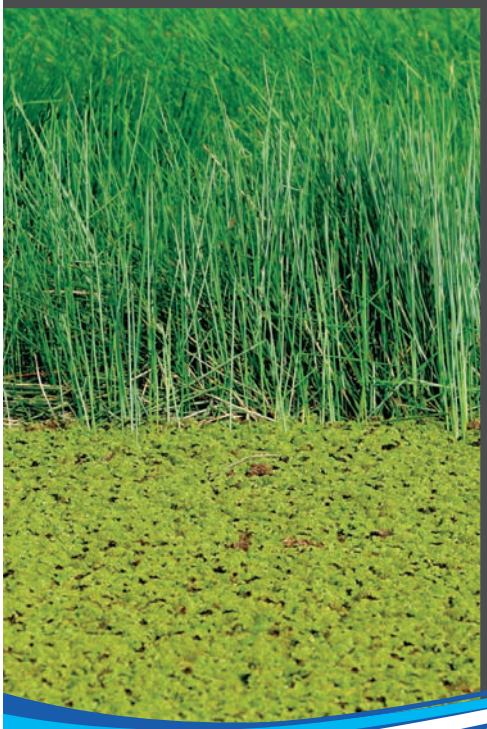
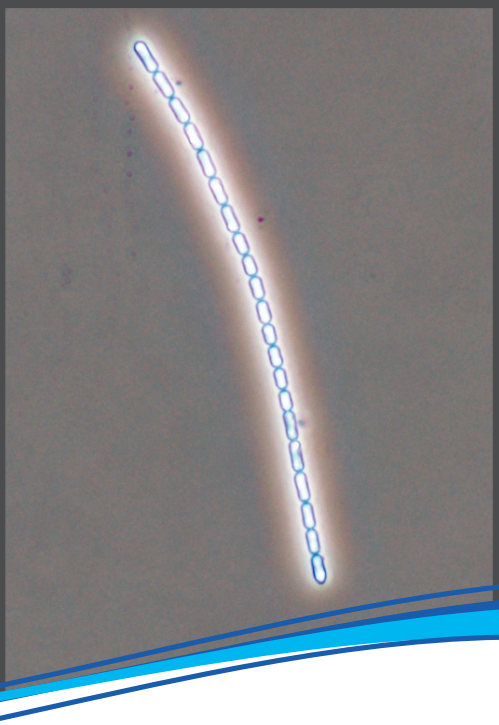
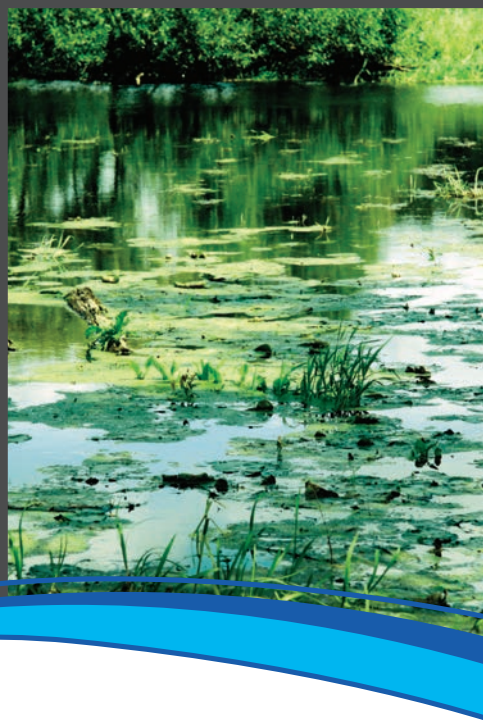
A Water Utility Manager's Guide to Cyanotoxins







American Water Works Association

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Introduction to Cyanotoxin Issues

Toxin-producing cyanobacteria are a growing concern for water utilities that use surface water supplies across the country. To make informed decisions about how to limit exposure to cyanotoxins, water utilities need to understand:

- How, when, and why cyanotoxins occur
- How to determine if they occur in a given water source
- What management strategies are available to reduce cyanotoxin production in source waters
- What treatment can prevent cyanotoxins from reaching customers

This guide was created in a partnership between the American Water Works Association (AWWA) and the Water Research Foundation (WRF). The guide provides a brief overview of current knowledge surrounding these questions so water utilities can gain a better sense of whether cyanotoxins are a water quality issue they should be preparing for and where to find relevant resources and knowledge when cyanotoxins do cause water quality problems.

Cyanotoxins may impact drinking water utility operations and customers. In order to take an informed approach to both managing cyanotoxins and communicating with customers, utilities need accurate information. Utilities need to understand the conditions under which cyanotoxins can be found, as well as effective monitoring and treatment approaches for managing cyanotoxin events if they do occur.

