Optimizing Water Treatment Plants for Cyanotoxin Removal

OHA Drinking Water Services
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The purpose of this document is to provide options to surface water treatment plants to optimize existing treatment to address detections of cyanotoxins at their water systems. For more detailed information on these alternatives, see US EPA's Water Treatment Optimization for Cyanotoxins referenced in the Additional Resources section. Consult with your regulator at the OHA's Drinking Water Services (DWS) for questions on implementing any of the following.

1. Introduction: Harmful algal bloom cyanotoxins can be present in both intracellular (within a cyanobacteria cell) and extracellular (outside the cyanobacteria cell). Optimize existing treatment to remove both forms of cyanotoxins.

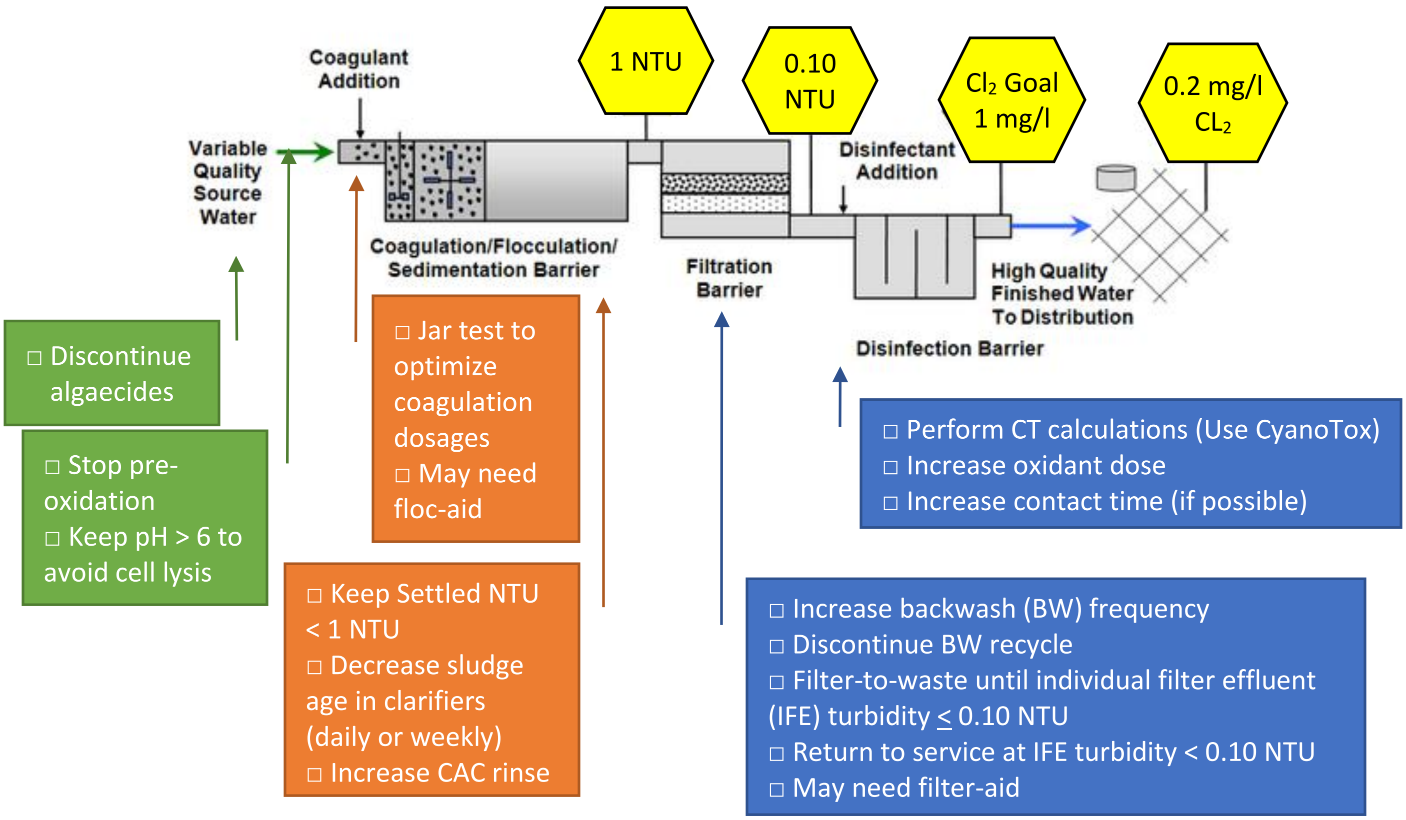
2. The multiple barrier approach: Water treatment plants employ the multiple barrier approach. Each unit process provides a distinct barrier to waterborne pathogens, such as *Giardia*, *Cryptosporidium*, viruses, and cyanotoxins. Water treatment plant optimization is the process of improving the performance of particle and chemical (e.g. total organic carbon [TOC]) removal beyond regulatory requirements without making major capital expenditures.

