Ohio Environmental Protection Agency

Developing a Harmful Algal Bloom (HAB) Treatment Optimization Protocol

Guidance for Public Water Systems

Division of Drinking and Ground Waters
Version 2.1 January 2019

Page intentionally left blank.

Definitions

Anatoxin-a: A nerve toxin produced by a number of cyanobacteria.

Biovolume: The volume of cells in a unit volume of water. Biovolume is calculated to determine the relative abundance of co-occurring phytoplankton of varying shapes and sizes.

Blue-green algae: Common name for cyanobacteria, see definition below.

Cyanobacteria: Photosynthesizing bacteria, also called blue-green algae, which naturally occur in marine and fresh water ecosystems, and may produce cyanotoxins which at sufficiently high concentrations can pose a risk to public health.

Cyanotoxin: Toxin produced by cyanobacteria. These include liver toxins, nerve toxins and skin toxins. Also, sometimes referred to as "Algal toxin."

Cylindrospermopsin: A liver toxin produced by a number of cyanobacteria.

ELISA (Enzyme-Linked Immunosorbent Assay): A rapid immunoassay-based analytical method commonly used to detect microcystins, cylindrospermopsin, and saxitoxins.

Extracellular: Located or occurring outside of a cell or cells.

Finished drinking water: Treated water ready for human consumption.

HAB (Harmful Algal Bloom): A concentration of cyanobacteria that discolors the water, or a cell count greater than 4,000 cells/ml of cyanobacteria genera capable of cyanotoxin production (Shambaugh and Brines, 2003). Accumulations of cyanobacteria cells may be present at the water surface, at a defined depth, or throughout the water column.

Intracellular: Located or occurring within a cell or cells.

Microcystins: Liver toxins produced by a number of cyanobacteria. Total microcystins are the sum of all the variants/congeners (forms) of the cyanotoxin microcystins.

Natural Organic Matter (NOM): Withering material from plants and animals and their degradation products. Typically measured as TOC (see below).

Photic zone: The uppermost layer in a body of water into which light penetrates in sufficient amounts to influence living organisms, especially by permitting photosynthesis.

Phytoplankton: free-floating photosynthesizing microscopic organisms that inhabit almost all bodies of water, and include cyanobacteria, diatoms, green algae and dinoflagellates.

qPCR (quantitative Polymerase Chain Reaction): Molecular technique for quantifying the presence of specific genetic material (DNA) in a sample.

Saxitoxins: Nerve toxins produced by a number of cyanobacteria.

Scum: A cyanobacteria bloom that has a dense surface accumulation of cyanobacteria cells.

Source water: Water used as a source for public drinking water.

Total Organic Carbon (TOC). Most comprehensive measurement to quantify the presence of natural organic matter in water (may be used synonymously with NOM). TOC can be divided into Dissolved Organic Carbon (DOC), which is the dissolved portion of TOC (smaller than 0.45 uM), and Particulate Organic Carbon (POC), the larger fraction of TOC that is retained on a 0.45um filter.

Vicinity of intake: Area where there is a likelihood of contaminants being drawn into the intake (within 500 yards of the intake).

Zeta Potential: The charge that develops at the interface between a solid surface and a liquid, as measured in MilliVolts. It is related to the electrostatic repulsion between particles and affects colloidal stability and associated flocculation processes.

Introduction

When required under Ohio Administrative Code (OAC) Rule 3745-90-05, a Harmful Algal Bloom (HAB) treatment optimization protocol (TOP) must include treatment adjustments that will be made under various raw and finished water quality conditions. While HABs can produce many different cyanotoxins, the TOP must focus on optimization of existing treatment for microcystins removal. While not required, if other cyanotoxins have been detected in the PWS source water(s), including optimization strategies to address those cyanotoxins is recommended.

The PWS must consider effective strategies for cyanotoxin treatment such as:

- Avoiding lysing cyanobacterial cells;
- Optimizing removal of intact cells;
- Optimizing extracellular cyanotoxin removal or destruction;
- Optimizing sludge removal; and,
- Discontinuing or minimizing backwash recycling.

Source strategies, if available, must also be included, such as:

- Avoidance strategies (e.g., alternate intake, alternate source, suspending pumping);
- Reservoir management/treatment; and,
- Nutrient management.

Source and treatment plant optimization options must include at least those strategies that are available to the PWS as part of their current processes. Additional treatment options that can be installed and implemented immediately may be considered but must receive Ohio EPA approval before installation.

Aside from avoidance, an efficient and cost-effective optimization method is the removal of intact cyanobacterial cells. The treatment optimization protocol must describe how the water system will optimize removal of intact cells through coagulation/flocculation/filtration while avoiding additional cell lysis. Optimizing conventional treatment for turbidity removal (or other relevant indicators, such as natural organic matter (NOM) removal or zeta potential that gauges effective coagulation) can also assist in cell removal.

The coagulation, flocculation and sedimentation processes are effective in removing cyanobacteria cells and associated intracellular cyanotoxins but are ineffective at removing extracellular cyanotoxins. A multi-barrier approach, which couples optimization of intact cell removal with steps to remove extracellular cyanotoxins, is needed because cyanobacteria cells can release cyanotoxins during their normal life cycle or when cells die and lyse (cell walls rupture). Extracellular microcystins have been measured at up to 77% of total microcystins in Lake Erie intake samples and 100% of saxitoxins have been in extracellular form in intake samples collected at inland lakes and reservoirs. Extracellular cyanotoxins are more difficult to remove than intracellular cyanotoxins and require additional physical or chemical processes. Processes that target extracellular cyanotoxins include Powdered Activated Carbon (PAC) or Granular Activated Carbon (GAC) for adsorption, a strong oxidant (e.g., permanganate, chlorine, ozone) for destruction, or rejection through membranes.

How to Use this Document

This guidance describes source water and HAB treatment optimization options as well as water quality monitoring parameters and operational triggers for plant optimization. The guidance is divided into five parts to facilitate drafting the treatment optimization protocol (TOP):

- Part I — PWS Existing Treatment Processes Summary Information
- Part II — Establishing Triggers for Optimization Based on Raw and Finished Water Quality
- Part III — Source Water Management Strategies
- Part IV — Treatment Plant Optimization Strategies
- Part V — Response Based on Raw and Finished Water Cyanotoxin Detections

Completing the sections contained in the accompanying TOP template will assist a PWS in meeting the rule criteria established for submission of the TOP. Examples are provided throughout this guidance to assist in understanding the level of detail that should be provided in the TOP. The information in the examples is not applicable to all water systems, since each water treatment plant and their associated source water is unique. Additional references and resources are provided in the Appendix.