Finally, many utilities may benefit from dispelling some misconceptions about cyanotoxins, their indicators, and the effectiveness of different treatment methods. A short self-assessment near the end of this guide is a resource for utility managers to evaluate whether their water systems may be at risk and, if so, where they can go for additional information and guidance. A more detailed technical guide (which will be available soon) will serve as a companion to this overview by presenting detailed information about cyanotoxin occurrence, measurement, and management. Like this overview, the technical guide is intended to benefit water utility managers, customer service and public relations staff, operators, and consultants. It will be organized to help readers navigate the issues and make informed decisions about making sound evaluations and taking appropriate mitigation measures.

1. *What are cyanotoxins and where do they come from? What does a cyanotoxin-producing bloom look like?*

Cyanobacteria, also known as blue-green algae, are photosynthetic bacteria that can live in many types of water. They are important primary producers (organisms that make energy directly from the sun) in aquatic ecosystems. While critical to water and soil resources, excessive cyanobacteria growth can cause ecological and public health concerns. Rapid, excessive cyanobacteria growth is commonly referred to as a "bloom."

Cyanobacteria blooms can be inches thick, especially those located near the shorelines of lakes and reservoirs, and they commonly occur during warm weather. They can appear foamy or accumulate as mats or scum covering the water surface. Some cyanobacteria sink and rise through the water column, depending on the time of day. Cyanobacteria blooms may appear blue, blue-green, brown, and other colors, depending on many factors. Sometimes blooms are mistaken for materials such as spilled paint because they can have a similar appearance.

Cyanobacteria can cause problems for water utilities such as:

- Producing unpleasant tastes and odors, especially earthy and musty ones
- Interfering with water treatment plant performance
- Increasing disinfection by-product precursors
- Producing cyanotoxins (AWWA 2010)

Cyanobacteria blooms that produce cyanotoxins are one subset of blooms sometimes called *harmful algal blooms* (HABs). However, the HAB terminology can be misleading because cyanobacteria that are capable of producing cyanotoxins do not always do so. Also, while some

cyanobacteria that produce cyanotoxins also produce taste and odor compounds, this is not always the case. Not all taste- and odor-producing blooms are cyanotoxin-producing blooms, nor are all cyanotoxin-producing blooms taste- and odor-producing blooms.

Cyanotoxins make up a large and diverse group of chemical compounds that differ in molecular structure and toxicological properties. They are generally grouped into major classes according to their toxicological targets: liver, nervous system, skin, and gastrointestinal system. A single bloom may contain multiple types of cyanotoxins because some cyanobacteria can produce several toxins simultaneously (Chorus and Bartram 1999).

2. *Why are cyanotoxins a human health concern?*

Human exposure to cyanotoxins can occur in several ways:

- Ingesting contaminated water, fish, or shellfish
- Making skin (dermal) contact with water containing cyanotoxins
- Inhaling or ingesting aerosolized toxins when swimming or otherwise recreating in waters when cyanotoxins are present
- Consuming drinking water impacted by a toxic cyanobacteria bloom

While confirmed occurrences of adverse health effects in humans are rare, some incidents have been documented worldwide (AWWA 2010). In 1931, approximately 8,000 people fell ill when their drinking water originating from tributaries of the Ohio River was contaminated by a massive cyanobacteria bloom (Lopez et al. 2008). In 1975, approximately 62 percent of the population of Sewickley, Pennsylvania, reported gastrointestinal illness, which the Centers for Disease Control (CDC) attributed to cyanotoxins released into open finished-water storage reservoirs (Lippy and Erb 1976).

Health effects of cyanotoxins can be acute or chronic and have been observed in the liver, nervous system, and gastrointestinal system. Liver cyanotoxins (i.e., microcystins) seem to be the most commonly found in cyanobacteria blooms and the most frequently studied. At least 80 microcystins are known. In laboratory animal studies, researchers have observed both acute and chronic effects from microcystins. In some studies, microcystins have rapidly concentrated in the livers of test animals, and at high doses, have resulted in organ damage, heart failure, and death. Long-term animal studies revealed chronic effects, including liver injury, renal damage, and an increased number of tumors (Humpage et al. 2000).

