Control and Treatment

Highlights

On this page:

What are some measures to prevent cyanobacterial blooms in surface waters?

While the best way to prevent HABs is to reduce the amount of nutrients that enter the water body in the first place, there are a number of control methods available to both prevent cyanobacteria from proliferating and to treat HABs once they have occurred (remedial).

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Various preventive measures target external nutrient input from point sources (which may include discharges from sewage treatment plants and confined animal feeding operations) and non-point sources (which may include diffuse runoff from agricultural fields, roads and stormwater). In addition to external sources, nutrients exist internally within the sediment layer and cycle through the water column periodically (internal loading) to contribute towards the formation of HABs.

The table below provides a summary of common measures to prevent HABs in surface waters.

DISCLAIMER: U.S. EPA does not endorse any of the techniques presented on this page.

Waterbody Management Method to Prevent HABs Example link	Description	Benefits	Limitations
Biological Controls (Bio-manipulation)			

Waterbody Management Method to Prevent HABs Example link	Description	Benefits	Limitations
Floating Treatment Wetlands (FTW)	Consists of emergent wetland plants growing on floating mats on the water's surface. The plant's roots provide enough surface area to filter and trap nutrients. FTWs also encourage biofilm processes that reduce cyanobacteria levels. Periodic harvesting of mature plants is conducted to prevent stored nutrients from re-entering the aquatic ecosystem, mitigating risk of HABs by keeping nutrient levels in balance.	Assimilates nutrients and encourages particle adsorption. Covered surface area minimizes light penetration and limits opportunity for algae growth. Able to tolerate fluctuations in water depth. Utilizes natural processes with minimal technical attention required.	Often dependent upon the amount of input (i.e., the number of plants and mats). Excessive coverage can lead to de-oxygenation of the water. Plants only have access to nutrients in the water column and not ones in sediment.

Waterbody Management Method to Prevent HABs Example link	Description	Benefits	Limitations
Riparian Vegetation	Vegetated zones (trees, shrubs, and other plants) adjacent to surface waters serve as a buffer between the water and point/non-point sources of pollution.	Intercept nutrients and other pollutants from entering surface waters. Provides shade from sunlight, which helps to reduce higher temperatures that can cause HABs. Long-term sustainability. Little maintenance and upkeep once installed.	Feasibility and effectiveness largely depend on geographic characteristics of water body and surrounding land mass.
Physical Controls			

Waterbody Management Method to Prevent HABs Example link	Description	Benefits	Limitations
Aeration	Aerators pump air throughout the water column to disrupt stratification. Many operate by pumping air through a diffuser near the bottom of the water body, resulting in the formation of plumes that rise to the surface and create vertical circulation cells as they propagate outwards from the aerator.	Limits the accessibility of nutrients to the surface. Disrupts the behavior of cyanobacteria to migrate vertically. Reduces competitive advantage of cyanobacteria by maintaining healthy levels of dissolved oxygen.	Individual devices have limited range; areas further away may remain stratified and provide a suitable environment for growth. De-stratification of the water column may harm aquatic habitats that rely on colder bottom temperatures.

Waterbody Management Method to Prevent HABs Example link	Description	Benefits	Limitations
Mechanical Circulation	Mechanical circulators operate by pumping water from the surface layer downwards or draw water up from the bottom to the surface layer. Similar to aerators, mechanical mixers interfere with stratification of the water column, intercepting conditions ideal for HABs to occur.	Limits the accessibility of nutrients to the surface. Disrupts the behavior of cyanobacteria to migrate vertically. Reduces competitive advantage of cyanobacteria by maintaining healthy levels of dissolved oxygen.	Individual devices have limited range; areas further away may remain stratified and provide a suitable environment for growth. Certain algae prefer an unstable environment and are benefitted by circulation.

