



GCSA Training Workbook: HABs Part 2: Understanding Cyanobacteria Risks

Prepared by INCOG, 2025

Summary: Harmful Algal Blooms (HABs) are potentially dangerous overgrowths of blue-green algae in water bodies. Cyanobacteria, commonly called blue-green algae, are bacteria that produce liver toxins and neurotoxins that can be harmful or fatal when ingested. Under summer heat and when nutrients overload waterbodies in the correct ratios, cyanobacteria can take over and produce dangerous levels of these toxins. These HABs are not uncommon in Northeastern Oklahoma. It is essential that Oklahoma's municipal stormwater staff understand the organisms and environmental conditions responsible for HABs so that they can stay resilient to potential HAB conditions.

This workbook is adapted from a 123-slide presentation titled "Understanding Cyanobacteria" given by INCOG staff on May 2, 2024.

1. Cyanotoxins

Cyanotoxins come in many types, such as neurotoxins, liver toxins (hepatotoxins), skin irritants, and toxins that affect the stomach.

Most cyanotoxins are not well understood, but two specific toxins are used as representatives for the group, hepatotoxins **microcystin and cylindrospermopsin**.

Cyanotoxins

- ✓ Microcystins
- ✓ Anatoxin-a
- ✓ Cylindrospermopsin
- ✓ Saxitoxin

Above are some of the more common cyanotoxins. Many are not well studied, and we will focus on microcystins and cylindrospermopsin as being somewhat representative for the group. (EPA. EPA 822-R-19-001. 2019)

"Microcystins can be produced by a variety of toxigenic cyanobacteria genera, including *Microcystis*, *Anabaena*, *Dolichospermum*, *Nostoc*, *Oscillatoria*, *Fischerella*, *Planktothrix*, and *Gloeotrichia*. Some of these species can be distributed through the water column, concentrate in the upper layers, or form surface scums depending on environmental conditions."¹

¹ EPA 822-R-19-001. 2019

Microcystins can be intra- or extra- cellular, either dissolved in water, bound to soil, or stored inside the toxigenic cells. They are the most common cyanotoxin found in the world, and usually have a half life of four to 14 days depending on water conditions.² Despite this, microcystins can persist for **months**³ if bound to dried scum or sediment; or; microcystins can have a half life as small as **one day**⁴ when aerobic bacteria are present.

“Cylindrospermopsin can be produced by a variety of toxigenic cyanobacteria, including *Cylindrospermopsis raciborskii*, *Aphanixomenon*, *Anabaen*, *Lyngbya wollei*, and *Raphidiopsis*. Some of these species tend not to form visible surface scums, and the highest concentrations of total cyanobacterial cells typically occur below the water surface.”⁵

Like microcystin, cylindrospermopsin can be intra- or extra-cellular depending on which cyanobacterium it comes from. The decay rate for cylindrospermopsin also varies greatly, likely depending on environmental factors and other bacteria concentrations.

Microcystin Decay Rates

- “Microcystins have been observed to persist for 21 days to two to three months in solution and up to six months in dry scum (Funari and Testai 2008; Rapala et al. 2006).” (EPA. EPA 822-R-19-001. 2019)
- “According to Tsuji et al. (1994, 1995), microcystin-LR was photodegraded with a half-life of about five days in the presence of 5 mg/L of extractable cyanobacterial pigment. In deeper or turbid water, the breakdown rate is slower.” (EPA. EPA 822-R-19-001. 2019)

Cylindrospermopsin Decay Rates

- “Half-lives of 11 to 15 days and up to eight weeks have been reported for cylindrospermopsin in surface waters.” (EPA. EPA 822-R-19-001. 2019)
- “The biodegradation of cylindrospermopsin in natural water bodies is a complex process that can be influenced by many environmental factors, including toxin concentration, water temperature, sunlight, and the presence of cell pigments and bacteria.” (EPA. EPA 822-R-19-001. 2019)