The impacts of chronic or acute exposure to cyanotoxins in humans, especially at the lower levels more common in drinking water, remain

Monitoring Cyanobacteria Blooms in North Carolina and Texas

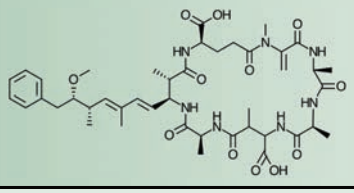
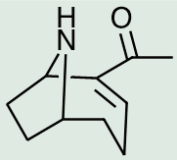
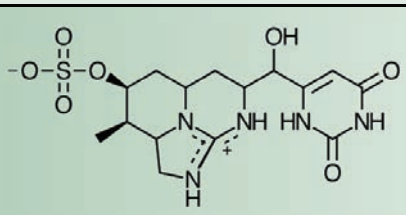
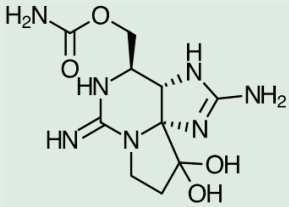
Raleigh and High Point, NC, teamed up with the CDC and North Carolina State University to develop an early warning system for three major drinking water reservoirs. Continuous monitoring data collected throughout the water column, as well as manually collected samples, have enhanced understanding about factors influencing algal growth. These monitoring data have been extremely valuable for tracking the chemical parameters that influence cyanobacteria blooms (Werblow 2008).

The City of Waco, Texas, was concerned that cyanobacteria blooms in its reservoir might be toxic. To track whether this is an issue for their water supply, the city has established an ongoing source water monitoring program that monitors raw water for anatoxin-a and microcystin at established locations in the reservoir, including the intake, and compares the city's results to the World Health Organization (WHO) guideline levels.

elusive. Studies in China have reported a correlation between liver or colorectal cancer and the consumption of water contaminated with microcystin-producing cyanobacteria blooms (Zhou et al. 2002). More research is needed to understand how cyanotoxins promote tumor growth and cancer.

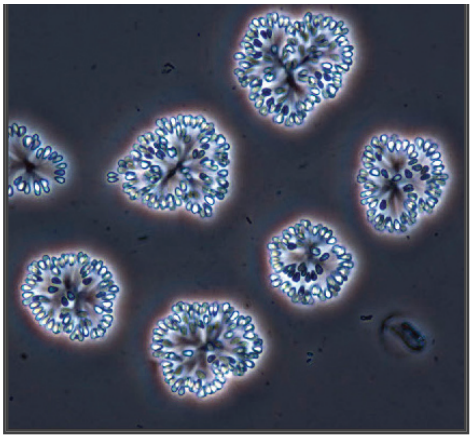
Anatoxin-a targets the nervous system and at very high levels of exposure can induce paralysis and death by respiratory failure. Other nonlethal cyanotoxins can trigger fevers, headaches, muscle and joint pain, diarrhea, vomiting, or allergic skin reactions. Table 1 briefly summarizes the toxicological effects of different cyanotoxins and the genera of cyanobacteria known to produce the toxins.

Table 1 Cyanotoxin structures, toxicological effects, and known producers

Toxin	Structure	Organ	Genera
Microcystin		Liver (possible carcinogen)	*Microcystis* *Anabaena* *Planktothrix* *Anabaenopsis*
Anatoxin - a		Neurotoxin (nerve synapse)	*Anabaena* *Planktothrix* *Aphanizomenon* *Cylindrospermopsis*
Cylindrospermopsin		Liver (possible kidney, genotoxic and carcinogen)	*Cylindrospermopsis* *Aphanizomenon*
Saxitoxin		Neurotoxin (sodium channel blocker)	*Anabaena* *Aphanizomenon* *Cylindrospermopsis* *Lyngbya* *Planktothrix*

3. *Are cyanobacteria blooms a new problem? Where have cyanotoxins been observed?*

Cyanobacteria blooms are not a new problem, although they are being more frequently observed and reported in recent years. At least 35 states have reported cyanobacteria blooms, with many of those blooms producing cyanotoxins (Lopez et al. 2008). When considering cyanobacteria blooms and cyanotoxin events, it is important to distinguish between *recreational water* and *drinking water*. Cyanotoxin-producing blooms have been identified in recreational waters more frequently in recent years, and contact recreation (swimming, for example)



Snowella

has been restricted more often in the last decade than in previous decades because of these blooms. In the summer of 2006, elevated levels of cyanotoxins caused at least 12 states to post advisories or close lakes and rivers out of concern for people and animals (Graham 2007).

Cyanotoxins have been found less often in drinking water supplies than in recreational waters. A 2000 Florida survey of finished drinking water reported cyanotoxins ranging from below detection level to 12.5 µg/L microcystin, 8.46 µg/L anatoxin-a, and 97.1 µg/L cylindrospermopsin (Burns 2008). As of early 2015, nationwide (U.S.) cyanotoxin occurrence in finished drinking water has not been gathered, although it could be conducted in the future through the Unregulated Contaminant Monitoring Rule (UCMR).

