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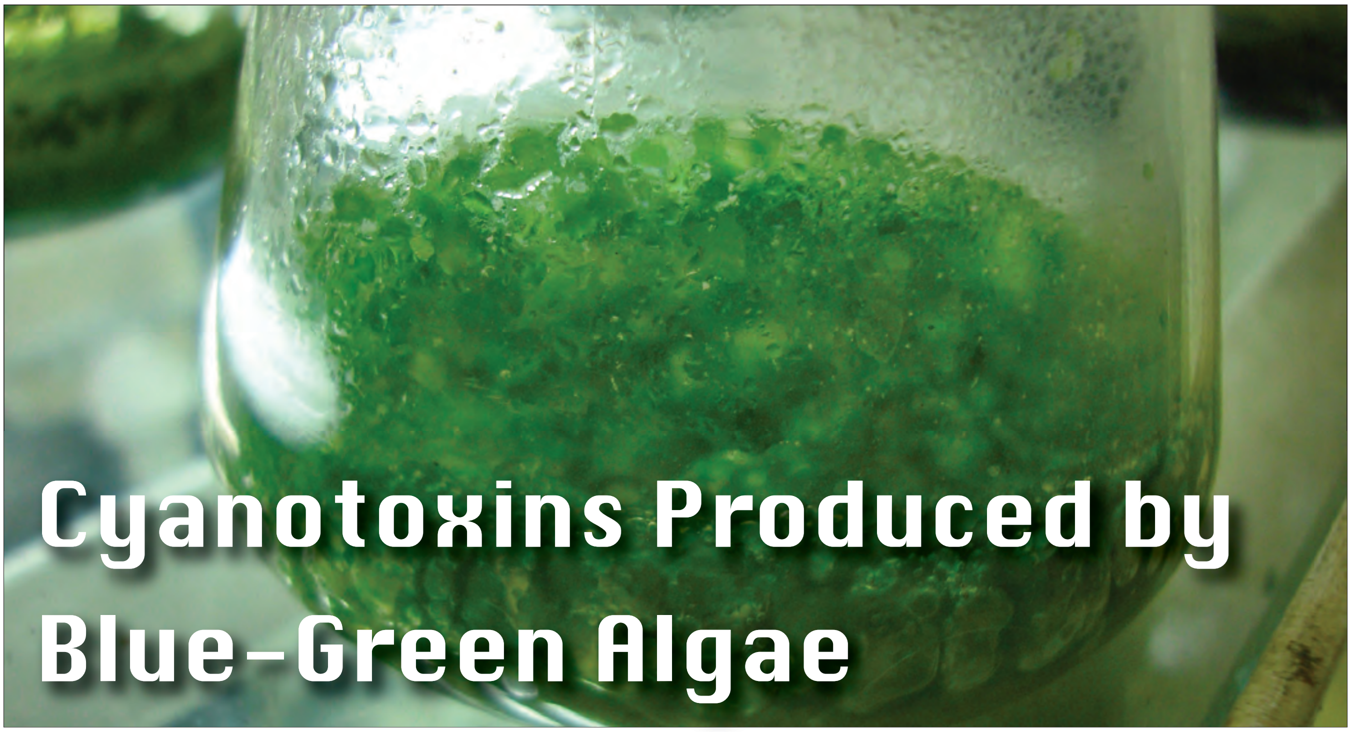

Cyanotoxins Produced by Blue-Green Algae

If you enjoy fishing, boating, or swimming at any of the freshwater lakes and/or reservoirs in Kansas, you are probably aware of the frequent occurrences of blue-green algae blooms. You have probably read or watched a local news story regarding a "Public Health Watch" or "Public Health Warning" having been issued by the Kansas Department of Health and Environment at a lake or reservoir due to the concentration of cyanobacteria (blue-green algae) cell counts or by the concentration of harmful toxins (cyanotoxins) created by cyanobacteria. Exposure to cyanobacteria and their toxins, either by drinking water contaminated with cyanotoxins or through direct contact, can lead to a variety of symptoms within minutes to days after exposure – fever, headache, diarrhea, vomiting, eye irritation, sore throat, and congestion to name a few. In severe (and rare) cases, seizures, liver failure, and death have occurred. There have also been many documented reports of dog, bird, and livestock deaths as a result of drinking water during a blue-green algae bloom. So it shouldn't come as too big of a surprise to anyone in the drinking water industry that three of the most common cyanotoxins in water bodies that are sources of drinking water in the U.S. were listed on EPA's third drinking water Candidate Contaminant List (CCL3): microcystin-LR, anatoxin-a, and cylindrospermopsin.

What are cyanobacteria?

Blue-green algae, or more correctly known as cyanobacteria, are a group of microorganisms that possess characteristics of algae (chlorophyll-a and oxygenic photosynthesis). They are found in both fresh and marine waters of the U.S. Cyanobacteria is commonly mistaken for filamentous green algae – they both produce dense mats that can impede activities like swimming and fishing and both may cause odor problems and oxygen depletion. However, green algae have not been found to produce toxins like cyanobacteria. When conditions are favorable, cyanobacteria can multiply rapidly and cause blooms. Factors that contribute to algal blooms include light availability and intensity, nutrient availability (especially nitrogen and phosphorus), water temperature, pH, water flow and water column stability. Several types of cyanobacteria have gas-filled cavities that allow them to float to the surface or to various levels below the surface, depending on the optimal light conditions and nutrient levels.