² EPA 822-R-19-001. 2019

³ Funari and Testai 2008; Rapala et al. 2006; EPA 822-R-19-001. 2019

⁴ Christoffersen et al. 2002; Jones et al. 1994; EPA 822-R-19-001. 2019

⁵ EPA 822-R-19-001. 2019

2. Animal Exposure Risks

Animals, livestock, and pets have an increased risk of exposure to cyanotoxins because they are more likely to consume contaminated water and mats of dead bacteria.⁶ Pets, such as dogs, may lick cyanobacterial cells from their fur after swimming in an algal bloom. This is highlighted because “while there have been no HAB-associated human deaths in the United States, there have been many pet deaths (especially dogs) due to cyanotoxin exposure via swimming and ingesting contaminated waters.”⁷

After ingesting cyanotoxins, pets and livestock may vomit excessively, exhibit ataxia, seizures, convulsions, rashes, or sudden death.⁸

3. Human Health Risks

Like animals, humans are at risk when exposed to harmful algal blooms. Symptoms vary widely: while most blooms are harmless, others can cause rashes, hives, skin blisters, stomach cramps, diarrhea, vomiting, headache, fever, muscle weakness, or difficulty breathing.

Nerve toxins are a cyanotoxin that is harmful to human health. According to the Oklahoma Department of Tourism website, “exposure to nerve toxins may produce tingling in fingers

Animal Exposure

“The earliest observations of adverse effects of cyanobacterial exposure to animals include the rapid death of stock animals in Australia in 1878 (Francis 1878). Since then, numerous cases of mammal and bird deaths have been documented (Baker et al. 2015; Hilborn and Beasley 2015)”. (EPA. EPA 822-F-19-001. 2019)

Under-recognized Cases

“These cases were reported throughout the 20th century on all continents except Antarctica (Stewart et al. 2008). The impacts of cyanotoxins on domestic and companion animals are likely under-recognized because many cases are misdiagnosed, few cases are biochemically confirmed, and even fewer are reported in the scientific literature or to animal health systems (Zaias et al. 2010)”. (EPA. EPA 822-F-19-001. 2019)

⁶ Backer et al. 2013; EPA 822-F-19-001. 2019

⁷ EPA 822-F-19-001. 2019

⁸ CDC 2017a; New York Sea Grant 2014; Trevino-Garrison et al. 2015; EPA 822-F-19-001. 2019

and toes, numbness in the lips and dizziness.”⁹ Another toxin type, liver toxins, can cause abdominal pain, diarrhea, vomiting, and even permanent kidney and liver damage in humans.

Severe toxicity symptoms may take several hours or days to appear depending on the contact method. Harmful exposure can occur through inhalation of cells, accidental ingestion, and skin contact.

3a. Exposure Types

Incidental ingestion during primary contact recreation (e.g. swimming) is currently the highest-known potential cyanotoxin exposure pathway.¹⁰ Even canoeing, kayaking, and jet skiing have risk of ingestion if a boat flips or capsizes.

While microcystin and cylindrospermopsin are not easily aerosolized, other cyanotoxins may

Kidney and Liver Damage

- “Exposure to elevated-levels of microcystins can potentially lead to liver damage; the kidneys and liver appear to be the primary target organs for cylindrospermopsin toxicity.” (EPA. EPA 822-F-19-001. 2019)
- “However, in both the critical study and the supporting studies there is evidence that cylindrospermopsin can also alter the shape of red blood cells.” (EPA. EPA 822-F-19-001. 2019)

Routes of Exposure

“Exposure to cyanotoxins from recreational water sources can occur via oral exposure (incidental ingestion while recreating); dermal exposure (contact of exposed parts of the body with water containing cyanotoxins during recreational activities such as swimming, wading, or water skiing); and inhalation exposure to contaminated aerosols (while recreating).” (EPA. 84 FR 26413. Document Number 2019-11814. 2019)

Inhalation Exposure

“Microcystins that are free or bound to particulate matter in air can be deposited into the deepest bronchiolar or alveolar cavities; air borne cyanobacterial cells from aerosolized water droplets would likely be deposited in the upper respiratory tract (Wood and Dietrich 2011).” (EPA. EPA 822-R-19-001. 2019)