Waterbody Management Method to Prevent HABs Example link	Description	Benefits	Limitations
Hypolimnetic Oxygenation	To increase oxygen concentrations in the hypolimnion layer. Mechanisms include submerged oxygen chambers, side stream oxygenation and direct oxygen injection.	High oxygen delivery rates reduce potential for sediment to release nutrients. Minimizes impact to hypolimnion by maintaining water column structure and temperature (thermocline, pycnocline, etc.).	Techniques are relatively expensive. Requires a significant understanding of system in order to operate.
Chemical Controls			

Waterbody Management Method to Prevent HABs Example link	Description	Benefits	Limitations
Alum, ferric salts, clay (Coagulation and Flocculation)	Alum, ferric salts, or clay can be applied to the water body as coagulants that cause cyanobacteria to settle down away from the top layer of the water body. When applied to water, alum forms an aluminum hydroxide precipitate called a floc. As the floc settles, it removes phosphorus and particulates (including algae) from the water column. The floc settles on the sediment where it forms a layer that acts as barrier to phosphorus. Phosphorus, released from the sediments, combines with the alum and is not released into the water to fuel algae blooms.	Injection of aluminum compounds can be effective at reducing phosphorus levels in the water body.	Effectiveness varies with amount of alum added and depth of water body. The addition of aluminum can impact pH levels of the water body. Best suitable for well-buffered hard water. Buffering soft water lakes with either sodium aluminate or carbonate type salts to prevent undesirable pH shifts that can be toxic to biota may be needed.

Waterbody Management Method to Prevent HABs Example link	Description	Benefits	Limitations
Barley Straw	Barley straw, when exposed to sunlight and in the presence of oxygen, produces a chemical that inhibits algae growth. Barley straw bales are broken apart and placed in a buoyant net deployed around the perimeter of the water body to facilitate the necessary chemical reactions and natural processes that prevents algae growth.	A low cost method to preventing HABs.	Amount used depends on size of water. Does not kill existing algae, but inhibits the growth of new algae. May take anywhere from 2 to 8 weeks for the barley straw to begin producing active chemical. Potential to cause fish kills through the deoxygenation of the water body due to decay.

What are some mitigation measures for the presence of HABs in surface waters?

Remedial measures can be employed once blooms have already occurred to control the phytoplankton blooming rate and to remove blooms. The table below provides a summary of the common biological, physical, and chemical remediation practices for cyanobacteria in surface waters.

See the table below for a summary of the various water management techniques used for cyanotoxin removal and their respective effectiveness.

A Summary of Waterbody Management Methods for Cyanobacterial Blooms

Waterbody Management Method	Description	Benefits/Effectiveness	Limitations
Physical Controls			
Aeration	Aerators operate by pumping air through a diffuser near the bottom of the waterbody, resulting in the formation of plumes that rise to the surface and create vertical circulation cells as they propagate outwards from the aerator. This mixing of the water column disrupts the behavior of cyanobacteria to migrate vertically in addition to limiting the accessibility of nutrients.	Successfully implemented in small ponds and waterbodies. Proven effectiveness in several field studies. May also provide more favorable growth conditions for competing organisms.	Generally more efficient in deeper water columns. Also highly dependent upon the degree of stratification and the air flow rate.
Hydrologic manipulations	Low flow conditions in waterbodies can lead to stratification of the water column, which aids cyanobacterial growth. Particularly in regulated systems, the inflow/outflow of water in the system can be manipulated to disrupt stratification and control cyanobacterial growth.	Easy to implement in controlled systems (i.e., reservoirs, dams, treatment facilities).	Requires sufficient water volume and the ability to control flow. Oftentimes can be expensive. Unintended consequences for other aquatic organisms are likely.
Mechanical mixing (circulation)	Mechanical mixers are usually surface-mounted and pump water from the surface layer downwards or draw water up from the bottom to the surface layer. This mixing of the water column disrupts the behavior of cyanobacteria to migrate vertically in addition to limiting the accessibility of nutrients.	Successfully implemented in 350+ waterbodies in the U.S. Also used in other countries.	Individual devices have limited range; areas further away may remain stratified and provide a suitable environment for growth.