4. *Are cyanotoxins regulated in drinking water and what levels of toxins are of concern?*

As of early 2015, there are no federal regulatory standards or guidelines for cyanobacteria or cyanotoxins in drinking water. The Safe Drinking Water Act (SDWA) requires the US Environmental Protection Agency (USEPA) to publish a list of substances that could potentially be of concern and warrant further study, known as the Contaminant Candidate List (CCL). USEPA uses the CCL to prioritize research efforts to help determine whether a contaminant should be considered for regulatory action. Cyanotoxins were listed on the third CCL as a group and were also included on the proposed CCL4. USEPA's research is expected to focus on anatoxin-a, microcystin-LR, and cylindrospermopsin.

For microcystin-LR, the World Health Organization (WHO) has developed a provisional finished drinking water guideline of 1 µg/L, based upon chronic exposure (WHO 2003). A 2014 survey of state drinking water administrators found that three states out of the 34 states responding to the survey have drinking water advisory thresholds for microcystin (ASDWA 2014). Two of those same three states also have drinking water advisory thresholds for other cyanotoxins (see Table 2). Four additional states have drafted policies for addressing cyanotoxins, while eight more are in the process of preparing policies.

5. *What are the most important conditions leading to cyanobacteria blooms?*

The many types of cyanobacteria and diversity of their habitats make it complicated to predict the precise conditions favoring their growth. Physical factors that affect whether cyanobacteria grow include available light, weather conditions, water flow, temperature, and mixing within the water column. Chemical factors include pH and nutrient (primarily nitrogen and phosphorus) concentrations.

- *Water temperature:* Most algae favor temperatures between 60°F and 80°F; optimum conditions for many cyanobacteria are in even warmer waters, while some cyanobacteria grow at temperatures below 60°F.
- *Nutrients:* Elevated levels of nutrients foster algae and cyanobacteria growth.
- *Flow:* Quiescent or low-flow conditions favor cyanobacteria blooms. Turbulence disrupts buoyancy, and light can be limited at

Table 2 Specific drinking water advisory thresholds for microcystin and other cyanotoxins

State/Agency	Threshold Microcystin - LR (µg/L)	Threshold Anatoxin-a (µg/L)	Threshold Cylindrosper-mopsin (µg/L)	Threshold Saxitoxin (µg/L)
Ohio	1	20	1	0.2
Oregon	1	3	1	3
Minnesota	0.04*			
Quebec	1.5	3.7		
Health Canada	1.5			
WHO	1			

*The Minnesota level for microcystin is intended to be protective of a short-term exposure for bottle-fed infants.

NOTE: Health Canada and WHO data include information from other sources that was not provided through the ASDWA survey.

depths where there is vertical circulation in the water column.

- *Thermal stratification:* Cyanobacteria can regulate their buoyancy, giving them a competitive edge when the water column is stratified. Stratification can also affect nutrient availability to favor cyanobacteria.
- *Rainfall:* Rain events can increase the amount of runoff carrying nutrients into a water body and result in a cyanobacteria bloom.

Cyanobacteria blooms usually develop in waters rich in nutrients, especially phosphorus. Nutrients originate from point and nonpoint sources. Municipal wastewater and stormwater, as well as agricultural runoff, are common sources of nutrients. Some water bodies already contain enough nutrients in their sediments and aquatic ecosystem that cyanobacteria blooms can occur without additional nutrient input from any of these other sources.

Predicting and managing cyanobacteria blooms effectively require an understanding of a water utility's surface supply. The conditions likely to trigger blooms are ultimately site-specific (e.g., presence of cyanobacteria, nutrient levels, hydraulic conditions). Some utilities experience blooms in surface water supplies in early summer when the water reaches a warm enough temperature. Other utilities witness blooms when the thermocline begins to destratify in late summer or early fall (i.e., when turnover begins). Blooms may take place after a rain event, or they may occur after a series of sunny days. Algae and zooplankton as well as cyanobacteria can flourish under particular source water conditions and can have implications for drinking water treatment.

6. *If the surface water supply has cyanobacteria blooms, does that mean my utility has a cyanotoxin problem?*

Experiencing a cyanobacteria bloom does not always mean there is a cyanotoxin problem. Multiple strains of cyanobacteria can exist in a single bloom, and not all strains are capable of producing cyanotoxins. Even strains that can produce toxins do not always do so under all conditions. The conditions that trigger or inhibit production of cyanotoxins remain poorly understood. Laboratory analysis is usually needed to determine if the cyanobacteria are actually producing toxins.