I. PWS Information and Existing Treatment Processes

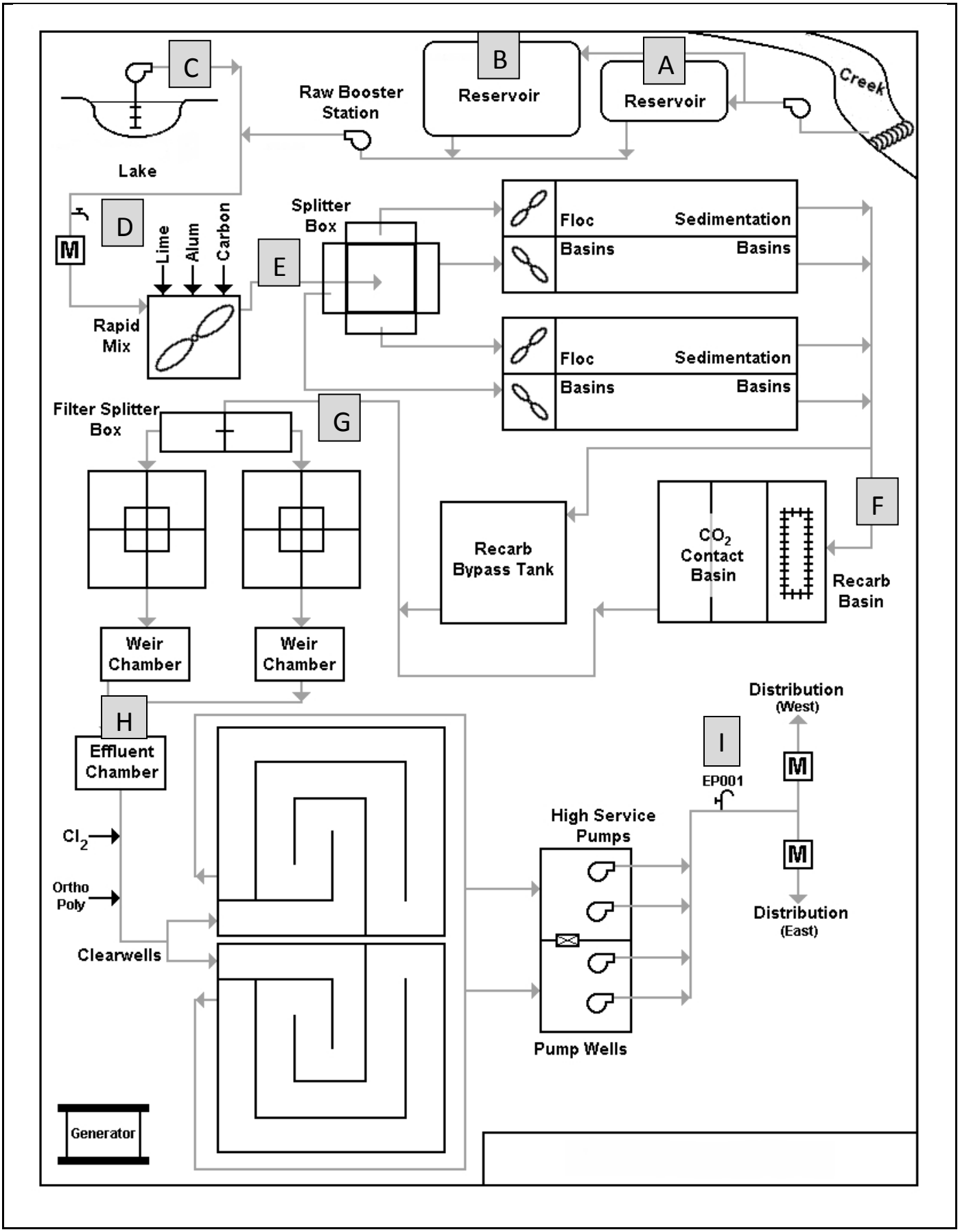
This section must provide detailed information on the PWS, the Operator(s) of Record, and contact information for the individual(s) completing the TOP. The existing water treatment process must be documented in three sections: schematic, raw, and finished water sources.

A. Schematic

Provide a schematic that depicts, at minimum, all sources, treatment plant components/processes and chemical addition points. Indicate the locations where treatment train samples would be collected, if necessary, to determine cyanotoxin removal through individual plant processes. Treatment train and reservoir sample results can be submitted to Ohio EPA's electronic data reporting system (EDWR) as special purpose (SP) samples using the process point (PP001-PP005) and intake (IN) sample stations in eDWR. Using consistent sampling locations and names is strongly recommended, so results from one sampling event can be more readily compared to future sampling events. In addition, treatment train data may help the water system develop a HAB General Plan, if one is required. Please note, if collecting additional raw water (LT2001) or finished water (EP001) samples beyond the required compliance samples, those can also be submitted to EDWR as "special purpose" samples.

An example schematic is on the following page and the table below describes the associated sampling points. Not all plants will have the same "PP00#" sampling points- the important thing is for each plant to consistently name and sample the same locations within their system.

Example Sampling Points (refer to example schematic on following page)			
Map Key	EDWR Sample Point Name	Sampling Location Description	Sample Type
A	IN82557	Reservoir 1 Intake	Special Purpose
B	IN82558	Reservoir 2 Intake	Special Purpose
C	IN82560	Lake Intake	Special Purpose
D	LT2001	Raw Water Tap in Plant	Compliance
E	PP001	Post Rapid Mix	Special Purpose
F	PP002	Post Clarification	Special Purpose
G	PP003	Post Recarbination Basin	Special Purpose
H	PP004	Combined Filter Effluent	Special Purpose
I	EP001	Entry Point to Distribution (Finished Water)	Compliance


C
B
A
Raw Booster Station
Reservoir
Reservoir
Creek
Lake
D
M
Lime
Alum
Carbon
Splitter Box
E
Rapid Mix
Floc
Sedimentation
Basins
Basins
Floc
Sedimentation
Basins
Basins
Filter Splitter Box
G
F
Recarb Bypass Tank
CO_2 Contact Basin
Recarb Basin
Weir Chamber
Weir Chamber
H
Effluent Chamber
Cl_2
Ortho Poly
Clearwells
Distribution (West)
I
EP001
M
High Service Pumps
M
Distribution (East)
Pump Wells
Generator

B. Raw Water Sources

Identify all raw water sources to treatment plant. Please include all of the following (if applicable):

- River/Stream – Describe the location(s) [such as shoreline or feet offshore], capacity(s), and depth(s) of intake(s). If multiple intakes or intake depths are available, specify which are typically used in normal operations.
- Lake/Reservoir(s) – Describe the intake location(s) [including feet offshore], capacity(s), and depth(s)]. If multiple reservoirs exist, specify which, if any, can be isolated and describe normal operations. If reservoirs are filled from a stream or river, identify the source(s) and describe the normal reservoir filling procedures.
- Describe how water is transferred from source to plant (length and diameter of lines, valving, manual versus automated controls) and any chemical feed points prior to entering the plant.
- Ground Water wells – List the number of wells and their pumping capacities. Describe the normal use of ground water, including the usual blend of ground versus surface water employed.

Example: Somewhereville has intakes on River A and River B. Intake structures extend approximately 15 feet from the shoreline and are located behind low head dams. The intake on River A pumps into reservoir 1 (250 million gallon capacity) and the intake on River B can pump directly into Reservoir 2 (150 MG capacity) or into Reservoir 3 (150 MG capacity). Pumping and valves are controlled remotely using SCADA. Reservoir 1 has one set intake depth (8' off bottom), and the intake extends 25 feet into reservoir. The newer reservoirs 2 and 3 have three intake gates -5' off bottom, 10' off bottom, and 20' off bottom. The middle intake gate is open in normal operation and the top and bottom gates are closed (but are regularly exercised). Concrete intake structures on Reservoirs 2 and 3 are approximately 20 feet from reservoir shoreline and are accessible from shore via a catwalk. Reservoirs 2 and 3 are maintained at depths of 25 to 35 feet.

Reservoir 1 gravity feeds into the water treatment plant via a 500-foot 36 inch line and Reservoirs 2 and 3 must be pumped to the plant via 1200 and 1300 foot 24 inch lines, respectively. Can pump from each reservoir separately or blend sources. Typically alternate between using reservoir 1 exclusively and combined reservoirs 2 and 3.

There are onshore wet wells on the shoreline of River A and B where up to 10 ppm of potassium permanganate can be added to the raw water line prior to pumping to the reservoirs.

After the drought of 1988, two ground water wells were installed with 300 gpm pump capacity. The wells can be pumped into reservoirs 2 and 3 if needed but cannot be pumped directly to the plant.

C. Finished Water Sources

List supplying systems and/or emergency interconnections that can be used as alternate sources of finished water during a HAB event. If no interconnections with another PWS exist, describe the water system's plan to provide water in the event of a HAB-related "Do Not Drink" advisory. This information should be consistent with the water system's contingency plan required by OAC Rule 3745-85-01. For more information see Ohio EPA's Contingency Plan Guidance template, Appendix U Alternate Water Source Procedure, available at: ***https://epa.ohio.gov/Portals/28/documents/security/Contingency_Plan_Template.docx***

Example: The City of Somewhereville has interconnections with Overhere and Overthere water systems. Overhere and Overthere can only provide 50% of average Somewhereville demand but could provide 100% of demand to areas of distribution that could be hydraulically isolated (approximately 30% of distribution, in highland region).

ALTERNATE WATER SOURCE PROCEDURE

A description of your facility's standard operating procedure for providing water through alternative sources.

Alternative sources of water can include, but are not limited to:

☐ a. Hauling water using the approved haulers

Company Name	Contact	Day-Time Phone	After Hours

☐ b. Activating an existing emergency connection to another public water system or installing a new emergency connection to another public water system with approval of Ohio EPA.