3. Overall optimization strategies:
    a. Utilize alternate sources or interties with other nearby water systems.
    b. Lower the flow through the treatment plant. Less water being treated will increase the time for each process to remove turbidity.

4. Source water:
    a. Do not apply algaecides during a cyanobacteria bloom as this risks cell lysis, or stressing the cells, potentially causing cyanotoxin release.
    b. For water systems with intakes within multiple water layers, utilize the intake from the layer that may be least impacted by an algal bloom or cyanotoxin detections.
    c. Cease any recycling of process water, for example filter backwash water.

5. Conventional and direct filtration: Conventional and direct filtration plants are encouraged to optimize their treatment processes and adopt water quality goals more stringent than the regulatory drinking water standards. Improved turbidity removal results in increased intracellular cyanotoxin removal. The following graphic summarizes cyanotoxin removal strategies and optimization goals for conventional and direct filtration plants.
    a. Coagulation and flocculation:
        i. Discontinue pre-chlorination at the front end of the plant to prevent cell destruction.
        ii. Optimize coagulation pH and alkalinity for increased turbidity, TOC, and cell removal.
        iii. Use jar tests to simulate varying coagulant dosages and plant mixing hydraulics to obtain desired floc formation and increased turbidity removal.
        iv. Compare coagulation feed rates or dosages to periods of similar bloom events or cyanotoxin detections to optimize the delivery of coagulants to increase the removal of cells.
        v. If powdered activated carbon (PAC) is plumbed to the front of the plant, turn on the feed to aid in toxin removal.
    b. Sedimentation:
        i. Measure and record settled water turbidity daily and meet settled water turbidity optimization goals (settled water below 1 NTU when raw is less than 10 NTU and settled water below 2 NTU when raw is greater or equal to 10 NTU).
        ii. Conduct more frequent clarifier or sedimentation basin sludge removal, such as on a daily or weekly basis.
        iii. Conduct more frequent contact adsorption clarifier (CAC) rinses.
        iv. Do not recycle supernatant to the head of the plant.
    c. Filtration:
        i. Produce filtered water that meets the optimization goal of less than or equal to 0.10 NTU.
        ii. Establish your individual filter run and filter-to-waste durations based on meeting 0.10 NTU and quarterly post-backwash filter turbidity profiles.
        iii. Increase backwash frequency.

iv. Reduce filter loading rates and filter run times.
v. Ensure that the backwash sufficiently expands the filter bed media (sand and anthracite layers) to at least 20% to remove remnant particles.



Optimization goals and strategies for cyanotoxin removal at conventional and direct filtration plants

6. Slow sand filtration:
   a. Lower the filtration rate to allow the toxins to be metabolized. Lowering filtration rates to less than 0.02 gpm/ft^2 should be avoided to keep biota viable.
   b. Divert filtered water to waste if there is enough finished water storage available to meet demands, or another source(s) is available. Keeping water flowing through the filters will help prevent starving the filter biota of nutrients and dissolved oxygen, ultimately making the filter less capable of removing cyanotoxins should the filter be needed to meet demands.