Flow-routing baffle protects raw water from an *Aphanizomenon sp.* biomass

7. *If the surface water supply has taste and odor problems, does that mean cyanotoxins are also in the water?*

While some of the same types of cyanobacteria can produce cyanotoxins and taste and odor compounds such as geosmin and 2-methylisoborneol (MIB), a taste-and-odor episode does not necessarily mean cyanotoxins are also present. In addition, some cyanobacteria that produce cyanotoxins do not produce these musty and earthy compounds. Cyanotoxin production and taste and odor production should not be assumed to always occur together. However, if a source has a history of taste and odor concerns linked to cyanobacteria blooms, it may also have the potential for cyanotoxins.

Taste and odor events that do not produce cyanotoxins are also important because these events can lead to customer complaints and can undermine consumers' confidence about the safety of their water supply (AWWA 2010).

8. *Does my utility need to conduct a more thorough assessment to determine if cyanotoxins are a problem in the surface water supply?*

Neither the appearance of a cyanobacteria bloom nor the presence of taste and odor compounds alone is a clear indication that cyanotoxins are present, although both are indicators that potentially cyanotoxin-producing strains could also be present. Many cyanobacteria strains can be simultaneously present in one bloom. Toxin-producing cyanobacteria strains, when present, may or may not be actively producing cyanotoxins. While the presence of a toxin-producing strain does not always mean cyanotoxins are being produced, identification of these strains is still a widely used method for determining whether a bloom may be of concern (Merel et al. 2013). Some rapid and fairly simple methods, such as algae cell counts or microscopic examination, may be enough for a preliminary assessment of whether a potential hazard exists. However, definitively confirming the presence and type of cyanotoxins requires a more thorough assessment. Detection methods available for cyanotoxin measurement in freshwater are covered under questions 9 and 10.

9. *Can cyanotoxin-producing cyanobacteria blooms be predicted?*

Predicting cyanobacteria blooms before they occur can be challenging or in some cases not possible. Well-designed monitoring programs can provide effective early warning that cyanobacteria blooms are occurring, but additional steps are needed to understand actual toxin levels. Water utilities can benefit from observations that experienced water operators have made regarding past cyanobacteria blooms in water sources (e.g., after a significant summer rainstorm, when the water temperature reaches a certain point, following several days of sunshine, once the thermocline starts to weaken in late summer before turnover). Monitoring influent raw water can help utilities understand the potential for cyanobacteria entering the treatment plant.

Table 3 provides an overview of a range of different monitoring approaches. At the most basic level, monitoring for visual indicators of

cyanobacteria requires some staff training but will not require new, specialized facilities or equipment. Monitoring of chemical and physical variables (e.g., nutrient concentrations, physical conditions, and transparency) can help identify in a timely manner that a bloom is developing. Cyanobacteria blooms can develop quickly, over a period of just days. Consequently, developing a monitoring program requires striking a balance between monitoring type and frequency and the usefulness, complexity, and cost of running the program.

Table 3 Different types of monitoring, parameters, and personnel or equipment required to detect the possible presence of cyanotoxins

Monitoring Type	Parameters/ Variables	Demands on Equipment and Personnel	Who
Basic		Minimal	
Site inspection for indicators of cyanobacteria in water body	Transparency, discoloration, scum formation, detached mat accumulation	Secchi disc, regular site inspection by trained staff; basic skill requirement, training easily provided	Operators, practitioners
Surrogates		Low to moderate	
Potential for cyanotoxin problems in water body	Total phosphorus, nitrate and ammonia, flow regime, thermal stratification, transparency, phycocyanin	Boat, depth sampler, Secchi disc, submersible temperature/oxygen probe; fluorometer; spectrophotometer; basic skills but requires specific training and supervision	Limnologist
Cyanobacteria		Low to moderate	
In water body and drinking water	Dominant taxa (quantity): determination to genus level is often sufficient; quantify only as precisely as needed for management	Microscope, photometer is useful; specific training and supervision are required, but skills required can be readily mastered	Phycologist or a technician trained by a phycologist
Cyanotoxins		Moderate to high	
In water body and drinking water	Microcystin, anatoxin-a, cylindrospermopsin	Enzyme-linked immune assay (ELISA) kits (moderate); liquid chromatography photo-diode array (LC/PDA, moderately high); liquid chromatography mass spectrometry (LC/MS, high) specific training and supervision are required, but skills required can be readily mastered	Chemist

Microstysis bloom

10. How are cyanotoxins detected?

Several assays and analytical methods have been developed to either screen for or quantify cyanotoxins. In some cases, a utility's laboratory may be able to perform testing, provided the necessary laboratory equipment and expertise are available. In other instances, especially for advanced techniques, an external laboratory with experience and appropriate approvals may be the best choice. Not all laboratories will be equipped to analyze samples for cyanotoxins. Therefore, utilities may wish to research available options before making monitoring and laboratory choices.