Company Name	Contact	Day-Time Phone	After Hours

☐ c. Providing bottled water for potable use from the following organization(s):

Company Name	Contact	Day-Time Phone	After Hours

☐ d. Other:

II. Establishing Triggers for Treatment Optimization Based on Raw and Finished Water Quality

Rule 3745-90-05 requires the treatment optimization protocol include treatment adjustments that will be made under various raw and finished water conditions.

The purpose of this section is to identify changes in raw water or in treatment processes that may indicate a HAB event is developing or occurring. The associated treatment changes the PWS intends to make in response to a HAB event are covered in Section IV of this document.

A. Raw water screening tools

Aside from raw and finished water monitoring of microcystins, other raw water monitoring parameters can be used to indicate a bloom is developing or occurring. To utilize this data as a screening tool, baseline water quality conditions should be established for these parameters. Once baseline conditions are established, the water system can observe changes and identify trends that are present when a bloom is developing or occurring. Raw water quality parameters which may assist with identifying bloom occurrence include:

- cyanotoxin-production genes
- pH
- phycocyanin or chlorophyll-a concentration
- cyanobacteria or phytoplankton identification and cell counts
- remote sensing satellite or hyperspectral imagery data

Many PWSs have incorporated data sondes and probes into their source water monitoring protocol to collect this information. Ohio EPA strongly recommends water systems acquire continuous monitoring equipment to collect and transmit relevant source water information. Water systems can also collaborate with each other or other entities that are conducting monitoring on their source water to collect this information. An analysis of this data should be conducted to identify trends that can be used as bloom indicators. Trends and usefulness of the data will be site-specific and may differ from water system to water system. Including those listed above, the following parameters may be useful as indicators.

<u>Cyanotoxin-Production Genes</u>

Quantitative polymerase chain reaction (qPCR) can be used to quantify the presence of cyanotoxin-production genes in a water sample and provide an estimate of cyanobacteria in a sample. Results are reported as gene copies/microliter (GC/µL). Routine qPCR cyanobacteria screening is a requirement under OAC Rule 3745-90-05 and triggers follow-up monitoring by Ohio EPA for saxitoxins and cylindrospermopsin. In some source waters, the mcyE microcystins production gene has been detected 1-4 weeks prior to detecting microcystins and can provide an early warning of a developing HAB. Additionally, the assay provides an estimate of total cyanobacteria concentration as the 16S gene, which can be correlated with other parameters (e.g., phycocyanin or pH) to set baseline conditions or thresholds for a bloom.

<u>pH</u>

A small uptick (a few tenths) in pH values from baseline numbers may indicate bloom development. During severe blooms, pH values can exceed 9. Diurnal cycles or variations in pH may be indicative of cyanobacteria as a result of their photosynthesis and respiration.

Cyanobacteria Cell Counts

Cyanobacteria cell densities greater than 10,000 cells/mL can be indicative of detectable cyanotoxin concentration in the raw water source. Microcystis cell counts as low as 6,000 cells/mL can result in elevated microcystin~~s~~ concentrations. Some water systems send samples to a phycologist to conduct routine cell counts. Cyanobacteria cell counts are not often performed by water system personnel due to the cumbersome nature of this method, however, water systems can compare changes in number of colonies per slide over time. Increasing cyanobacteria cell counts or increases in qualitative measures can indicate the beginning of bloom formation. An upward trend over time can be an indicator of the bloom increasing in severity.

Phytoplankton ID

Can be used to determine if the bloom contains cyanobacteria and which genera or species dominates the bloom. Knowledge of cyanobacteria genera can help focus reservoir management and treatment optimization strategies. For example, Planktothrix blooms may require higher doses or different formulations of algaecide to control than Microcystis blooms.

Phycocyanin and Chlorophyll-a Concentrations

If phycocyanin levels are detectable, this is an indicator that the bloom contains cyanobacteria. The phycocyanin pigment is only present in cyanobacteria and not in other types of algae. An increase in phycocyanin levels can indicate increased cyanobacteria and potentially an increase in levels of cyanotoxins. Since not all cyanobacteria produce cyanotoxins, an increase in phycocyanin is not always associated with a cyanotoxin producing bloom.

Source waters with high levels of chlorophyll-a may also have high levels of cyanobacteria If the phytoplankton community is dominated by cyanobacteria, then chlorophyll-a concentrations can also be a good estimate of cyanobacteria; however, chlorophyll-a concentrations should be evaluated in conjunction with phycocyanin levels or cell count data, as all algae contain chlorophyll-a.

Both phycocyanin and chlorophyll-a can be measured in situ with sondes/probes, in the laboratory, or through satellite and hyperspectral imagery. Satellite and hyperspectral imagery from aircraft use the optical properties of these pigments to estimate cyanobacterial concentration (cells/mL). Lake Erie has historical and ongoing satellite data. PWSs using Lake Erie as a source water are encouraged to use this data; hyperspectral data is available at: ***www.glerl.noaa.gov/res/HABs_and_Hypoxia/airSatelliteMon.html***, and satellite data on HABs is available at: ***www.glerl.noaa.gov/res/HABs_and_Hypoxia/bulletin.html***. Satellite information on HABs is also publicly available for large inland lakes from NOAA at: ***https://products.coastalscience.noaa.gov/hab/.***

Water systems are encouraged to routinely review HAB satellite data for their source waters, if available.

Oxidation Reduction Potential (ORP)

As a bloom intensifies, ORP may decrease as oxygen is consumed. ORP may be a useful indicator in some source waters. A PWS will need to verify how well ORP correlates with the occurrence of cyanobacteria and cyanotoxins.

Turbidity

Turbidity may be a useful indicator in some water systems. A system will need to verify how well turbidity correlates with occurrence of cyanobacteria and cyanotoxins. Turbidity from storm events may interfere with the correlation of turbidity and occurrence of cyanotoxins.

Visual Inspection

It may be useful to make an initial assessment of source water quality based on visual evidence, which can then be refined as additional information is collected. This could be useful for water systems with multiple reservoirs where the required HAB compliance results may not reflect water quality in individual reservoirs. Guidance on the visual appearance of cyanobacteria blooms versus other green algae blooms, including a picture gallery of blooms, is available on Ohio EPA's PWS HAB website at: ***epa.ohio.gov/ddagw/HAB.aspx***. Since a severe cyanobacteria bloom may not form a surface scum, in the absence of any additional data, a visible bloom should be regarded as severe until additional data is collected.

In some situations, a severe bloom may be present but not visually evident. This can be the case with cyanotoxin-producing *Planktothrix rubescens* blooms that can occur at significant depth in the water column and not be visible at the water surface and with *Cylindrospermopsis* blooms that can resemble turbid brownish-green water. These blooms do not appear like the more typical blue or green colored scum-forming cyanobacteria blooms and can pose a monitoring challenge. Benthic species of cyanobacteria that are not visibly apparent at the water surface can also be sources of cyanotoxins. **A water system should not rely on visual inspection alone.**

Taste and Odor

The taste and odor compounds Geosmin and 2-methylisoborneol (MIB) are most often produced by cyanobacteria. These compounds may signal that cyanotoxins could also be produced. Some cyanobacteria that produce cyanotoxins are not capable of producing Geosmine and MIB, so **an absence of taste and odor compounds does not mean an absence of cyanotoxins**. List water quality parameters and tools used to monitor raw water.

Example: A datasonde is installed at the wet well and transmits data in real time to our SCADA system. The sonde is equipped with pH, turbidity, chlorophyll-a and phycocyanin sensors. We set alarms at phycocyanin concentrations of 2 RFU. pH and turbidity are also measured throughout the plant every six hours and logged on a daily sheet.

We collect samples at each reservoir surface at the intake locations and send them for phytoplankton cell counts at least monthly (bi-weekly in summer). We also have a microscope in the plant lab and have someone trained in basic cyanobacteria identification. They will collect a fresh sample to determine if cyanobacteria are present if phycocyanin readings increase, or there are other changes in raw water quality, and will also evaluate any scum samples.

Compliance qPCR and microcystins samples are collected at our raw water plant tap.

Identify any raw water screening tools that will be used to trigger optimization or avoidance actions. Identify monitoring locations, the indicator's normal conditions, and the criteria that may indicate a HAB for each raw water quality indicator. See examples on following page.

