6. Management and Control Strategies for HCBs

Click here to use the 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 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. 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.

Any in-lake 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. 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-lake 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-lake treatments.

In-lake 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 toxins (if present)—from the system.

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.

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. Strategies presented in the Nutrient Reduction Section reduce the likelihood of HCB development downstream of the nutrient source. The strategies in this Section are solely initiated within the water body or immediate shoreline area, broadly characterized as "in-lake" treatments. 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.

6.1 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-lake strategies that can be considered to prevent future blooms or reduce or eliminate an ongoing bloom, summarized in Table 6-1. This table presents information to help you select the most useful and practical approach for your water body. Each management strategy entry summarizes the following information:

- name of the technique
- whether the approach is intended for prevention, intervention, or both
- documented history of use in the field and in research

- relative cost ($, $$, $$$) per growing season to implement and maintain the strategy
- maximum size of the water body 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 and in the document glossary: 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 nor 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 6-1, which provides a typical, cost-effective application for each strategy. For more specific information, strategies are hyperlinked to their fact sheets in Appendix C. We have compiled a range of cost estimates in Appendix C.2.
- Apply filtering criteria using our Management Strategy selection tool to refine the strategies best suited for the water body of concern.

Table 6-1. In-lake prevention and direct intervention strategies with typical cost-effective applications (See notes below for additional clarification)

Managemen Strategy	Management Strategy Type	Supporting Field Data	Cost per Growing Season	Water Body Size	Brief Technical Description
Acidification	Prevention	Limited	$$	Unknown	Lowering the pH out of the optimal growing range for cyanobacteria; changing how well the cell is able to regulate its buoyancy and maintain its cell wall
Artificial Circulation and Mechanical Mixing	Prevention	Substantial	$$$	Deep 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	$	Lake/reservoir	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	$$–$$$	Any	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 Compounds	Intervention and prevention	Substantial	$	Any	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	$$$	Small, shallow lake/reservoir	Physically removing the upper, nutrient-rich layer of bottom sediments to reduce internal nutrient loads and limit cyanobacterial growth
Floating Wetlands	Prevention	Limited	$$$	Small, shallow lake/reservoir	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	Substantial	$$–$$$	Any	Generally altering fish stocks to directly or indirectly reduce cyanobacteria abundance
Hydraulic Flushing	Intervention and prevention	Substantial	$$–$$$	Shallow lake/reservoir	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	$$$	Small, shallow pond	Inducing a phase change in water, yielding strong oxidizing agents that inhibit or kill cyanobacteria
Hypolimnetic Oxygenation and Aeration	Prevention	Substantial	$$$	Deep lake/ reservoir	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	$$	Deep lake/ reservoir	Withdrawing water via pumping or dam outlets from above or below the thermocline
Microbial Bio-manipulation	Intervention	Emerging	$$$	Small, deep 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	$	Any	Permitting HCBs to decline naturally. Requires communication with local users on threats and concerns and posting notices or signage.
Nanoparticles (Iron-based)	Intervention	Limited/ emerging	$–$$$	Unknown	Using iron-based (or other metals) nanoparticles to adsorb HCBs and degrade cyanotoxins

Organic Biocides	Prevention and intervention	Limited/ emerging	$$	Unknown	Applying any of a diverse group of biologically derived compounds (or synthetic analogs) that appear to have biocidal or bacteriostatic activity
Ozonation	Intervention	Limited	$$$	Lake/reservoir	Infusing ozone gas (a strong oxidizing agent), leading to a rapid breakdown of organic material
Phosphorus-binding Compounds	Prevention	Substantial	$$$	Large lake/reservoir	Adding lanthanum-substituted bentonite or aluminum-containing materials (e.g., alum) to bind phosphorus and limit internal phosphorus sources
Peroxide	Intervention	Substantial	$$	Small, shallow lake/reservoir	Applying granular or liquid peroxide compounds to HCB to levels approximating 3–7 mg/L to lyse cyanobacteria
Shading with Dyes	Prevention	Limited	$$	Lake/reservoir	Applying colored dyes to reduce photosynthesis of algae and cyanobacteria
Skimming and Harvesting	Intervention	Limited	$$–$$$	Lake/reservoir	Physically removing scum from buoyant HCBs
Ultrasound	Intervention and prevention	Limited/ Emerging	$$–$$$	Small lake/reservoir	Transmitting high-frequency pressure waves through the water column, yielding acoustic cavitation bubbles that, on collapsing, destroy gas vesicles of buoyant cyanobacteria
Ultraviolet (UV) Exposure	Intervention	Limited	$$$	Small, shallow lake/reservoir	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.

Descriptions of management strategies presented in Table 6-1, evaluated for effectiveness, advantages, limitations, relative cost, and regulatory and policy considerations, are included as individual fact sheets in Appendix C. Each fact sheet can stand alone and is intended to provide guidance and technical background to evaluate the use of a given management strategy in HCB-affected water bodies.

We necessarily limited this review to methods that are used in contemporary settings and have support from peer-reviewed literature. Some notable methods that were considered, but not reviewed in full, are included as Abridged Strategies in Appendix C. Methods that are considered outdated or have only a very narrow range of applicability, as well as those that have only anecdotal support or endorsement from commercial providers, are not addressed in this document.

Click here to use the Management Criteria Tool.