Table 4 summarizes the most frequently used methods and the use, selectivity, and detection levels for each of them. Each method has advantages and disadvantages that should be considered when deciding how the method will be used. For example, to evaluate the efficiency of a treatment process, a screening tool such as an enzyme-linked immune assay (ELISA) can be used to provide the data needed to make informed treatment decisions. Costs range considerably from laboratory to laboratory, depending on the method used, the laboratory's experience with the method, and other factors. Many tests fall somewhere in the range of $35–$200 per sample and generally have a turnaround time of 48 hours or less, although this varies substantially and will likely change as the methods become more standardized and more frequently used.

Table 4 Common freshwater cyanotoxin detection methods

Test	Use	Selectivity *(Does it measure only the targeted compound?)*	Minimum Detection Level
ELISA	Screening test (generally requires confirmation with another test type)	Based on antibody/antigen interactions. Less selective because of cross reactivity with other similar molecules, including other microcystins, and nonspecific binding.	0.16 ppb
LC/PDA	Confirmatory	Chromatography separates the microcystins, microcystins identified by UV spectrum. More selectivity than ELISA, less selective than LC/MS/MS.	0.1 ppm
LC/MS/MS	Confirmatory	Chromatography separates the microcystins, identifies microcystins by precursor ion. Most selective.	0.1 – 10 ppb

11. What are effective ways to treat drinking water for cyanotoxins?

Identifying which cyanobacteria and cyanotoxins are present helps utilities know they are using the appropriate treatment processes. Key factors to consider are the type of cyanotoxin and whether it is contained within the cyanobacteria cells (intracellular) or dissolved in the water (extracellular). Intracellular toxins can be eliminated by removing the cyanobacteria cells. Extracellular toxins are generally more difficult to remove. Sometimes water treatment itself can release toxins from cyanobacteria.

Table 5 provides a summary of the effectiveness of different water treatment technologies for removing cyanotoxins (Lopez at al. 2008; Westrick et al. 2010; USEPA 2012a). Treatment selection is context-specific and depends on the

concentration and types of cyanobacteria or cyanotoxins to be removed or inactivated. Treatment selection is context-specific and depends on the concentrations and types of cyanobacteria or cyanotoxins that are to be removed or inactivated. Table 5 provides a general summary of treatment approaches and their effectiveness, but additional site-specific examination of conditions is necessary before making any treatment decisions. The configuration of a particular treatment system can substantially change the effectiveness of any particular action.

Table 5 Common cyanotoxin treatment practices and their relative effectiveness

Treatment Process	Relative Effectiveness
Intracellular Cyanotoxins Removal (intact cells)	
Conventional coagulation, sedimentation, filtration	Effective for the removal of intracellular/particulate toxins by removing intact cells. Generally more cost effective than chemical inactivation/degradation, removes a higher fraction of intracellular taste and odor compounds, and easier to monitor.
Flotation (e.g., dissolved air flotation)	Effective for removal of intracellular cyanotoxins because many toxin-forming cyanobacteria are buoyant.
Pretreatment oxidation (oxidant addition prior to rapid mix)	Overall, can either assist or make treatment more difficult, depending on the situation. Pre-oxidation processes may lyse (cause dissolution or destruction of) cells, causing the cyanotoxins contained within to release the toxins. Ozone may be an exception (see "Ozone" row) because it both lyses cells and oxidizes the cyanotoxins.
Membranes (microfiltration or ultrafiltration)	Effective at removing intracellular/particulate toxins. Typically membranes require pretreatment.
Extracellular Cyanotoxins Removal/Inactivation	
Chlorination	Effective for oxidizing extracellular cyanotoxins (other than anatoxin-a) when the pH is below 8
Chloramines	Not effective
Potassium permanganate	Effective for oxidizing microcystins and anatoxins. Not effective for cylindrospermopsin and saxitoxins.
Chlorine dioxide	Not effective with doses typically used in drinking water treatment
Ozone	Very effective for oxidizing extracellular microcystin, anatoxin-a, and cylindrospermopsin
Activated carbon (powdered activated carbon and granular activated carbon)	Most types generally effective for removal of microcystin, anatoxin-a, saxitoxins, and cylindrospermopsin. Because adsorption varies by carbon type and source water chemistry, each application is unique; activated carbons must be tested to determine effectiveness.
UV radiation	Degrades toxins when used at high doses, but not adequate to destroy cyanotoxins at doses used for disinfection.
Membranes (reverse osmosis [RO] or nanofiltration [NF])	RO effectively removes extracellular cyanotoxins. Typically, NF has a molecular weight cut off of 200 to 2,000 Daltons, which is larger than some cyanotoxins. Individual membranes must be piloted to verify toxin removal.