Example:

Raw water quality indicator	Monitoring Location and Frequency	Normal Conditions	Criteria that may indicate a HAB
pH	Raw tap in lab (LT001) Every 6 hours and pH sensor on datasonde (continuous)	8.2 – 8.5	Any rapid increase (+/- 0.3 over 4 hours) pH > 9.0 in warm weather has historically occurred with HABs in our reservoir. Diurnal pattern (>9.0 during the day, lower overnight)
phycocyanin	Continuous via datasonde (incorporated in SCADA with alarm set at 2 RFU)	<0.5 RFU	Historically, low levels of microcystins (less than 1.6 ug/L) have been detected when phycocyanin was between 0.5 and 2 RFU. RFUs greater than 2 typically indicate onset of higher raw water microcystins concentrations
mcyE genes	biweekly	not detected	Typically, low level mcyE genes detections (<1 GC/uL) precede raw water microcystins detections by 1-2 weeks. When mcyE exceeds 5 GC/uL microcystins are typically detected in the raw water at concentration above the 1.6 ug/L adult action level.
microcystins	Weekly during HAB season	not detected	Any microcystins detection is a clear indication of a HAB. Treatment optimization will vary based on concentrations in the raw water, or if detections occur in the finished water.
phytoplankton cell counts	Monthly year-round, bi-weekly during summer	Total cyanobacteria <10,000 cells/ml, Microcystis <2,000 cells/ml	Total HAB-type cyanobacteria increase above 10,000 cell/ml or Microcystis increases above 5,000 cells/ml.
geosmin/MIB	Following customer complaint	not detected	geosim or MIB detected in summer or following fall turnover, and not associated with a recent significant rain event.
surface scum	Reservoirs are visually inspected once/day	surface scums are not present	Surface scums are present (confirmed by microscopic identification to be caused by cyanobacteria)

Specify how the water system will respond to raw water HAB indicators.

Example: Section IV specifies the treatment optimization strategies that will occur if microcystins are detected at various concentrations in the raw or finished water. If any of the other above listed raw water quality parameters indicate a HAB may be present (especially if recent microcystins sampling results are not available) treatment optimization for HABs will occur. As a start, pre-chlorination will be discontinued and PAC doses will be increased to at least 10 mg/L. If surface cyanobacteria scums are detected, reservoirs with the scums will be isolated (if possible) until additional microcystins analysis can be completed or scums can be manually removed.

C. Plant Treatment Process Observations that may Indicate a HAB

Higher than normal chemical demands (e.g., coagulants, PAC, chlorine), shorter filter run times or increased solids loading may be an indication of an algal bloom. Such changes should be monitored, and source water conditions investigated to determine the cause. List each operational indicator and the location and frequency of monitoring. Describe normal operating conditions for each parameter and changes that may indicate a HAB occurring in the source water.

Example:

Operational indicator	Monitoring Location and Frequency	Normal Conditions	Criteria that may indicate a HAB
Increased chlorine demand	Entry point tap in lab (EP001) Every 2 hours	Usual Cl demand in summer is ~3 mg/L	An increase to 3.5 mg/L or higher
Decreased filter run time	N/A	Filters backwashed at 100 hours, filter effluent turbidity maintained at <0.10 NTU	Decreased filter run times based on head loss or increased filter effluent turbidity >0.10 NTU.
Increased settled water turbidity	Daily at combined filter influent	Settled water turbidity <1.0 NTU	Increase in settled water turbidity >1 NTU are typically associated with HAB events at this plant

Specify how the water system will respond to operational HAB indicators.

Example: Any operational changes listed above that may indicate a HAB will trigger an evaluation of other raw water quality data related to HABS (see prior section). If recent raw water quality data are not available, operators will visually inspect the reservoirs and collect samples at each for phytoplankton identification. Additional sampling and analysis may be triggered if cyanobacteria are detected in the source water.

III. Source Water Management Strategies

The following are general recommendations for source water management strategies to improve the ability of the treatment plant to address cyanotoxins. These adjustments should be considered along with the feasibility of existing infrastructure and other treatment objectives of the PWS. A significant change of source or source treatment will require prior approval by Ohio EPA.

A. Avoidance Strategies

If the PWS has more than one approved source available, use the alternate, non-impacted source for raw water. Consider opportunities to switch sources or to blend sources (e.g., different reservoir, interconnections with other systems, ground water) to minimize the intake of cyanotoxins.

Consider using alternate intake depths. Cyanobacteria that regulate buoyancy (Microcystis, Anabaena, etc.) can change their position in the water column, typically on a diurnal cycle. If this cycle is predictable through sampling in the source water, pump water when the bloom is present on the surface and less concentrated at intake depths. This strategy would not work for most *Planktothrix* or *Cylindrospermopsis* blooms that are typically distributed throughout the water column and do not form scums at the water surface.

For systems that do not pump 24-7, consider timing the pumping of water into the plant when cyanotoxin concentrations are lowest at intake depth, as indicated by sampling. Some systems may be able to run on storage temporarily or may be able to avoid a short-term HAB event if a river source or shifting bloom on a large lake allows the HAB to move away from the intake. Describe avoidance strategies that can be employed at the water system, and the triggers for their implementation.

Examples:

If raw water compliance monitoring indicates cyanotoxins are present or cyanotoxin production genes are increasing, we will sample each individual source water for cyanotoxins and switch to an unimpacted reservoir, if possible.

If raw water compliance monitoring indicates cyanotoxins are present or cyanotoxin production genes are increasing, cyanotoxin concentrations at the three intake depths in the reservoir will be evaluated to determine if changing the intake in use would result in better quality water.

Whenever possible, will avoid refilling reservoirs when nitrates in source streams are greater than 3 mg/L or total phosphorus is greater than 0.5 mg/L

B. Source Water/Reservoir Management

A common practice to control cyanobacteria is the application of algaecide. Diatoms and other types of non-toxin producing algae (green) can be beneficial and do not always require the use of algaecides. Conducting phytoplankton identification and/or enumeration prior to algaecide application will allow algaecide application to be targeted to when cyanobacteria start to pose a concern (shift in dominance from diatoms or green algae to cyanobacteria). The use of algaecides should be on a targeted basis, as overuse of algaecides can have long-term source water quality and environmental impacts, including potentially developing copper-resistant cyanobacteria strains. Hydrogen peroxide-based algaecides may be more specific to control of cyanobacteria and may have fewer long-term environmental impacts (build-up of copper compounds) as compared to copper-based algaecides. Overall, when algaecides are applied to a drinking water source under controlled conditions, they can effectively control the growth of cyanobacteria. Application to the early stages of a cyanobacteria bloom is the preferred approach to minimize release of high concentrations of intercellular cyanotoxins that could negatively impact treatment.

If a moderate cyanobacteria bloom is present and producing intracellular cyanotoxins, **algaecides should not be applied, unless that source of water can be taken out of service or the system has advanced cyanotoxin treatment in place**. Algaecide application to severe blooms, or any blooms that are producing microcystins, on active sources of drinking water is prohibited by the pesticide general permit, unless prior approval is received from Ohio EPA. Ideally, algaecides should only be applied at the early stages of a bloom when cyanobacteria cell counts are low (<10,000 cells/mL) or if cyanotoxin concentrations in the source water (bloom) are not detected, because: 1) this is when the potential for cyanotoxin release is low; and 2) if the treatment is applied at the early stages of a bloom and cyanotoxins are released into the water, the lower concentration of cyanotoxins may be removed effectively during the treatment processes.

If multiple raw water reservoirs are available, and one or more that are not in use are impacted by a HAB event and can be isolated, a PWS can consider algaecide treatment of these reservoirs. By treating impacted reservoirs prior to their need, cyanotoxins that are released may degrade over time and minimize the additional treatment required. The isolated reservoir(s) that have been treated with an algaecide must be sampled prior to being placed back online.

Consider physically removing scums or mats (manually or with vacuum trucks, etc.), especially scums located near intake structures.

Other reservoir management strategies that may minimize HABs include:

- Nutrient reduction strategies for inputs into reservoir;
- Source water protection strategies;
- Dilution and flushing of reservoir system with higher quality water;
- Sonication;
- Phosphorus inactivation treatment; or,
- Hypolimnetic aeration (oxygenation) and reservoir mixing/circulation.

The success of a particular approach will be site-dependent and should be thoroughly reviewed and investigated before a significant investment is made.

Describe anticipated source/reservoir management strategies for your raw water sources and triggers for implementing a source treatment optimization strategy.