Waterbody Management Method	**Description**	**Benefits/Effectiveness**	**Limitations**
Reservoir drawdown/dessication	In reservoirs and other controlled waterbodies, can draw down the water level to the point where cyanobacteria accumulations are exposed above the waterline. Subsequent dessication and/or scraping to remove the layer of cyanobacteria attached to sediment or rock is required, in addition to the reinjection of water into the system.	Easy to implement in controlled systems (i.e., reservoirs, dams, treatment facilities).	Can have a significant impact on other aquatic organisms in the system. Often times is expensive and requires a significant input of resources.
Surface skimming	Cyanobacterial blooms often form surface scums, especially in the later stages of a bloom. Oil-spill skimmers have been used to remove cyanobacteria from these surface scums. Often times this technique is coupled with the implementation of some coagulant or flocculant.	Useful method for blooms that are in later stages and have formed surface scums. Successful results seen in field studies in Australia.	This technique cannot be effectively employed until the later stages of a bloom, at which point many of the harmful aspects of a bloom have materialized. Requires proper equipment prior to implementation.
Ultrasound	An ultrasound device is used to control HABs by emitting ultrasonic waves of a particular frequency such that the cellular structure of cyanobacteria is destroyed by rupturing internal gas vesicles used for buoyancy control.	Successfully implemented in ponds and other small waterbodies. A single device can cover up to 8 acres. Non-chemical; inexpensive.	Also disrupts cellular functioning of green algae. Effectiveness are dependent upon waterbody geometry and cyanobacteria species. Further research of method is required.
Chemical Controls			

Waterbody Management Method	Description	Benefits/Effectiveness	Limitations
Algaecides	Algaecides are chemical compounds applied to a waterbody to kill cyanobacteria. Several examples are: • Copper-based algaecides (copper sulphate, copper II alkanolamine, copper citrate, etc.) • Potassium permanganate • Chlorine • Lime	Wide range of compounds with a history of implementation. Relatively rapid and well-established method. Properties and effects of compounds are typically well-understood.	Risk of cell lyses and the release of toxins. Thus, is often used at the early stages of a bloom. Certain algaecides are also toxic to other organisms such as zooplankton, other invertebrates, and fish.
Barley straw	Barley straw bales are deployed around the perimeter of the waterbody. Barley straw, when exposed to sunlight and in the presence of oxygen, produces a chemical that inhibits algae growth. Field studies suggest significant algistatic effects. Several causes for the observed effects have been suggested; however, the exact mechanism of this process is not well understood.	Studies have shown that decomposed barley straw inhibits the growth of cyanobacteria Microcystis sp. Successfully implemented in many reservoirs and dams in the United Kingdom with positive results.	Does not kill existing algae, but inhibits the growth of new algae. May take anywhere from 2 to 8 weeks for the barley straw to begin producing active chemical. Potential to cause fish kills through the deoxygenation of the waterbody due to decay.
Coagulation	Coagulants are used to facilitate the sedimentation of cyanobacteria cells to the anoxic bottom layer of the water column. Unable to access light, oxygen, and other critical resources, the cells do not continue to multiply and eventually die.	Several studies have shown that cells can be coagulated without damage; however, further research is required. Successfully implemented in several treatment facilities.	Subject to depth limitations. Coagulated cells become stressed over time and lyse, releasing toxins to the waterbody.

Waterbody Management Method	**Description**	**Benefits/Effectiveness**	**Limitations**
Flocculation	Flocculants are used to facilitate the sedimentation of nutrients to the anoxic bottom layer of the water column, thereby limiting nutrient levels in the waterbody and inhibiting cyanobacterial growth.	Successfully implemented in larger lakes and ponds (e.g., Florida DEP, Lake Hilaman).	Subject to depth limitations.
Hypolimnetic oxygenation	Techniques used to achieve hypolimnetic oxygenation include: airlift pumps, side stream oxygenation and direct oxygen injection. The primary goal of this method is to increase the oxygen concentration in the hypolimnion in order to prevent or reduce the release of nutrients from the sediment while maintaining water column stratification. This serves to limit upper level nutrient levels thereby inhibiting cyanobacterial growth.	Maintains water column structure (thermocline, pycnocline, etc.).	Techniques are relatively expensive. Requires a significant understanding of system in order to determine effectiveness.
Biological Controls (Biomanipulation)			
Floating artificial wetlands	Artificial wetlands are constructed using floating mats and placed in a waterbody. As the plants grow, they function as a sink for excess nutrients such as phosphorous and nitrogen. Periodic harvesting of mature plants is conducted to prevent the stored nutrients from re-entering the aquatic ecosystem, which helps to mitigate the risk of cyanobacterial blooms by keeping nutrient levels in balance.	Implemented in small waterbodies with limited success.	Often dependent upon the amount of input (i.e., the number of plants and mats). Also subject to depth limitations.

