic systems. These two groups compete for resources such as nutrients and light. Phytoplankton have a competitive advantage over benthic populations for light due to their habitat location. They can also inhibit benthic populations by shading and limiting the light reaching the bottom. Benthic populations have a competitive advantage over phytoplankton in their ability to sequester nutrients from multiple sources. For more information on nutrient sources for benthic algae, see Section 1.3.4.2. If nutrients in the water column are sufficient to support metabolic demands of the phytoplankton, they will dominate. Conversely, if nutrients in the water column are not sufficient, benthic populations will dominate due to reduced shading by phytoplankton and more light reaching benthic surfaces. When selecting a treatment strategy, one should consider these interactions. Treatment strategies that limit nutrients in the water column will reduce phytoplankton in the system and lead to increased light penetration. Increased light to benthic populations will cause them to proliferate when water column nutrients are low because they can use nutrients in the sediments. Proliferations of benthic populations have been increasingly observed in oligotrophic lakes around the world due to high levels of nutrients in groundwater, climate changes, hydrodynamic changes, and changes in food webs (Vadeboncoeur et al. 2021). Algaecide treatments targeted at phytoplankton populations will reduce that population and potentially lead to an increase in benthic populations due to increased light and nutrients from sinking and decaying phytoplankton material. A strong foundation in understanding the ecology of a system will help assess the risks associated with a treatment. Additional monitoring should be performed posttreatment to ensure that problems do not arise.

The strategies here are solely initiated within the water body or immediate shoreline area, broadly characterized as “in-water” treatments. If you wish to prevent future blooms by reducing inflowing nutrients from multiple land uses in a watershed, nutrient management strategies can be found in Section 7 of HCB-1 (ITRC 2021). Strategies presented in Section 7 of HCB-1 (ITRC 2021) reduce the likelihood of HCB development downstream of the nutrient source.

Note that this document uses imperial units (feet, acres) for large, linear, and spatial measurements and metric units (mg, L) for small mass and volume measurements.

4.1 Summary Table

HCBs pose serious threats to humans, domestic animals, and wildlife, as well as aesthetics, for some water bodies. We have assembled a suite of in-water strategies that can be considered to prevent future blooms or reduce or eliminate an ongoing bloom, summarized in Table 4-1. This table presents information to help you select the most useful and practical approach for your type of bloom and water body. Each management strategy entry summarizes the following information for treatment strategies related to both planktonic and benthic blooms:

- name of the technique
- whether the approach is intended for prevention, intervention, or both
- relative cost ($, $$, $$$) per growing season to implement and maintain the strategy
- documented history of use in the field and in research
- water body type in which the strategy may be practically applied
- a brief technical description of the strategy, including possible negative impacts

For the purposes of characterization, working definitions for the following terms have been included as table notes: intervention, prevention, substantial, limited, emerging, small, large, shallow, deep, lake/reservoir, pond, bay/estuary, and river. Definitions for these terms vary across different sources. The working definitions offered here are not absolute or endorsed and are not necessarily recognized as the standard. They are defined explicitly for the purpose of characterizing the HCB management and control strategies covered in this guidance document.

For more detailed fact sheets summarizing relevant information for potential implementation of each strategy, you may:

- Follow the hyperlinked strategy in Table 4-1 to the relevant fact sheet in Appendix C, which provides a typical, cost-effective application for each strategy.
- Apply filtering criteria using our Management Strategy Selection tool to refine the strategies best suited for the water body of concern.

Table 4-1. In-water prevention and direct intervention strategies with typical cost-effective applications

Management Strategy	Management Strategy Type	Relative Cost*	Documented Effectiveness		Water Body Type	Brief Technical Description
			Planktonic	Benthic		
Acidification	Prevention	$$	Limited	Limited	Pond Lake/Reservoir	Lowering the pH out of the optimal growing range for cyanobacteria; changing how well the cell is able to regulate its buoyancy and maintain its cell wall
Artificial Circulation and Mechanical Mixing	Prevention	$$$	Limited	Not Applicable	Pond Lake/Reservoir	Destratifying a water body to reduce limiting nutrient concentrations in the hypolimnion and avoid sudden delivery of nutrient-rich bottom waters into the epilimnion
Barley and Rice Straw	Prevention	$	Substantial	Limited	Pond Lake/Reservoir River	Placing barley straw bales or bags in the shore zone of a water body 1–1.5 months prior to expected bloom
Clay and Surfactant Flocculation	Intervention	$$-$$$	Substantial	Limited	Pond Lake/Reservoir River	Mixing a slightly acidified solution of clay and surfactant and dispersing it over a bloom; sand may be added to cap the settled material
Copper Algaecides	Intervention and Prevention	$	Substantial	Substantial	Pond Lake/Reservoir River	Controlling algae in water bodies (registered by USEPA but prohibited in some states from use); copper algaecides interfere with the ability of algal cells to respire, photosynthesize, and, at some concentrations, maintain cell integrity