Example: Algae identification and the relative proportions of algae type are determined weekly in-house. As soon as practicable after the predominant algae transitions from diatoms or green algae to cyanobacteria, algaecide will be applied. The PWS's algaecide application permit includes copper sulfate and peroxide-based algaecides. At the manufacturers' recommended application rates, XXX pounds of copper sulfate or YYY pounds of peroxide-based algaecide will be applied by PWS staff using the PWS's boat. Effectiveness of algaecide application will be evaluated through a daily check of the proportions of algae type. Algaecide application will be repeated FREQUENCY as recommended by the manufacturer until cyanobacteria no longer dominates.

The nutrient levels of SOURCE RIVER are evaluated prior to pumping to the reservoir to minimize nutrient loading. In general, the reservoirs will not be filled if stream nitrate concentrations exceed 3 mg/L or phosphorus concentrations exceed 0.5 mg/L.

IV. Strategies for Optimization of Existing Treatment

The following are general recommendations for treatment adjustments to improve the ability of existing treatment processes to address cyanotoxins. These adjustments should be considered along with capability of existing infrastructure and other treatment objectives of the PWS. A significant change to the treatment plant process will require prior approval by Ohio EPA.

In addition to these optimization strategies, ensure all treatment and monitoring equipment is fully functional, regular maintenance is conducted, regular equipment calibration (chemical feed systems, pumps, sensors, etc.), and critical spare parts are available on-site before a HAB event occurs. If any equipment needs maintenance that could impact optimization, please describe and provide the expected time frame for resolution.

A. Permanganate

Do not apply an oxidant ahead of filtration, if possible. If an oxidant is necessary prior to filtration, permanganate is preferred over chlorine, chloramines or chlorine dioxide. To minimize cell lysis, keep permanganate dosing to 1 mg/L or less, if possible. Any oxidant use for pre-treatment should be followed by PAC to offset release of cyanotoxins from lysed cyanobacteria cells.

Permanganate's ability to both lyse cells while also destroying cyanotoxins may depend on the species of cyanobacteria and may be influenced by pH, in addition to the applied dose and contact time and other competing demands. Proceed with caution ~~in~~ with its use in this manner. Permanganate should be used in combination with PAC to address any cyanotoxins released and not destroyed.

The only exception would be if testing established that:

1) A significant majority of cyanotoxins are extracellular; and
2) A significant majority of the cyanobacteria cells have already been lysed coming into the treatment plant.

In this scenario, higher doses of permanganate could be used to destroy cyanotoxins from the start of the treatment process and maximize contact time with permanganate. Follow-up with PAC to adsorb cyanotoxins not destroyed by permanganate. Consider the impact of the presence of natural organic matter (NOM) in establishing doses.

Instructions: Describe the water system's use of permanganate. Include the feed location(s), the usual dosage range, the trigger for changing feed rate during a HAB event, the dosage during a HAB event, and other treatment adjustments that may be needed as a result. Indicate if the use of permanganate varies on a seasonal basis.

Example: $NaMnO_4$ is fed at the intake for zebra mussel control and NOM reduction. $NaMnO_4$ is also important to help settle buoyant algal cells. The usual $NaMnO_4$ dosage is 0.3 – 0.5 mg/L when water temperatures are less than 10 °C and 1.1 – 1.5 mg/L the rest of the year. When microcystins are detected in the raw water at >5 ug/L, the intracellular (IC) and extracellular (EC) concentrations will be determined. If the cyanotoxin is mostly intracellular, $NaMnO_4$ will be reduced to 0.5 mg/L. Jar testing to optimize NOM removal will be performed. If the cyanotoxin is mostly extracellular, $NaMnO_4$ mg/L will be increased to 1.5 – 1.9 mg/L. Permanganate concentration will be tested every 6 hours in the filter influent to ensure there is no breakthrough.

B. Pre-oxidation with Chlorine

If possible, do not apply chlorine ahead of filtration, because any dose of chlorine is expected to lyse cyanobacteria cells. Use permanganate instead, at doses less than 1 mg/L, to minimize cell lysis. (See permanganate discussion, above.) If either oxidant is used, follow-up with PAC.

The only exception would be if testing established:

1) A significant majority of cyanotoxins are extracellular; and
2) A significant majority of the cyanobacteria cells have already been lysed coming into the treatment plant.

In this scenario, pre-filter dosing which results in a free chlorine residual could be used to destroy cyanotoxins earlier in the treatment process and maximize contact time. Microcystins destruction via chlorine is more effective at lower pH, however, and raw water pH during a HAB is typically elevated. Consider the impact of the presence of natural organic matter (NOM) and the formation of disinfection byproduct (DBP) when establishing a dose. Consider the use of downstream PAC to assist in cyanotoxin and NOM/DBP reduction.

Instructions: Describe the water system's use of pre-oxidation with chlorine. Include the feed location(s), the usual dosage range, the trigger for changing feed rate during a HAB event, the dosage during a HAB event, and other treatment adjustments that may be needed as a result. Indicate if the use of chlorine varies on a seasonal basis. If there are chlorine injection points that are typically not used, include these locations and describe the circumstances in which they would be used.

Example: If mcyE genes or microcystins are detected in the raw water, pre-filter chlorination will be discontinued. If the majority of microcystins are extracellular, application of chlorine immediately pre-filter (post sedimentation) may be used to increase CT.

C. Chlorine dioxide or chloramines

Chlorine dioxide and chloramines can lyse cells, which release cyanotoxins, but are not effective at destroying microcystins.

The use of chlorine dioxide should be avoided during a HAB event. If it must be used in pre-treatment, follow up with PAC, if possible, to assist in cyanotoxin reduction.

Practicing chloramination as part of a secondary disinfection strategy to maintain a disinfectant residual in the distribution system can continue, however, efforts should be made to optimize contact time with free chlorine post-filtration to destroy cyanotoxins prior to the point of ammonia addition.

Instructions: Describe any use of chlorine dioxide or chloramines in treatment process and if any modifications to treatment that will occur during a HAB event.

Example:

Stop feeding chlorine dioxide at the onshore wet well when there is any indication of a HAB (phycocyanin greater than 2, mcyE detection, microcystin detection). Other steps will be taken during this time to minimize potential for DBP formation (start feeding PAC).

The ammonia feed point was moved closer to the finished water's entry to distribution to maximize chlorine contact time in the clearwell prior to the formation of chloramines.

D. PAC

The type of PAC is important, and effectiveness of a particular PAC may vary for different cyanotoxins. Jar testing is recommended to assist with PAC selection and estimate PAC removal capacity for microcystins or other cyanotoxins of concern. When possible, jar testing should be performed with cyanobacteria from the water system source water, to better represent site-specific conditions (including natural organic matter and microcystin variants). The iodine number is not a good indicator of performance for microcystin~~s~~ removal. For microcystins, a wood-based PAC that has a higher mesopore volume, is typically most effective (although not all wood-based PACs are equivalent).

Consider how PAC can be introduced into the treatment process (e.g., fed as a slurry (preferred) or dry. Also, consider how to switch PAC types if a different PAC is used for another treatment objective, such as taste and odor or saxitoxin~~s~~ removal (higher microporous PACs are typically more effective in these cases).

Capacity of feeders to dose 40 -to 50 mg/L of PAC is strongly recommended. Adequate, safe storage facilities must be provided. A supply of PAC must be available to feed at these rates at expected flow demands. When PAC is manually added to the hopper from bags, consider the impacts on staff resources and the sustainability of this additional workload during an extended HAB event. Consider how quickly additional PAC can be delivered to replenish the supply if a prolonged HAB event occurs. Test maximum feed rates prior to a HAB to determine potential impacts on downstream processes (blind filters) and potential for line clogging at higher feed rates.

Multiple feed point locations should be considered to optimize contact time with the cyanotoxins and overcome competing demands or interferences. Adequate mixing must also be provided. Consider feed points at the:

1) raw water intake
2) rapid mix
3) before settling

Feed points for permanganate, or other oxidants, and PAC should be at least 20 minutes apart to avoid interference.

PAC should be applied downstream of any of the pretreatment oxidants listed above.

PAC use can increase solids loading on processes and in residual handling, which needs to be considered.

