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Summary of Cyanotoxins Treatment in Drinking Water

Conventional water treatment (consisting of coagulation, sedimentation, filtration and chlorination) can generally remove cyanobacterial cells and low levels of toxins. However, water systems may face challenges providing drinking water during a severe bloom event, when there are high levels of cyanobacteria and cyanotoxins in drinking water sources.

Once cyanobacteria and/or their cyanotoxins are detected in the surface water supplying the water system, the treatment system operators can act to remove or inactivate them in a number of ways. Some treatment options are effective for some cyanotoxins, but not for others. Effective management strategies depend on understanding the growth patterns and species of cyanobacteria that dominates the bloom, the properties of the cyanotoxins (i.e., intracellular or extracellular), and appropriate treatment processes. For example, oxidation of microcystin depends on the chlorine dose, pH and the temperature of the water. Applying the wrong treatment process at a specific state in treatment could damage cells and result in the release rather than removal of cyanotoxins.

The table below summarizes the effectiveness of different types of water treatment to remove intact cyanobacteria cells and treatment processes that are effective in removing extracellular dissolved toxins of several of the most important cyanobacteria. Drinking water operators are encouraged to monitor the treated water to confirm the removal of cyanotoxins.

A Summary of Cyanotoxin Treatment Processes and Their Relative Effectiveness

Treatment Process	Relative Effectiveness
<i>Intracellular Cyanotoxins Removal (Intact Cells)</i>	
Pre-treatment oxidation	Oxidation often stresses or lyses cyanobacteria cells releasing the cyanotoxin to the water. If oxidation is required to meet other treatment objectives, consider using lower doses of an oxidant less likely to lyse cells. If oxidation at higher doses must be used, sufficiently high doses should be used to not only lyse cells but also destroy total toxins present (see extracellular cyanotoxin removal).
Coagulation/ Sedimentation/ Filtration	Effective for the removal of intracellular toxins (cyanobacteria cells). Ensure that captured cells accumulated in sludge are removed frequently to release toxins. Ensure that sludge supernatant is not returned to the supply after sludge separation.
Membranes	Effective for removal of intracellular cyanotoxins (cyanobacteria cells). Microfiltration and ultrafiltration are effective when cells are not allowed to accumulate on membranes for long periods of time. More frequent cleaning may be required during a bloom event.
Flotation	Flotation processes, such as Dissolved Air Flotation (DAF), are effective for removal of intracellular cyanotoxins since many of the toxin-forming cyanobacteria are buoyant.
<i>Extracellular (Dissolved) Cyanotoxins Removal</i>	
Membranes	Depends on the type of cyanotoxin, membrane material, membrane pore size distribution, and influent water quality. Nanofiltration is generally effective in removing extracellular microcystins. Reverse osmosis filtration is generally applicable for removal of microcystins and cylindrospermopsin. Cell lysis is highly likely. Further research is needed to characterize performance.
Potassium Permanganate	Effective for oxidizing microcystins and anatoxins. Further research is needed for cylindrospermopsin. Not effective for oxidizing saxitoxin.

Treatment Process	Relative Effectiveness
Ozone	Very effective for oxidizing microcystins, anatoxin-a, and cylindrospermopsin. Not effective for oxidizing saxitoxin.
Chloramines	Not effective.
Chlorine dioxide	Not effective at doses typically used in drinking water treatment.
Free Chlorine	Effective for oxidizing microcystins as long as the pH is below 8. Effective for oxidizing cylindrospermopsin and saxitoxin. Not effective for oxidizing anatoxin-a.
UV Radiation	UV radiation alone is not effective at oxidizing microcystins and cylindrospermopsin at doses typically used in drinking water treatment. When UV radiation is coupled with ozone or hydrogen peroxide (called “advanced oxidation”), the process is effective at oxidizing anatoxin-a, cylindrospermopsin, and with high UV doses, microcystins.
Activated Carbon Adsorption	<p>Powdered activated carbon (PAC): Effectiveness of PAC adsorption varies based on type of carbon, pore size, type of cyanotoxin, and other water quality parameters such as natural organic matter (NOM) concentration. Wood-based activated carbons are generally the most effective at microcystins adsorption. More research is needed to evaluate PAC’s effectiveness at adsorbing cylindrospermopsin, anatoxin-a, and saxitoxin, however the limited research has demonstrated promising results. Doses in excess of 20mg/L may be needed for complete toxin removal, especially if NOM concentrations are high.</p> <p>Granular activated carbon (GAC): Effectiveness of GAC adsorption varies based on type of carbon, pore size, type of cyanotoxin, and other water quality parameters such as NOM concentration. GAC is effective for microcystins, and likely effective for cylindrospermopsin, anatoxin-a and saxitoxin. The condition of the carbon is an important factor in determining GAC’s effectiveness for cyanotoxin removal. GAC may need to be regenerated more frequently to ensure adequate adsorption capacity for HAB season.</p>

Learn more about ways to treat cyanotoxins in drinking water systems:

- **Cyanobacteria and Cyanotoxins: Information for Drinking Water Systems Fact Sheet**
<<https://epa.gov/ground-water-and-drinking-water/cyanobacteria-and-cyanotoxins-information-drinking-water-systems>>
- **Water Treatment Optimization for Cyanotoxins** <<https://epa.gov/ground-water-and-drinking-water/water-treatment-optimization-cyanotoxins-document>>

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