c. Consider controls that allow a constant water level (supernatant or "headwater") above the filter at all times, (i.e., throttle the intake valve to maintain a constant headwater throughout the filter run). This requires the use of piezometers or other pressure sensor to determine headloss. Maintaining deeper headwater keeps water temperatures low in the filter cell which can minimize the chance of an algal or cyanobacteria bloom in the filter itself.
d. Monitor head loss so that the filter can be cleaned during the time of year less likely to have HABs. Graphing head loss development versus time can reveal how fast the filter plugs as the filter approaches the time when cleaning is needed.
e. Staggering cleanings may allow longer filter-to-waste times without the risk of the other filters plugging in the interim.
f. Increase filter-to-waste times after cleaning to ensure the filter is fully ripened. Filter-to-waste for at least 24-48 hours.
g. Just prior to cleaning, sample influent and effluent coliform counts in units of MPN/100 ml and determine the percent removal. Clean the filter and repeat the sampling after the first 24 hours of filtering to waste to determine the post-cleaning percent removal. Use the pre- and post-cleaning coliform removals as an indicator of the filter recovery following a cleaning. Avoid returning a filter to service when filter effluent coliform counts are more than 5 MPN/100 ml, turbidity is above 1 NTU, or % coliform removal is less than 90% (2-log).
h. Blending with a source that has lower cyanotoxins and/or cells may help, however, use caution when blending with groundwater as this can "starve" the slow sand filter of nutrients. Keep blended groundwater to a minimum and monitor coliform removal twice a week to watch for elevated coliforms in the effluent or declining coliform removals. If possible, investigate this option prior to a HABs event and consider nutrient amendments such as acetic acid to provide a food source for filter biota.

7. Membrane filtration:
   a. Conduct direct integrity testing daily at the test pressures approved by DWS and ensure that any filter units that fail a direct integrity test are removed from service, repaired, and re-tested prior to being put back into use (think of the direct integrity test as if you were to test a tire for a leak by pumping it up - the less air you pump into the tire, the more

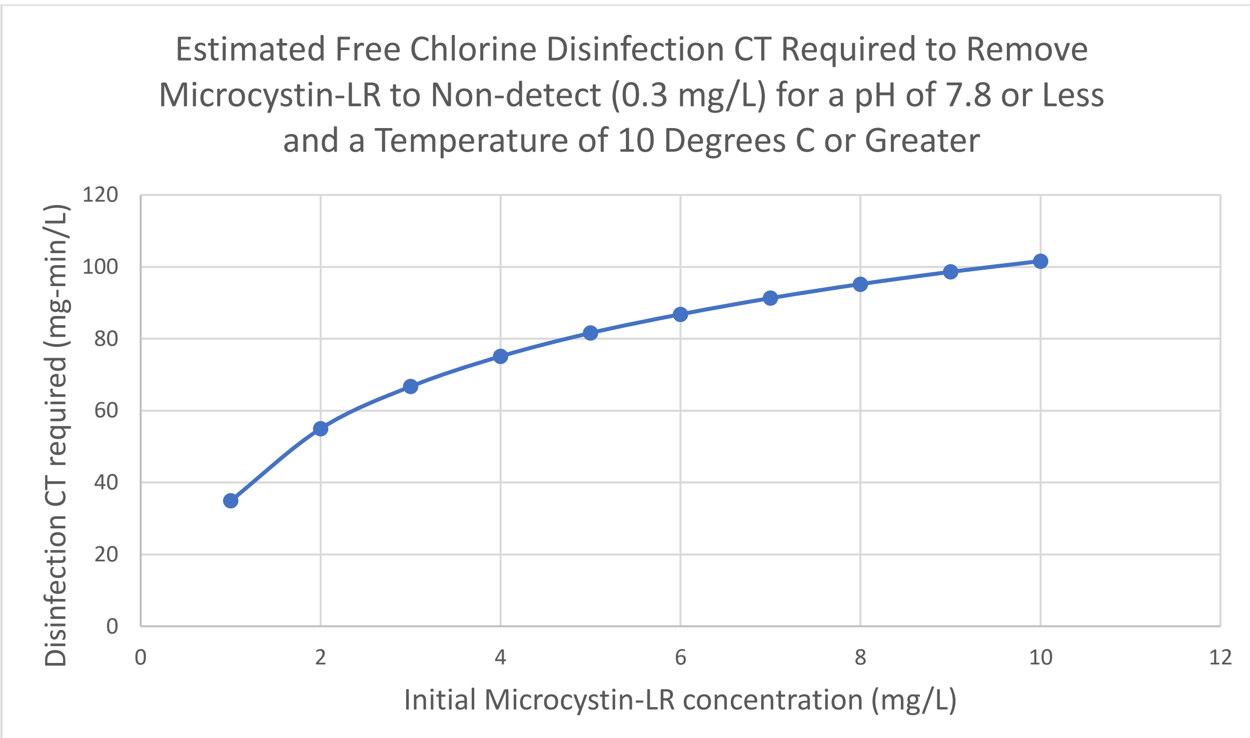
likely small leaks will go undetected). Keeping membranes intact is key to cyanobacteria cell removal (and therefore intracellular toxin removal).