What are cyanotoxins?

Cyanotoxins are produced and contained within the cell of actively growing cyanobacteria. Most commonly, when the cell dies or the cell membrane is ruptured, the toxins are released into the water. However, in other species of cyanobacteria, cylindrospermopsin for example, toxins may be released by the live cyanobacteria cell. Cyanotoxins include neurotoxins (affect the nervous system), hepatotoxins (affect the liver), and dermatoxins (affect the skin).

Cyanotoxins in drinking water

At this time, there are no enforceable limits on cyanobacteria and/or their toxins in drinking water in the U.S. However, there are a few states in the U.S. that have established guidelines for cyanotoxin monitoring and threshold levels for public water systems. More than a dozen countries outside the U.S. have developed regulations or

KDHE Lake/Reservoir Public Health Advisory Levels

Public Health Watch

Microcystin concentration of 4 µg/L to < 20 µg/L or cyanobacterial cell counts are 80,000 to <250,000 cells/mL.

- Notifies public that a hazardous condition may exist
- Signs may be posted at all public access locations
- Water may be unsafe for humans/animals
- Discourage water contact

Public Health Warning

Microcystin concentration of > 20 µg/L or cyanobacterial cell counts are > 250,000 cells/mL.

- Notifies public that conditions are unsafe
- Signs will be posted at all public access locations
- Water contact should not occur
- All conditions of Public Health Watch remain in effect

guidelines for cyanotoxins in drinking water and recreational waters. The World Health Organization established a provisional value of 1.0 µg/L for microcystin-LR for drinking water. As previously mentioned, three types of cyanotoxins were included on EPA's third CCL and on the draft CCL4. EPA uses the CCL to identify priority contaminants and to determine which contaminants may require future regulation. In 2015, the EPA developed non-enforceable Health Advisories (HA) for the cyanobacterial toxins – microcystins and cylindrospermopsin. EPA recommends HA levels at or below 0.3 µg/L for microcystins and 0.7 µg/L for cylindrospermopsin for children less than six years old. For ages six years through adults, EPA recommends HA levels at or below 1.6 µg/L for microcystins and 3.0 µg/L for cylindrospermopsin.

Source water management; drinking water treatment options

For public water systems that use a lake/reservoir source, once cyanobacteria and/or their toxins are detected in the source water, there are a few options to consider in order to avoid the release of cyanotoxins in the treatment plant. Systems with access to more than one intake could switch if the alternate intake is not as severely impacted by the bloom. Or systems could adjust the intake depth to avoid drawing contaminated water. There are additional controls that systems may consider when it comes to source water management for cyanobacterial blooms. Physical controls include aeration, mechanical mixing, surface skimming, ultrasound, and more. Chemical controls include algaecides, barley straw, coagulation, and flocculation. There are other biological control methods that include floating artificial wetlands (to draw in excess nutrients), increasing the amount of aquatic organisms that feed on cyanobacteria, or increasing the amount of competing organisms (such as macrophytes). There are benefits and limitations to be considered along with each control option.

The Safe Drinking Water Act requires EPA to publish a list of unregulated contaminants that are known or expected to occur in drinking water and may pose a health risk every five years. This list is known as the Candidate Contaminant List. Cyanotoxins (microcystin-LR, anatoxin-a, and cylindrospermopsin) were included on the CCL3 in 2009 and on the draft CCL4 in 2015.

Removal of cyanotoxins

In terms of removing cyanotoxins at the treatment plant, conventional filtration (coagulation, flocculation, sedimentation, and filtration) can be effective. Here are some other treatment options to consider:

- Pretreatment oxidation: If oxidation is required to meet other treatment objectives, consider lowering the dose of oxidant because oxidation causes intact cyanobacteria cells to rupture and release toxins
- Coagulation/Sedimentation/Filtration: Effective in removing intact cyanobacterial cells. Cells will accumulate in sludge so be sure to not return to the source water after removal
- Dissolved Air Flotation: Effective in removal of intact cyanobacterial cells since most are buoyant
- Membranes: Further studies are required to characterize performance
- Potassium Permanganate: Effective for oxidizing microcystins and anatoxins
- Ozone: Very effective for oxidizing microcystin, anatoxin-a, and cylindrospermopsin
- Chloramines: Not effective
- Chlorine Dioxide: Not effective
- Chlorination: Effective for most cyanotoxins (except anatoxin-a) as long as pH is below 8
- UV Radiation: Effective, but at impractically high doses
- Activated Carbon: PAC is effective for removal of most cyanotoxins; GAC is effective for removal of microcystin but less effective for anatoxin-a and cylindrospermopsins

In conclusion, public water systems that draw water from a lake or reservoir source need to keep an eye out for cyanobacterial blooms and consider reviewing EPA's Recommendations for Public Water Systems to Manage Cyanotoxins in Drinking Water: https://www.epa.gov/sites/production/files/2015-06/documents/cyanotoxin-management-drinking-water.pdf. Cyanotoxins could very well be regulated by EPA in the near future.

Monica Wurtz began work with KRWA in October 2013. She previously worked at the Kansas Department of Health and Environment and also worked at US EPA Region 7 for four years. Monica is considered a national expert on various drinking water regulations.