Instructions: Describe the water system's use of PAC. Include the feed location(s), the usual dosage range, the type of PAC typically used during HAB events, the trigger for changing feed rate during a HAB event, the dosage during a HAB event, and other treatment adjustments that may be needed as a result. Indicate if the use of PAC varies on a seasonal basis.

Example: A wood-coal blend PAC is fed year-round at the rapid mix for T&O and NOM reduction. This PAC was selected based on jar testing, and also demonstrates superior microcystins adsorption capacity. The PAC feed point is approximately 2.5 hours after the $NaMnO_4$ application point at design and ~5 hours at typical summer demand. In the winter, the usual dosage is 3 – 5 ppm. The summer dosage when there is no HAB event is 5 – 10 ppm. The usual feeder at the rapid mix can dose up to 25 ppm. With an auger change, 50 ppm can be fed. We tested the capability of feeding 50 ppm of PAC under normal operations for four hours and did not experience any line clogging or blinding of filters. Since $NaMnO_4$ is required at the intake for Zebra mussel control (see permanganate discussion), during HAB events, PAC at the rapid mix will be increased depending on the raw cyanotoxin concentration as in the table below. If raw cyanotoxins exceed 5 ppb, microcystins will be tested in the filter effluent and the PAC dosage adjusted to maintain a cyanotoxin concentration of 0.5 ppb or lower.

Raw microcystins, ppb	PAC dose if primarily intercellular, ppm	PAC dose if primarily extracellular, ppm
<1	3-5	3-5
1-5	3-5	10-20
5-10	5-10	20 Consider auger change if cyanotoxins are increasing
>10	5-10	20-40, may require auger change
response to a finished water microcystins detection	Max Dose	Max Dose

PAC can also be fed at the settling basin influent. This injection point has not been approved by Ohio EPA. Detailed plans will be submitted before the start of the 2019 HAB season. We will seek emergency temporary approval for this feed point following a finished water microcystins detection if detailed plans have not been approved by that time.

E. Flocculation/Sedimentation

Jar testing should be conducted to determine the conditions necessary for optimization of particulate/cell removal. Jar testing results can assist with optimizing coagulant dosing, contact time and filter aids. Be aware that increases in pH due to HABs may impact the effectiveness of coagulants. Coagulant addition should be adjusted with changing raw water conditions based on jar testing. The PWS should develop a reference sheet with chemical addition and dosing requirements for various raw water qualities.

The PWS should increase the frequency of sludge removal to dispose of intact accumulated cells before they can lyse. Recirculation of sludge during a HAB event should be discontinued, if possible. Recycling of sludge supernatant should also cease during a HAB event.

Instructions: Describe anticipated optimization strategies for flocculation/sedimentation and triggers for initiating change in treatment.

Example: Under usual operating conditions, sludge is removed hourly. Our clarifiers operate best with a 5 ft sludge blanket. Sludge depth is checked with a sludge judge once per shift. During a HAB event, sludge depth will be checked every 4 hours. If sludge begins to increase, the blow off duration or frequency will be increased to maintain 4½ to 5 ft of sludge. If necessary to improve performance, plant will transition from a 16 to 24-hour operation. Cyanobacteria cells in sludge will have less potential to lyse overnight and settled water turbidity goals may be more readily achieved.

F. Filtration

Shorten filter runs and backwash more frequently to remove intact cells captured in the filter bed to avoid lysing. The frequency of backwash can be more finely established through monitoring of the filter influent and effluent to determine if cells within the filter are lysing and contributing to extracellular cyanotoxin concentration.

Cease filter backwash recycle during a HAB event to avoid reintroducing intact cells and cyanotoxins from lysed cells.

For residuals handling, consider how increased loads from sludge removal and filter backwash waste will be accommodated with current residual handling processes (e.g., on-site lagoons, equalization basins, a permitted discharge to surface water or discharge to a wastewater treatment plant).

Instructions: Describe anticipated optimization strategies for filters and triggers for initiating change in treatment. Include the usual backwash trigger and filter run time, the trigger for backwash frequency during a HAB event, how filter operation will be changed during a HAB event, and any other treatment adjustments that may be needed as a result.

Example: Backwashing is triggered from head loss build up and/or rapid changes in turbidity in the filters. During a HAB event, individual filter turbidity analysis frequency will be increased to two -three times daily. If turbidity for a filter increases NTU, the filter will be backwashed regardless of the head loss. Otherwise, backwash will continue to be triggered by head loss as above.

Backwash water is typically recycled. During a HAB event where raw water microcystins exceed 10 ppb, we will discharge backwash water to the city WWTP.

There are 3 sludge lagoons, one in use and two that were used each of the two previous years. The oldest lagoon is cleaned each fall. Lagoon use is rotated in the spring. Each lagoon is sized to hold 150% of a typical year's sludge.

The water system has a discharge permit for overflow from the lagoons to Somewhere Creek.

G. Clearwell(s)

Chlorine

A free chlorine residual paired with maximized contact time will optimize the destruction of microcystins. Consider the following:

1) Maintain a chlorine residual that targets microcystin~~s~~ destruction. Consider increasing the free chlorine residual by 0.5 mg/L to 1.0 mg/L higher than normal operation, up to 3.5 mg/L.
2) Maximize contact time with chlorine in the clearwell.

During an extracellular cyanotoxin event, the free chlorine dose can be increased further to provide more effective destruction of cyanotoxins. An increase in CT can increase DBP formation. However, if PAC is used, it will assist with organics removal and DBP formation may be mitigated. Also, total chlorine residuals entering the distribution system should not exceed the maximum disinfectant residual level (MRDL) of 4.0 mg/L, on a running annual average. Elevated levels of free chlorine should only be used in the short-term to avoid adrinking wateradvisory.

pH

If pH adjustment is an option, consider adjusting pH slightly to assist with microcystins oxidation. The effectiveness of chlorine on microcystin~~s~~ destruction is greater at a pH less than 8 and above a pH of 6. **Corrosion control must be considered when adjusting pH. Any adjustment to pH must not undermine a corrosion control treatment objective or violate any approved corrosion control plan.**

Contact Time (CT)

To determine a specific benchmark for CT, see AWWA's CT calculator for destruction of microcystins by chlorine, as a starting point: ***www.awwa.org/resources-tools/water-knowledge/cyanotoxins.aspx***. Once you log in or register (free), click on the "Cyanotoxin Oxidation Calculator" link. AWWA's calculator can be used for estimating oxidant dose (including chlorine and other oxidants) for destruction of cyanotoxins (including microcystins and other cyanotoxins). The AWWA calculator allows for inputs of pH, temperature, chlorine dose and contact time, as well as initial and targeted final microcystin~~s~~ concentrations. The calculator specifies limitations and assumptions of the tool within the first tab of the spreadsheet. Water quality-specific chlorine demands (such as NOM) will also impact chlorine dose. **Chlorine dose and contact time estimates generated from a CT calculator may underestimate required CT because of the limitations and assumptions of the model. A safety factor of at least two should be used.**

Instructions: Describe anticipated optimization strategies for chlorine oxidation in clearwells. Estimate chlorine microcystins oxidation capacity under normal and optimized conditions using the AWWA CyanoTOX calculator and a safety factor of 2.

Example: Our typical chlorine residual goal entering the clearwell is 1.2 ppm. If microcystins are detected in the raw water, the AWWA CyanoTOX 2.0 calculator will be run with a safety factor of 2, and assuming 100% of the raw water microcystins are extracellular and will enter the clearwell. Chlorine dose and residual will be increased, if necessary, to achieve a predicted target finished water microcystins concentration of 0.15 ug/L. The table below was created as a guide for our operators using the CyanoTOX calculator under worst case conditions (entry to clearwell pH of 9, minimum clearwell depth of xft, additional safety factor of 2). We can adjust the on-off levels of the clearwell to increase contact time, if necessary. We can increase CT by up to 10%. We adjust pH to around 8.7 using caustic. Our optimal water quality parameters require pH to be maintained above 8.2. During a HAB event, we will adjust the caustic feed to achieve a pH of 8.5 to enhance microcystins oxidation.

If microcystins are detected in the finished water at any concentration, entry to clearwell chlorine dose will be increased so that a maximum 3.5 mg/L free chlorine residual is maintained at the entry to distribution sampling location.