12. How can cyanobacteria and cyanotoxins monitoring be incorporated into a utility's management plan?

Establishing a monitoring program and benchmarks for when source and/or finished water should be analyzed for different water quality parameters provides a solid foundation for a cyanotoxin management approach. If specific test results exceed pre-established levels, a water utility can take follow-up actions, defined in advance, such as:

- Initiating more frequent, detailed, or specific monitoring
- Drawing water from a different intake depth or location, if multiple depths/locations are available
- Adjusting treatment to specifically remove/destroy cyanobacteria and/or extracellular cyanotoxins
- Switching sources, if multiple sources are available

Management plans should be specific to the utility's circumstances. Depending on

Addressing Cyanobacteria Growth in New Jersey

United Water has developed a plan to address concerns about cyanobacteria growth and related compounds in Lambertville Reservoir, a water supply in central New Jersey. The purpose of the Monitoring, Management and Treatment (MMT) Plan is to reduce the likelihood and magnitude of cyanobacteria blooms and related taste and odor compounds and toxins, and to effectively treat the water should a bloom occur. The MMT Plan has three key components:

Blue-green *Aphanizomenon sp.* on Klamath River

1. ***Monitoring*** Collect site-specific data in the reservoir to assess and respond to conditions in a more effective manner.
2. ***Management*** Implement both in-lake and watershed-based measures to improve the overall water quality of the reservoir.
3. ***Treatment*** Develop a proactive treatment strategy for the reservoir and implement additional control measures at the water treatment facility to remove algae toxins from the drinking water.

United Water also performed a bathymetric assessment of the reservoir bottom (surveyed the submarine terrain features), prepared a hydrologic determination of how much water is entering and leaving the reservoir, and developed a process for detecting and mitigating levels of nutrients that encourage algae growth, particularly phosphorus.

The improved treatment strategy includes using water quality data to determine when to treat for algae, rather than adhering to a fixed schedule for treatments. United Water adopted the use of liquid chelated copper-based algaecides in the reservoir, which provides a more uniform dose, are more persistent, and appear to be more effective than copper sulfate crystals against the cyanobacteria in the Lambertville Reservoir.

Finally, United Water upgraded its water treatment facility by installing a powdered activated carbon (PAC) system as a backup for MIB/geosmin and algal toxin control, and upgraded the plant's filters to accommodate the additional solids load from the PAC. (Cartnick 2014).

local conditions, a water utility may choose to use one or a combination of strategies. Good data are essential to crafting this management plan. For example, using intakes at different depths requires knowledge of the cyanobacteria bloom's distribution and dynamics throughout the reservoir and water column. Sometimes a utility can minimize drawing contaminated water by varying intake depths, but there must be an understanding of where in the water column cyanobacteria are concentrated.

A complete plan will address communication to customers as well as monitoring and managing the utility's water supplies and treatment strategy. Notifying consumers of potential cyanotoxin risks can be challenging. Establishing protocols for when to inform customers and preparing communication materials in advance facilitates more timely and effective communication (USEPA 2012a; Westrick et al. 2010).

Key elements of an effective response plan can include, but are not limited to:

1. Convening a group to develop, maintain, and modify the plan
2. Defining specific actions at different alert levels and the responsibilities of personnel implementing the plan. This includes instructions for management, monitoring, water treatment, and communicating with the public.
3. Planning for effective communication among key government agencies, health authorities, water supply agencies, hospitals, as well as the public
4. Making prior agreements about standardized communications plans and when those plans go into effect. The release of information to the media should be well coordinated.

Additional Resources

Several helpful guides are available for water utility staff who want to learn more about managing cyanotoxins and their impacts. AWWA and the WRF are preparing a technical guide to accompany this introduction to cyanotoxins. The technical guide will be available for members and subscribers on AWWA's and the WRF's websites.

Additional publications include, but are not limited to:

- USEPA's Cyanobacterial Harmful Algal Blooms resource page at http://www2.epa.gov/nutrient-policy-data/cyanobacterial-harmful-algal-blooms-cyanohabs
- International Guidance Manual for the Management of Toxic Cyanobacteria (2009) from the Global Water Research Coalition at www.waterra.com.au/cyanobacteria-manual/PDF/GWRCGuidanceManualLevel1.pdf
- Newcombe, G. et al. 2010. *Management Strategies for Cyanobacteria (Blue-Green Algae): A Guide for Water Utilities: Research Report No. 74*
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- Association of State Drinking Water Administrators Harmful Algal Blooms (HABs) resource page includes links to state web pages addressing cyanobacteria blooms and cyanotoxins: www.asdwa.org/habs.