Dredging	Prevention	$$$	Limited	Limited	Pond Lake/Reservoir River	Physically removing the upper, nutrient-rich layer of bottom sediments to reduce internal nutrient loads and limit cyanobacterial growth
Floating Wetlands	Prevention	$$$	Limited	Limited	Pond Lake/Reservoir River	Planting artificial islands with emergent plants designed to absorb nutrients and support aquatic microbial communities attached to roots; eventual removal of plants reduces nutrient loading
Food Web Manipulation	Intervention and Prevention	$$	Limited	No Available Supporting Field Data	Pond Lake/Reservoir	Generally altering fish stocks to directly or indirectly reduce cyanobacteria abundance
Hydraulic Flushing	Intervention and Prevention	$$-$$$	Substantial	Limited	Pond Lake/Reservoir River	Manipulating in-lake hydraulics by the pass-through of a large volume of water to control cyanobacterial growth and favor the growth of beneficial algae
Hydrodynamic Cavitation	Intervention	$$$	Emerging	Not Applicable	Pond	Inducing a phase change in water, yielding strong oxidizing agents that inhibit or kill cyanobacteria
Hypolimnetic Oxygenation and Aeration	Prevention (Planktonic), Intervention (Benthic)	$$$	Substantial	No Available Supporting Field Data	Lake/Reservoir River	Maintaining thermal stratification and supplying bottom waters with oxygen to decrease internal nutrient loading by inhibiting sediment release of needed nutrients and preventing their introduction into the epilimnion above
Hypolimnetic Withdrawal and Drawdown	Prevention	$$	Substantial	Limited	Lake/Reservoir River	Withdrawing water via pumping or dam outlets from above or below the thermocline

Microbial Bio-manipulation	Intervention and Prevention	$$$	Emerging	No Available Supporting Field Data	Pond Lake/Reservoir	Adding indigenous bacteria, viruses, protozoa, or other zooplankton to a water body with a dense surface bloom of cyanobacteria
Monitored Natural Attenuation	Intervention	$	Substantial	Emerging	Pond Lake/Reservoir River	Permitting HCBs to decline naturally—requires communication with local users on threats and concerns and posting notices or signage
Nanobubbling	Intervention and Prevention	$$	Emerging	No Available Supporting Field Data	Pond Lake/Reservoir River	Forming nanobubbles impregnated with air, oxygen, or ozone and dispersing them throughout the water column to oxidize cyanobacteria
Nanoparticles (Iron-based)	Prevention	$-$$$	Limited/ emerging	No Available Supporting Field Data	Pond Lake/Reservoir	Using iron-based (or other metals) nanoparticles to adsorb HCBs and degrade cyanotoxins
Organic Biocides	Intervention and Prevention	$$	Limited/ emerging	Limited	Pond Lake/Reservoir	Applying any of a diverse group of biologically derived compounds (or synthetic analogs) that appear to have biocidal or bacteriostatic activity
Ozonation	Prevention	$$$	Limited	No Available Supporting Field Data	Pond Lake/Reservoir River	Infusing ozone gas (a strong oxidizing agent), leading to a rapid breakdown of organic material
Phosphorus-binding Compounds	Prevention	$-$$	Substantial	Limited	Pond Lake/Reservoir	Adding lanthanum-substituted bentonite or aluminum-containing materials (e.g., alum) to bind phosphorus and limit internal phosphorus sources
Peroxide	Intervention	$$	Substantial	No Available Supporting Field Data	Pond Lake/Reservoir River	Applying granular or liquid peroxide compounds to HCB to levels approximating 3–7 mg/L to lyse cyanobacteria

Shading and Dyes	Prevention	$$	Limited	No Available Supporting Field Data	Pond Lake/Reservoir Rivers	Applying colored dyes to reduce photosynthesis of algae and cyanobacteria
Skimming and Harvesting	Intervention	$$-$$$	Limited	No Available Supporting Field Data	Pond Lake/Reservoir River	Physically removing scum from buoyant HCBs
Ultrasound	Intervention and Prevention	$$-$$$	Limited/ Emerging	Limited	Pond Lake/Reservoir	Transmitting high-frequency pressure waves through the water column, yielding acoustic cavitation bubbles that, on collapsing, destroy gas vesicles of buoyant cyanobacteria
Ultraviolet (UV) Exposure	Intervention	$$$	Limited	No Available Supporting Field Data	Pond Lake/Reservoir River	Passing water over UV lamps, resulting in the destruction of organisms' DNA

Notes:	
Intervention:	an in-lake strategy that may be implemented to provide immediate relief for an ongoing bloom or if certain key thresholds have been crossed (cell counts, visual, taste and odor, cyanotoxin concentration, etc.); thresholds may be specific to the water body or site.
Prevention:	an in-lake strategy that may be implemented prior to some key threshold being reached to decrease the likelihood or intensity of a future bloom.
Substantial:	multiple conclusive studies support this method.
Limited:	few conclusive studies support this method, or there are multiple inconclusive studies.
Emerging:	new area of research (post-2015).
Small:	less than 600 acres (Cael, Heathcote, and Seekell 2017).
Large:	greater than 600 acres (Cael, Heathcote, and Seekell 2017).
Shallow:	light penetration to the bottom; typically average depth of about 10 feet or less.
Deep:	experiences thermal stratification; typically depths greater than 10 feet.
Lake/Reservoir:	shallow shoreline area that may support rooted plant growth and a deeper portion where sunlight does not penetrate to the bottom; frequently stratifies during the summer.

Pond:	shallow standing water in which light penetrates to the bottom, potentially supporting rooted plant growth; lack of thermal stratification and presence of muddy sediments.
Bay/Estuary:	body of water partially enclosed by land that is directly open, or connected, to the ocean, where one or more streams or rivers enter and mix freshwater with seawater.
River:	natural flowing water channel, usually freshwater, flowing toward an ocean, sea, lake, or another river.