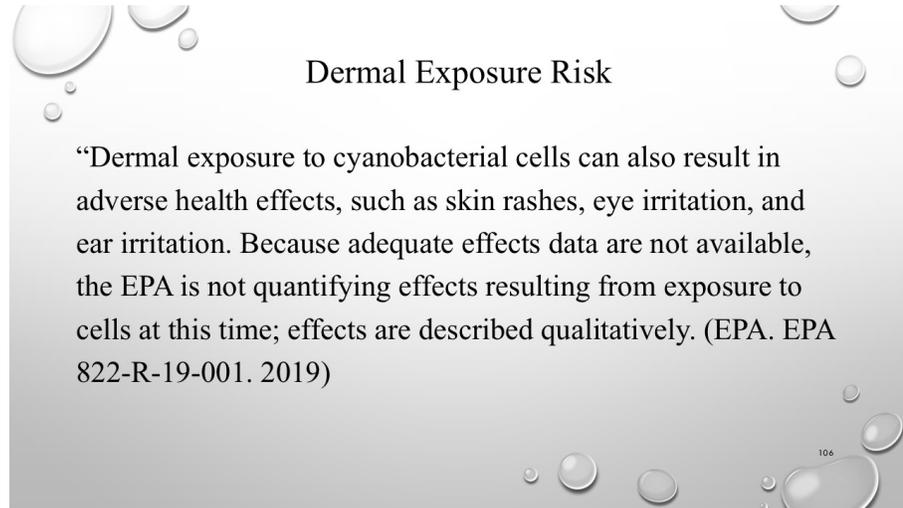
⁹ Oklahoma Department of Tourism website. 2024

¹⁰ EPA 822-R-19-001. 2019

be carried into the air when bound to particulate matter. While these inhaled doses can still cause symptoms, they are much less potent than ingested doses.

Harmful dermal¹¹ exposure to cyanotoxins can lead to rashes, blisters, and other effects. These symptoms are thought to be more common in individuals with chronic rhinitis.¹²

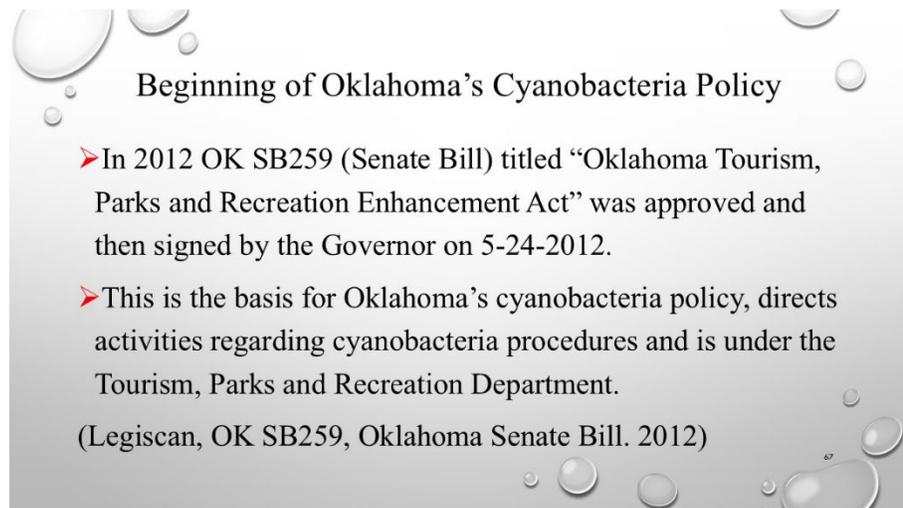
In algal bloom outbreaks from 2009 to 2010, reports indicated at least 61 illnesses, with skin irritation, gastrointestinal issues, and respiratory issues being the most common symptoms.¹³



4. Oklahoma’s Cyanobacteria Policies

Cyanobacteria-related policies in Oklahoma arose in 2012, with OK SB259, or the “Oklahoma Tourism, Parks and Recreation Enhancement Act.” In the policy, the Oklahoma Legislature delegated the issuance

of certain advisories and emergencies for lakes, including those regarding algal blooms, to the Oklahoma Tourism and Recreation Department. SB259 was codified in the Oklahoma Statutes as Section 2301 of Title 74 on May 24, 2012.



¹¹ Skin contact.

¹² Rhinitis is when a reaction occurs that causes nasal congestion, runny nose, sneezing, and itching.