The references and bibliography listed at the end of this document provide a more thorough overview of cyanobacteria and cyanotoxins research. Additionally, many states have helpful resources available on their websites.

Secchi disk is barely visible in an algae bloom

Quick Self-Assessment

Step 1: How prepared is my system for potential cyanotoxin events?

Asking the following questions can give a water utility a better idea of whether the utility should be preparing itself for possible cyanotoxin problems. This brief assessment considers three categories: 1) source water monitoring; 2) source water quality; and 3) cyanobacteria present during the treatment process. This tool is applicable only for water utilities using water from surface water bodies.

	High Concern	Medium Concern	Low Concern	Very Low Concern
Source Water Monitoring				
Does the utility have a source water monitoring program in place?	Doesn't monitor source water before treatment	Conducts some tests on source water (e.g., turbidity, total organic carbon) as it enters treatment plant	Monitors source water monthly (e.g., chlorophyll *a*, algae counts) at different depths and locations	Has a comprehensive source water monitoring program, sampling at least weekly at different depths, locations
Does the source water quality monitoring program evaluate changes to the water over the year?	No	No	Yes, tracks monthly water quality trends (e.g., to help determine which source(s) to use)	Yes, tracks trends at least weekly of all monitored parameters
Does the utility track changes by comparing water quality data from year to year?	No	No	Yes, seasonal or annual averages are tracked and compared	Yes, charts are created with monthly data for at least the last five years
Source Water Quality and Aesthetics				
Does the source water have algae growth?	Yes, there are blooms and copper sulfate is added regularly	Yes, but treatment adjustments are not necessary in response	Minor algae growth, but no visually obvious blooms	Very minimal, if any, growth
Does the source water stratify thermally in the summer?	Yes, strong thermocline and turnover in late summer/fall with noticeable water quality changes	Yes, stratifies but no noticeable changes in water quality with turnover	Stratifies some during the day but mixes at night	No
Is the surface water source affected by drought?	Yes, water level drops, water is warmer due to drought conditions	Yes, water level drops a small amount, no water temperature increases	No	No
Does the source water have taste and odor producing blooms?	Yes	N/A	N/A	No

	High Concern	Medium Concern	Low Concern	Very Low Concern
Cyanobacteria in the Treatment Process				
Are there restrictions on treating the source water (e.g., in reservoirs)?	Stringent restrictions (source water treatments not allowed)	Some restrictions (source water treatments limited)	Minimal restrictions	No restrictions
Are any treatment processes exposed to sunlight?	Yes, most of the unit processes are outdoors and uncovered	Yes, at least one unit processes is exposed to sunlight	No	No
Is the filter backwash green?	Yes, frequently	Yes, periodically	No	No
Does the utility have taste and odor problems?	Yes, frequent complaints during the summer	Yes, periodic complaints	Once every few years	No
Are the basins regularly cleaned?	No, never	Maybe once every few years	At least once a year	More than once a year

Algae skimmer removes biomass in a dissolved air flotation plant in Waco, Texas

Microsystis

Quick Self-Assessment

Step 2: What tools are available to respond to cyanotoxins?

The next step is to determine whether the utility has effective measures in place to 1) control cyanobacteria growth and/or treat water for cyanobacteria and cyanotoxins; 2) reliably use an alternative supply or select from different intakes; and 3) communicate effectively with consumers and the public health community. For each topic in the following table, check whether the utility has that measure available. If it is available, check whether or not it has been evaluated specifically for addressing cyanotoxins.

	Yes	No	If yes, has the measure been evaluated for addressing cyanotoxins?
Water Quality Management/Treatment			
Algae reduction tools for source water supply, including: Enhanced aeration/circulation/mixing Chemical addition (e.g., copper sulfate, chlorine) Ultrasound Other			
Ability to select from different intakes, both in terms of depths/locations *and* time (i.e., the ability to switch intakes without delay or much effort)			
Intake inline oxidant addition: Permanganate Chlorine Chlorine dioxide Other			
Conventional treatment			
Membrane filtration			
Activated carbon (powdered or granular) or other adsorptive media			
Oxidative processes (in use for DBP precursor removal, taste and odor control, or other chemical contaminant removal): Ozone Peroxide Other			
Disinfection processes			
Supplying Water			
For disruptions lasting longer than the system's ability to supply customers using existing finished water storage, have you worked with regulatory agency to develop a plan consistent with *Planning for an Emergency Drinking Water Supply?* (EPA 600/R-11/054, June 2011. http://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=502174)			
Communicating with the Public			
Reviewed and updated or prepared communication materials for both cyanotoxins and taste and odor events			
Established communication network with the local public health and medical community			

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Anabaena sp. and *Aphanizomenon sp.* form a biomass near a raw-waterintake