<table>
<tr><th>Waterbody Management Method</th><th>Description</th><th>Benefits/Effectiveness</th><th>Limitations</th></tr>
<tr><td>Increasing grazing pressure</td><td>Various measures can be introduced to encourage the growth of zooplankton, benthic fauna, and other aquatic organisms that feed on cyanobacteria, thereby limiting the proliferation of cyanobacteria populations. Techniques include:
The removal of fish that feed on zooplankton and other benthic fauna or the introduction of predators to these fish, and
The development of niches to encourage the growth of beneficial organisms.</td><td rowspan="2">Biomanipulation has fewer direct detrimental effects on other aquatic organisms when compared to chemical and physical methods.</td><td rowspan="2">Unintended consequences may arise related to the deliberate modification of the biodiversity of the system. Requires constant monitoring. Increasing resource competition has only proven effective in shallow water bodies with moderate nutrient levels</td></tr>
<tr><td>Increasing resource competition</td><td>The introduction of other primary producers such as macrophytes can limit the available phosphorus and therefore limit cyanobacterial growth. An example of this technique is the introduction of floating wetlands (see above).</td></tr>
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What are some remedial measures for the presence of HABs in drinking water supplies?

Conventional water treatment (flocculation, coagulation, sedimentation and filtration) if done properly is effective in removing algal cells and intracellular cyanotoxins. The use of microstrainers or fine screens to remove debris from the water intake are useful in removing larger algae, cyanobacterial cells and aggregated cells. Oxidants are often added at the intake to reduce taste and odor problems and to discourage biological growth (zebra mussels, biofilm, and algae) on the intake pipe; however, pretreatment oxidation is not recommended because it may rupture cyanobacteria cells releasing the cyanotoxin to the water column. This may also cause the formation of chlorinated disinfection by-products.

Conventional water treatment is usually not effective in removing extracellular cyanotoxins (soluble toxins). Neither aeration nor air stripping are effective for removing soluble toxins or cyanobacterial cells. Advanced treatment processes, such as powdered and granular activated carbon adsorption, must be implemented to remove extracellular toxins as well as intact cells.

Different cyanotoxins react differently to chlorination. While chlorination is an effective treatment for destroying microcystins and cylindrospermopsin, effectiveness is dependent on the pH and does not have an effect on anatoxin–a. Other chlorine disinfectants such as chloramines and chlorine dioxide have little impact on microcystin, cylindrospermopsin, anatoxin-a, and saxitoxins. Therefore, those treatment utilities that use these disinfectants may not have an oxidant treatment barrier for cyanotoxin inactivation.

See the table below for a summary of the various water treatment techniques used for cyanotoxin removal and their respective effectiveness.

A Summary of Cyanotoxin Treatment Processes and Their Relative Effectiveness

Treatment Process	**Relative Effectiveness**
Intracellular Cyanotoxins Removal (Intact Cells)	
Pretreatment oxidation	Avoid pre-oxidation because often lyses cyanobacteria cells releasing the cyanotoxin to the water column. If oxidation is required to meet other treatment objectives, consider using lower doses of an oxidant less likely to lyse cells (potassium permanganate). If oxidation at higher doses must be used, sufficiently high doses should be used to not only lyse cells but also destroy total toxins present (see extracellular cyanotoxin removal).
Coagulation/ Sedimentation/Filtration	Effective for the removal of intracellular toxins when cells accumulated in sludge are isolated from the plant and the sludge is not returned to the supply after separation.
Membranes	Study data is scarce; it is assumed that membranes would be effective for removal of intracellular cyanotoxins.
Flotation	Flotation processes, such as Dissolved Air Flotation (DAF), are effective for removal of intracellular cyanotoxins since many of the toxin-forming cyanobacteria are buoyant.
Oxidation	Avoid because often lyses cyanobacteria cells releasing the cyanotoxin to the supply.
Extracellular Cyanotoxins Removal	