¹³ Elizabeth D. Hilborn, DVM et al. 2014

Section 1.D. of the policy specifies procedures regarding cyanobacteria, and reads as follows:

“Any state or municipal agency with authority to manage a recreational lake or reservoir in this state, to regulate water quality or regulate public health shall:

- a. Issue advisories for blue-green algae for recreational lakes or reservoirs only when both the blue-green algae cell count and toxicity testing results exceed the World Health Organization guidelines for moderate probability of adverse health effects of one hundred thousand (100,000) cells per milliliter for cell count and twenty (20) micrograms per liter for microcystin toxin levels. The blue-green algae testing shall be conducted at predetermined locations which are published along with the testing results, and
- b. lift advisories for blue-green algae for recreational lakes or reservoirs if the blue-green algae cell count and toxicity testing results are below guidelines as set forth in subparagraph a of this paragraph for two consecutive tests taken at weekly intervals within thirty (30) calendar days of each other.”¹⁴

Oklahoma’s cyanobacteria policies focus on recreation since HABs have the greatest potential to harm human health in primary body contact contexts.

5. EPA Guidance

Under the Clean Water Act section 304(a), the EPA develops water quality criteria recommendations to provide guidance to states, tribes, and local agencies to protect designated uses for certain waters.¹⁵ Included in the water quality criteria

recommendations are cyanotoxins such as microcystin and cylindrospermopsin. These criteria are not regulatory and are simply recommended levels to be at or below. The EPA recommended cyanotoxin values are “based on children’s recreational exposures” because children are more sensitive to toxins due to smaller body mass so the recommendation is protective of older ages as well.¹⁶

EPA Recommended Levels

Recommended Magnitude for Cyanotoxins	
Microcystins	Cylindrospermopsin
8 µg/L	15 µg/L

For application as a recreational water quality criterion, EPA recognizes that a single exceedance of the recommended magnitude does not necessarily indicate that the designated use is not attained. (EPA. EPA 822-F-19-001. 2019)

¹⁴ Legiscan, OK SB259, Oklahoma Senate Bill. 2012

¹⁵ EPA. 84 FR 26413. Document Number 2019-11814. 2019

¹⁶ EPA 822-F-19-001. 2019

To decide when to put advisories in place, the EPA recommends “10-day assessment periods, not a rolling 10-day period, over the course of a recreational season to evaluate ambient water body condition and recreational use attainment.”¹⁷ If toxin concentrations are higher than the recommended levels during a 10-day period, the period is called an **excursion**. When three or more excursions occur in one recreational season, and the pattern reoccurs in two or more years, that indicates degradation of the water resource’s quality.¹⁸

Excursions

- “If toxin concentrations are higher than the criterion magnitude during a 10-day assessment period, then that event should be considered an excursion from the recreational criteria.” (EPA. EPA 822-F-19-001. 2019)
- The event is a 10-day period.
- An excursion is an exceedance during the 10-day period.

Use of the Recommended Magnitude Values

“In derivation of the recreational criteria and swimming advisory recommendations, the EPA uses these toxicity values as the measure of effect for oral exposure through incidental ingestion while recreating. The RfDs described in the EPA’s HESDs are based on short-term and subchronic studies and therefore are an estimate (with uncertainties spanning perhaps an order of magnitude) of the daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a short-term exposure period.” (EPA. EPA 822-R-19-001. 2019)

Along with excursions, swimming advisories can be issued if the magnitude of cyanotoxin is exceeded in a single day. These advisories are recommended to not be lifted until two samples, at least 24 hours apart, have a toxin concentration lower than the recommended criteria.¹⁹

It is important to note that these are **recreation criteria, not human health criteria**, and cannot be used to determine safety of drinking water or fish consumption.

¹⁷ EPA 822-F-19-001. 2019

¹⁸ EPA 822-F-19-001. 2019

¹⁹ EPA 823-R-21-002. 2021

Microcystins Recommendation Table

Application of Recommended Values	Microcystins		
	Magnitude ($\mu\text{g}/\text{L}$)	Duration	Frequency
Recreational Water Quality Criteria	8	One or more values exceeding 8 $\mu\text{g}/\text{L}$ in 10-day assessment period across a recreational season is an excursion	More than 3 excursions in a recreational season, not to be exceeded in more than one year
Swimming Advisory		One day	Not to be exceeded

(EPA. EPA 822-F-19-001. 2019)

The table above outlines the EPA's recommended microcystin concentration criteria.