H. Other Treatment Processes

Membranes [Microfiltration (MF)/Ultrafiltration (UF) and Nanofiltration (NF)/Reverse Osmosis (RO)]
Ensure adequate pretreatment and cleaning cycles to prevent fouling. Evaluate the ability of the membrane to remove cells (MF/UF) and to remove extracellular cyanotoxins (NF/RO). For cyanotoxin removal, consider increasing the percentage processed through the membrane (NF/RO). Consider how other optimization strategies can impact performance of the membrane.

Ozone
Ozone is highly effective for complete microcystin destruction, however residual dose and contact time must be sufficient for cyanotoxin destruction as well as other demands.

A potential limiting factor for some source water is the application of ozone can create disinfection byproducts, specifically bromate.

Granular Activated Carbon (GAC)
GAC can remove cyanotoxins through adsorption. Assess the cyanotoxin removal capacity of the GAC by evaluating the presence of competing contaminants, such as Natural Organic Matter (NOM). Reactivated or fresh media should be placed in contactors in advance of the HAB season. Consider conducting rapid small-scale column tests (RSSCT) with specific GAC media in the contactor using the plant's water and microcystin~~s~~ challenge concentration to determine the useful life of the GAC media. Routine treatment train sampling and analysis for TOC or UV254 may help determine changes in GAC adsorption capacity over time.

Biologically Active Filtration (BAF)
Assess functionality and ability to degrade cyanotoxins through sampling and studies.

UV Radiation with Advanced Oxidation Process
UV radiation, if used alone for disinfection, is minimally effective in microcystins destruction and should not be considered as an acceptable optimization option. Dosing of UV ahead of filtration must be avoided to prevent lysing of cells.

An advanced oxidation process used in association with UV, where UV is paired with hydrogen peroxide, has been shown to be effective for microcystins destruction. However, the power requirements for advanced oxidation are many times greater than what is required for UV disinfection.

Cartridge Filters

See filtration section. Consider increasing frequency of element replacement.

Slow Sand Filters

Assess functionality and ability to degrade cyanotoxins. Do not pre-chlorinate or treat with any oxidant.

Other Technologies (not noted above)

Explain and support optimization strategies associated with the process.

Instructions: Please describe the other treatment process and how it can be optimized for cyanotoxin removal and indicate triggers for optimization:

Example: Filtered water is pumped via transfer pumps to two parallel granular activated carbon (GAC) contactor trains, with each train consisting of two pressure vessels in series. Each contactor vessel has approximately 74 inches of media and an area of 113 sf to provide an empty bed contact time (EBCT) of 7.5 minutes at a flow rate of 1.0 MGD. In series, with both trains in service, a flow of 2.0 MGD could be treated and provide 15 minutes of EBCT. Currently, the GAC is used for taste and odor control and normally operates with 50% of the flow bypassing treatment. The plant typically produces 3MG in two 8-hour shifts (4.5 MGD flow rate). At 50% flow (2.25 MGD flow rate) going through GAC, that provides approximately 13 minutes of EBCT. If treatment train analysis demonstrates that microcytins are entering the GAC at concentrations greater than 5 ug/L, an additional shift will be added so the plant can operate continuously. At that point, 100% of plant flow will be routed through the GAC, with an approximate 11-minute EBCT. The GAC effluent flow rate is metered.

We have found that increasing the PAC feed upstream of the GAC has helped reduce the TOC and microcystins loading to the contactors (based on UV254 and microcystins analysis) and extends their life. During a HAB, PAC will be used as a primary barrier and an additional shift will only be necessary if microcystins breakthrough to post filtration at concentrations greater than 5 ug/L. The AWWA CyanoTox calculator estimates we can oxidize up to 10 ug/L microcystins with our chlorine barrier under typical HAB conditions (assuming a safety factor of 2), so allowing 2.5 ug/L to bypass GAC (if concentrations at 5 ug/L ahead of GAC and only treating 50% of flow) is acceptable.

GAC media is reactivated for two of the contactors every year. Flow is routed so that fresh media is always in the lag contactor.

I. Rate of Water Production

A recommended strategy during a cyanotoxin-producing HAB event is to reduce water production. Decreasing the flow rate is recommended to reduce loading on treatment processes and increase contact times. Consider extending operating time to decrease flow rate by going to a 24-hour operation if the plant normally runs less than 24 hours.

Instructions: List anticipated optimization strategies for general operation and maintenance. Include the usual flow rate and duration of daily operations, usual number of shifts, employees per shift, the trigger for changing operations, and other treatment adjustments that may be needed as a result.

Example: We normally operate at 3000 gpm for 5-7 hours per day (one shift). We have one superintendent and 4 operators. There are usually 3 people on duty at a time. During a HAB with raw concentrations greater than 25 ppb, we will reduce the flow to 1500 gpm, which will require us to operate two shifts. We do not have sufficient staff to operate two shifts on a long-term basis. We have agreements with two local area retired operators and two contract operators to work in the event of a HAB. We will split our experienced staff across the two shifts and supplement with this temporary staff.

If additional reductions are necessary, we can issue a water conservation order via the local media.

V. Treatment Optimization and Response to Raw and/or Finished Water Cyanotoxin Detections

In accordance with OAC Rule 3745-90, PWSs are required to conduct raw and finished water monitoring for microcystins and cyanobacteria screening. When cyanotoxin detections occur, a system should consider additional sampling to identify whether intracellular and extracellular cyanotoxins are present and conduct treatment train sampling to determine how processes are performing and where additional optimization is needed. To avoid an exceedance of the advisory levels for microcystins or other cyanotoxins a PWS must implement optimization strategies identified for their source and treatment.

Outline source, treatment and operations adjustments that will be made based on optimization strategies identified in Part III and/or IV, for each of the circumstances below.

Note: OAC Rule 3745-90-05(A) requires treatment optimization protocols to include treatment adjustments that will be made under various raw and finished water conditions. The purpose behind the three circumstances described below is for the water system to develop a staged or ramped approach and to consider what additional actions will be taken if the actions in the previous circumstance are insufficient.

A. Microcystins detection in raw water or other raw water quality indicators or treatment process changes that indicate a HAB, but non-detect in finished water.

Instructions: Describe any actions or changes to this scenario. Response may vary based on microcystins concentration in raw water (e.g., 0.3-1.0 µg/L, 1.1-4.9 µg/L, ≥5.0 µg/L).

Example:If microcystins are detected in the raw water, sample individual source waters (Reservoir 1, 2, and lake) for total and extracellular microcystins and switch to alternate source if higher raw water quality is available from an alternate source. Isolate impacted source and treat with algaecides following applicator recommendations for cyanobacteria control. If alternate sources are not available, consult with Ohio EPA prior to algaecide application. Implement treatment optimization strategies based on microcystins concentrations in raw water and if microcystins are intracellular or extracellular. See prior sections and summary table at the end of the template for details on how individual processes will be optimized.

B. Microcystins detections in raw water greater than 5 ug/L, but non-detect in finished.

Instructions: Specify all response actions to this scenario. Consider conducting treatment train sampling and analyze total, intracellular, and extracellular microcystins to target optimization.

Example: Individual sources will be resampled and treatment train samples will be collected for both total and extracellular microcystins. Switch to alternate source if higher water quality is available at alternate source. Continue source water treatment, including algaecide applications, on any isolated sources and coordinate with Ohio EPA on any treatments to source waters currently in use. See prior sections and summary table at the end of the template for details on how individual processes will be optimized.

C. Microcystins detected in finished water (>0.30 ug/L).

Instructions: Specify all response actions to this scenario. Consider maximum optimization and treatment options. Conduct treatment train analysis of total, intracellular and extracellular microcystins to target optimization, as well as distribution sampling. Look at alternate sources of finished water, if available. Notify Ohio EPA immediately.

Example: After receiving initial finished water microcystin detection results immediately make the following treatment adjustments if not previously implemented: increase chlorine feed rate to maintain maximum chlorine residual of 3.5 mg/L. Increase PAC feed rate to 40 mg/L (fed at rapid mix). Start feeding polymer to enhance coagulation based on dose determined from prior jar testing. Decrease flow through plant by adding extra shift (16 to 24-hour operation). Place all GAC contactors online and place 100% of plant flow through contactors. Increase backwash frequency to minimize cell accumulation on top of filters and discontinued backwash recycling. Increase sludge rake speed and blowoff to handle increased sludge production due to HAB and increased PAC dose. Seek Ohio EPA emergency approval to manually feed PAC at additional feed points.