b. Establish a conservative individual filter unit effluent turbidity goal of 0.05 NTU to alert you to sudden integrity breaches between direct integrity tests. The direct integrity test is the only way to directly test the integrity of the membranes, while the turbidity can indicate a problem between integrity tests.
c. Although cell removal is typically high (>99%), microfiltration (MF) and ultrafiltration (UF) systems can often benefit from coagulation using aluminum- or iron-based coagulants (think of making small cyanobacteria cells clump into bigger particles larger than the membrane pores). The addition of coagulants can keep membranes from fouling and can assist with cell removal. The membrane manufacturer should be consulted prior to adding any type of coagulant as some coagulants can quickly foul membranes. Polymers should never be applied to membranes without checking with the manufacturer due to material compatibility issues and irreversible fouling.
d. MF and UF systems are not generally capable of removing extracellular toxins – refer to sections 9 and 10 for additional treatment strategies.
e. Reverse osmosis (RO) and nanofiltration (NF) systems can remove extracellular cyanotoxins, however, the concentrate stream of these processes can have a high toxin retention level. Consider residual disposal issues that may arise due to high cyanotoxin concentrations (AWWA, 2010).

8. Cartridge filtration:
    a. Change the filters more frequently and at a lower pressure differential (difference between filter inlet and outlet pressure) than under standard operating conditions.
    b. Ensure gaskets and seals used in cartridge cannisters are in good working order and replace according to manufacturer's recommendation and if they appear worn or damaged.

9. Disinfection:
    a. Increase disinfection post-filtration.
    b. Decrease demand flows if able and increase contact chamber levels or volumes to increase contact time to achieve higher disinfection CTs.

c. Utilize the American Water Works Association's (AWWA)'s CyanoTOX model as an excel spreadsheet to estimate how much disinfection CT is necessary to remove toxins to an acceptable level, for a given pH, temperature, and oxidant.
d. If only total microcystins are detected, use microcystin-LR as the specific toxin to remove when using CyanoTOX, to be most conservative.
e. See below for estimated free chlorine disinfection CT needed to remove various amounts of microcystin-LR for conservative water quality conditions from CyanoTOX.



10. Adding treatment: If optimizing existing water treatment facilities is not enough to remove cyanotoxins, adding new treatment, such as granular or powdered activated carbon, may be useful. DWS plan review approval is required prior to adding new water treatment facilities. See www.healthoregon.org/pwsplanreview for further information or contact DWS. Caution should be exercised, and manufacturer consulted when considering PAC as it may damage polymeric membranes and plug slow sand and cartridge/bag filters.

11. Additional resources: The following additional resources may be found on either the Drinking Water Services (DWS) home page at www.healthoregon.org/dwp, under Cyanotoxin Resources for Water System Operators in the News and Hot Topics heading, or DWS' surface water treatment web page at www.healthoregon.org/swt:
    a. US EPA's Water Treatment Optimization for Cyanotoxins
    b. American Water Works Association (AWWA) CyanoTOX spreadsheet for cyanotoxin inactivation rates for various oxidants
    c. Oregon optimization goals for conventional and direct filtration plants
    d. Filter turbidity profile example
    e. Filter bed expansion measurement