Cylindrospermopsin Recommendation Table

Application of Recommended Values	Cylindrospermopsin		
	Magnitude ($\mu\text{g}/\text{L}$)	Duration	Frequency
Recreational Water Quality Criteria	15	One or more values exceeding 15 $\mu\text{g}/\text{L}$ in 10-day assessment period across a recreational season is an excursion	More than 3 excursions in a recreational season, not to be exceeded in more than one year
Swimming Advisory		One day	Not to be exceeded

(EPA. EPA 822-F-19-001. 2019)

The table above outlines the EPA's recommended cylindrospermopsin concentration criteria.

6. Methods for Quantification

Different tests exist for different cyanotoxins, with the most common being **ELISA** and **qPCR** tests for the most understood toxins.

Enzyme-linked immunosorbent assays (ELISA) are the most widely used due to their relatively low cost and availability, however, new methods have surfaced since ELISA tests. The most notable method is qPCR, a quantification of toxigenic cyanobacteria that helps to predict toxin concentrations based on the number of toxigenic cells present within a sample. ELISA and qPCR are most effective with microcystin, but cylindrospermopsin may also be identified using both methods.

In 2014, a do-not-drink order was placed over Lake Erie to protect Toledo, Ohio residents from cyanotoxins in their drinking water. This led to more stringent testing using qPCR gene detection methods for Lake Erie.

qPCR for Cyanobacteria (slide 2)

“More recently, the use of gene-based quantification methods has helped to shed light on the community dynamics within a bloom, understand some of the factors that trigger toxic blooms, and provide faster and less expensive measurements of potential bloom toxicity compared to ELISA- and LC/MS/MS-based methodologies.” (EPA. EPA 822-R-19-001. 2019)

qPCR Applications for Cyanobacteria

- “In August 2014, the city of Toledo, Ohio, issued a do-not-drink or –boil advisory to nearly 500,000 customers in response to the presence of total microcystins in the city’s finished drinking water at levels up to 2.50 µg/L.” (EPA. EPA 822-R-19-001. 2019)
- “The presence of the toxins was due to a cyanobacterial bloom near Toledo’s drinking water intake located on Lake Erie.” (EPA. EPA 822-R-19-001. 2019)

qPCR Applications for Cyanobacteria

“In response to the 2014 Lake Erie HAB event that contaminated the drinking water of Toledo, Ohio, the EPA revised the monitoring requirements for Ohio public water systems. Included in those requirements are testing for the *mcyE* gene. If > 5 *mcyE* genes/µL are detected in raw water samples, public water systems must monitor for microcystins (Ohio EPA 2017).” (EPA. EPA 822-R-19-001. 2019)

The last method used is cyanobacterial cell count. However, cell counts do not separate toxigenic cyanobacterial cells from harmless cells, so the merit of this method is questionable. Harmless blooms have the potential to look worse than a dangerous bloom because toxins are not as visible, so this method should not be chosen if other methods that can quantify toxin concentrations are available.

Cyanobacterial Cell Counts as an Indicator? (slide 2)

- “1. Toxigenic cell densities can be a better indicator of the potential of a bloom to produce cyanotoxins compared to measures of total cyanobacterial biomass.” (EPA. EPA 822-R-19-001. 2019)
- “Davis et al. (2009) observed that quantifying toxigenic *Microcystis* was a better predictor of in situ microcystin levels than other surrogates, such as total cyanobacteria and chlorophyll a.” (EPA. EPA 822-R-19-001. 2019)

Cyanobacterial Cell Counts as an Indicator? (slide 3)

- “2. Total cyanobacteria can be informative as an indicator for the presence of toxins if toxigenic species are abundant or the dominant members of the cyanobacterial community.” (EPA. EPA 822-R-19-001. 2019)
- “3. The proliferation of toxigenic cells and the timing of the presence of elevated toxin concentrations may or may not coincide with the visible proliferation of a HAB.” (EPA. EPA 822-R-19-001. 2019)