Conduct treatment train sampling, and additional raw water sampling (each intake depth and both reservoirs). Analyze for both total and extracellular microcystins. If majority of microcystins are extracellular, turn on post sedimentation pre-filtration chlorine feed to increase CT. Finalize distribution sampling sites in event distribution sampling is needed.

Based on source water data, transition to least impacted source(s). For example, transition from blending reservoirs to utilizing reservoir 2 only, and close upper intake gate (rely only on middle gate on reservoir 2, based on lowest measured microcystins concentration in raw). Treat isolated Reservoir 1 with algaecide.

Quick Reference Table (Example):

	Normal Operations	Raw Water Microcystins Detections	Finished Water Microcystins Detection
Pre-treatment	KMnO4 between 1-5 mg/L	KMnO4 <1 ug/L (unless majority extracellular cyanotoxins)	KMnO4 <1 ug/L (unless majority extracellular cyanotoxins, then increase to 5 mg/L)
PAC	5 mg/L	20 mg/L	Increase to maximum PAC dose (40-50 mg/L) that is operationally sustainable
Alum	? gpg	Conduct jar testing to determine if increased alum dose or polymer aid will enhance coagulation and sedimentation. Modify doses as appropriate.	Increase doses and polymer addition based on prior and any follow-up jar testing results.
Backwash	Recycle backwash	Discontinue backwash recycling	Increase backwash frequency and discontinue backwash recycling
Residuals	Weekly sludge removal	Increase sludge rake removal by 50% and daily removal from basins	Maximize sludge rake removal rate and sludge removal from basins.
Chlorine residual	Maintain 1.5 mg/L residual	Run CyanoTOX calculator and determine adequate residual (safety factor 2)	Increase dose to achieve maximum 3.5 ug/L chlorine residual
Advanced treatment	50% flow through GAC	Increase flow through GAC. If microcystins entering GAC exceed 5 ug/L, transition to 24-hour operation at reduced production rate so 100% flow can go through GAC.	100% flow through all GAC contactors, combined with decreased production rate (see below).
Water processing rate	16 -hour operation	16-hour operation (transition to 24-hour if microcystins post filtration exceed 5 ug/L)	Reduce production rate, 24-hour operation (slow flow through plant)

Submit a completed HAB optimization protocol to your appropriate district office, to the attention of the Drinking Water Manager:

Ohio EPA — Northeast District Office
DDAGW
2110 E. Aurora Road
Twinsburg, OH 44087
(330) 963-1200
EPAHABmailbox@epa.ohio.gov

Ohio EPA — Southeast District Office
DDAGW
2195 Front Street
Logan, OH 43138
(740) 385-8501
EPAHABmailbox@epa.ohio.gov

Ohio EPA — Central District Office
DDAGW
P.O. Box 1049
50 West Town Street, Suite 700
Columbus, OH 43216-1049
(614) 728-3778

EPAHABmailbox@epa.ohio.gov

Ohio EPA — Northwest District Office
DDAGW
347 N. Dunbridge Road
Bowling Green, OH 43402
(419) 352-8461
EPAHABmailbox@epa.ohio.gov

Ohio EPA — Southwest District Office
DDAGW
401 East 5th Street
Dayton, OH 45402
(937) 285-6357

EPAHABmailbox@epa.ohio.gov

Appendix.

Additional Resources:

The *Public Water System HAB Response Strategy* is also a good resource for implementation of a response by the public water system in the event of cyanotoxin detection in raw and/or finished water. For more information about treatment strategies for microcystins, as well as other cyanotoxins, please see Ohio AWWA/Ohio EPA's joint effort, *AWWA White Paper on Algal Toxin Treatment*. Both can be found on Ohio EPA's HAB website: ***epa.ohio.gov/ddagw/HAB.aspx***.

The resources used to develop these guidance documents can provide more detailed information about important water quality considerations and source and treatment optimization strategies for HABs. They are as follows:

- Water Research Foundation cyanotoxin-related applied research reports: ***www.waterrf.org/resources/StateOfTheScienceReports/Cyanotoxins_StateOfTheScience.pdf***
    - Algae: Source to Treatment (M57), 2010
    - Removal of Algal Toxins from Drinking Water Using Ozone and GAC, 2002
    - Reservoir Management Strategies for Control and Degradation of Algal Toxins, 2009
    - Early Warning and Management of Surface Water Taste & Odor Events, AWWA RF 2006
    - Identification of Algae in Water Supplies (CD-ROM), AWWA 2001
- World Health Organization (WHO), 1999. Toxic Cyanobacteria in Water: A Guide to their Public Health Consequences, Monitoring and Management (NOTE: this document will be updated in 2019) ***www.who.int/water_sanitation_health/resourcesquality/toxcyanbegin.pdf?ua=1***
- Water Quality Research Australia (WQRA) ***www.wqra.com.au/publications/document-search/***
- Newcombe G., Dreyfus, J., Monrolin, Y., Pestana, C., Reeve, P., Sawade, E., Ho, L., Chow, C., Krasner, S.W., Yates, R.S. 2015. Optimizing Conventional Treatment for the Removal of Cyanobacteria and Toxins. Water Research Foundation. Order Number 4315.
- WQRA International Guidance Manual for the Management of Toxic Cyanobacteria, 2009, edited by Dr. Gayle Newcombe, Global Water Research Coalition and Water Quality Research Australia. WATERRA [Online]. Available at: ***www.waterra.com.au/cyanobacteria-manual/PDF/GWRCGuidanceManualLevel1.pdf***
- ISOC-HAB Chapter 13: Cyanobacterial toxin removal in drinking water treatment processes and recreational waters. Westrick, Judy A.
- U.S. Geological Survey Algal Toxins Research Team ***http://ks.water.usgs.gov/studies/qw/cyanobacteria/***
- Graham, J, Loftin, K., Meyer, M., Ziegler, A., 2010. Cyanotoxin Mixtures and Taste-and-Odor Compounds in Cyanobacterial Blooms from the Midwestern United States, Environmental Science and Technology ***http://pubs.acs.org/doi/abs/10.1021/es1008938***
- Acero, J. L., Rodriquez, E., Meriluoto, J., 2005. "Kinetics of reactions between chlorine and the cyanobacterial toxins microcystins," Water Res., **39**, 1628-1638.
- *Mohamed, Z. A., Carmichael, W. W., An, J., El-Sharouny, H. M., 1999. "Activated Carbon Removal Efficiency of Microcystins in an Aqueous Cell Extract of Microcystis aeruginosa and Oscillatoria tenuis Strains Isolated from Egyptian Freshwaters", Env. Toxicol., 14(5), 197-201.*

- *U.S. EPA. (May 26, 2015) Webinar on Current Water Treatment and Distribution System Optimization for Cyanotoxins. [PowerPoint slides]. Obtained from webinar organizer, Cadmus Group:* ***webcastinfo@cadmusgroup.com****.*
- "Treatment Strategies to Remove Algal Toxins from Drinking Water". Lili Wang, P.E., U.S. EPA's Office of Water.
- "Removal of Cyanobacteria and Cyanotoxins Through Drinking Water Treatment". Nicholas Dugan, P.E., U.S. EPA's Office of Research and Development.
- *Walker, Harold W. "Cyanobacterial Cell and Toxin Removal Options for Drinking Water Treatment Plants", [Powerpoint Slides]. Taken from materials presented at The Ohio State University's Stone Lab Algal Toxins Workshop, August 2010.*
- *Walker, Harold W. Harmful Algal Blooms in Drinking Water: Removal of Cyanobacterial Cells and Toxins. Boca Raton, FL: CRC Press, 2015.*
- Lionel Ho, Paul Tanis-Plant, Nawal Kayal, Najwa Slyman and Gayle Newcombe. 2009. "Optimising water treatment practices for the removal of Anabaena circinalis and its associated metabolites", Journal of Water and Health. 7(4), 544-556.
- *AWWA Cyanotoxins resource site:* ***www.awwa.org/resources-tools/water-knowledge/cyanotoxins.aspx***
- *Drikas, M., Chow, C.W.K, House, J., Burch, M.D., 2001. "Using Coagulation, Flocculation, and Settling to Remove Toxic Cyanobacteria", Journal AWWA. February 2001, 100-111.*