Treatment Process	Relative Effectiveness
Membranes	Depends on the material, membrane pore size, and water quality. Nanofiltration and ultrafiltration are likely effective in removing extracellular microcystin. Reverse osmosis filtration would likely only be applicable for the removal of some extracellular cyanotoxins like cylindrospermopsin. Cell lysis is highly likely. Further research is required to characterize performance.
Potassium Permanganate	Effective for oxidizing microcystins and anatoxins.
Ozone	Very effective for oxidizing extracellular microcystin, anatoxin-a and cylindrospermopsin.
Chloramines	Not effective.
Chlorine Dioxide	Not effective with doses used in drinking water treatment.
Chlorination	Effective for oxidizing extracellular cyanotoxins as long as the pH is below 8; ineffective for anatoxin-a.
UV Radiation	Effective for degrading microcystin and cylindrospermopsin but at impractically high doses.
Activated Carbon	PAC: Most types are generally effective for removal of microcystin, anatoxin-a and cylindrospermopsin, especially wood-based activated carbon. GAC: Effective for microcystin but less effective for anatoxin-a and cylindrospermopsins.

What water supply managers should do to deal with cyanobacteria and their toxins?

Water supply managers should develop a contingency plan including:

- Monitoring Plan (when and where to sample, sampling frequency, sample volume, whether to sample for cyanobacterial cells or specific cyanotoxins or both, which analytical screening test to use, conditions when it is necessary to send sample(s) to an identified laboratory for confirmation, etc.).

- Management and Control Plan (nutrient reduction techniques, bloom control and management, water treatment techniques for cyanotoxin removal in treatment plants).
- Communication plans (required communication steps to coordinate with the agencies involved the appropriate actions that must be taken, and the steps to inform consumers and the public).

Chapter 6 (Situation Assessment, Planning and Management) from the WHO's Toxic Cyanobacteria in Water: A guide to their public health consequences, monitoring and management and the Incident Management Plans chapter from the International guidance manual for the management of toxic cyanobacteria (Water Quality Research Australia) could be used as resources to develop such plans.

More Information

The following links exit the site EXIT

US EPA A Compilation of Cost Data Associated with the Impacts and Control of Nutrient Pollution (PDF) (110 pp, 3 MB)
US EPA Cyanotoxin Management Plan Template and Example Plans
US EPA Water Treatment Optimization for Cyanotoxins
US EPA Partnering with States to Cut Nutrient Pollution Memo
US EPA Watershed Framework Approach
US EPA Watershed Analysis and Management (WAM) Guide for States and Communities
US EPA Webinar Prevention, Control and Mitigation of CyanoHABs Presentations
US EPA The Lake and Reservoir Restoration Guidance Manual (PDF) (340 pp, 19 MB)
US EPA Monitoring Lake and Reservoir Restoration, Technical Supplement (PDF) (148 pp, 54 K)
US EPA Recommendations for Public Water Systems to Manage Cyanotoxins in Drinking Water
US EPA Cyanobacteria and Cyanotoxins: Information for Drinking Water Systems Fact Sheet (PDF) (11 pp, 475 K)
AWWA/WRF A Water Utility Manager's Guide to Cyanotoxins
Sea Grant Harmful Algal Blooms (HAB) – The Beach Manager's Manual (PDF) (8 pp, 3 MB)
WHO Toxic cyanobacteria in water: A guide to their public health consequences, monitoring and management
WHO Guidelines for Safe Recreational Waters Volume 1 - Coastal and Fresh Waters
Australia Guidelines for Managing Risks in Recreational Water
WQRA Management Strategies for Cyanobacteria (Blue-Green Algae) and their Toxins: a Guide for Water Utilities (PDF) (112 pp, 3 MB)
WQRA Treatment Options, International Guidance Manual for the Management of Toxic Cyanobacteria (PDF) (107 pp, 3 MB)
The Practical Guide to Lake Management in Massachusetts, Commonwealth of Massachusetts Executive Office of Environmental Affairs, 2004 (PDF) (167 pp, 1 MB)
SWAMP's California Freshwater Harmful Algal Bloom Field Guide - Interpreting the Data & Posting Advisories

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