



# GCSA Training Workbook: Understanding HABs Part 1: Cyanobacteria (Blue-Green Algae)

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, is a bacterium that produces liver toxins and neurotoxins that can be harmful or fatal when ingested. Under summer heat and when nutrients overload waterbodies in the correct ratio, 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. Blue-Green Algae or Cyanobacteria?

Blue-Green Algae is likely the term you have heard when someone refers to Harmful Algal Blooms (HABs).

However, Blue-Green Algae are **not actually algae**, they are prokaryotic<sup>1</sup> **bacteria**.

They are not always

“harmful” and can be found in low numbers naturally in nearly every waterbody, whether freshwater or marine. These bacteria are an important part of their individual ecosystems because they photosynthesize like plants and feed other organisms. There are many species of cyanobacteria which are categorized into two distinct groups based on their behavior when a HAB occurs: the **planktonic** and the **mat-formers**.

A presentation slide with a light blue background and water droplet graphics. The title is 'Blue-Green Algae or Cyanobacteria?'. There are two bullet points: the first states that blue-green algae are primitive, free-floating, microscopic organisms naturally present in reservoirs, lakes, and streams, and are not really algae (they are bacteria); the second quotes the Oklahoma Department of Tourism and Recreation website, stating that blue-green algae (cyanobacteria) have been around forever, are found among the oldest fossils on earth, and are one of the largest groups of bacteria, while most species of algae are not harmful.

Blue-Green Algae or Cyanobacteria?

- Blue-green algae are primitive, free-floating, microscopic organisms naturally present in reservoirs, lakes and streams, and not really algae (they are bacteria).
- “Blue-green algae (cyanobacteria) have been around forever. The bacteria have been found among the oldest fossils on earth and are one of the largest groups of bacteria. Algae are vitally important to water ecosystems, and most species of algae are not harmful.” (Oklahoma Department of Tourism and Recreation website.)

<sup>1</sup> Single-celled organisms, either bacteria or archaea, with no distinct membrane surrounding a nucleus or other organelles to separate them.

## 2. Planktonic Cyanobacteria

Planktonic cyanobacteria are microscopic and cause the water to turn green and thick looking during a HAB, like **pea soup**. The most common examples are *Anabaena*, *Aphanizomenon*, and *Microcystis*.<sup>2</sup>

The image shown to the right is an example of a planktonic algal bloom. Notice that the water is both green and brown, and murky.

These cyanobacteria can also rise to the top of the water to create **surface scums** that block sunlight from reaching the bottom of the waterbody. Yellowish-green surface scum is indicative of planktonic cyanobacteria.



### Planktonic Cyanobacteria

“This yellowish-green scum formation is typical of most planktonic blue-greens. The formation of surface scums tends to block the light to the other types of algae and aquatic plants that live deeper in the water column. By shading out their competitors, blue-greens can completely dominate a body of water.” (Carole A. Lembi)

## 3. Mat-Forming Cyanobacteria

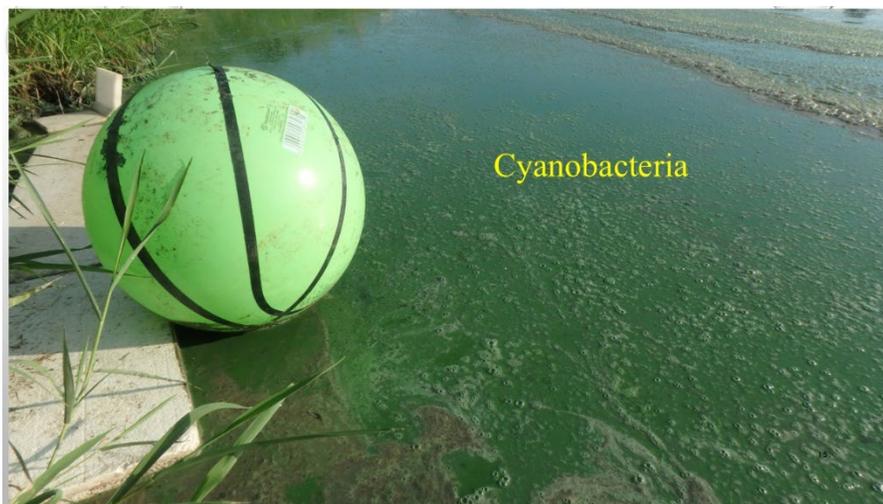
Mat-forming cyanobacteria grow on the bottom of the waterbody to form a “**mat**” and float up to the surface together when they die. These mats can be green, brown, or black and

### Mat-forming Cyanobacteria

“The mat-forming blue-greens form dark green or black slimy mats. These mats start growth on the bottom, but eventually float to the surface where they can be quite smelly and noxious looking.” (Carole A. Lembi)

<sup>2</sup> Commonly referred to as “Annie, Fannie, and Mike.”

consist of thousands to millions of dead bacteria that emit noxious odors as they decay on the surface. The picture to the right shows a bloom where there are mats of dead cyanobacteria washing up in the background.



#### 4. What is a Harmful Algal Bloom (HAB)?

Many blooms are completely harmless; however, the blooms can turn toxic in a short amount of time, so all cyanobacteria blooms are considered *potentially* harmful. Not all blooms produce significant amounts of toxins, but some do, making it too risky to ignore a HAB occurrence.

According to the EPA, “total cyanobacterial density in a bloom and cyanotoxin concentration are not always closely related.”<sup>3</sup> This means that even if a bloom does not appear large, it could produce harmful amounts of toxins, and vice versa.

#### 5. What causes HABs?

Blooms are dependent on numerous factors, including flow rate, water turbulence, temperature, sunlight, nutrient levels, pH, predation, interactions with other biota, and weather patterns.

Cyanobacterial blooms typically are seasonal events, and recreational exposures are likely to be episodic and may be short-term in nature. Major factors in harmful conditions include microbial interactions between cyanobacteria and other microbes, toxigenic cyanobacteria strains, and toxin cell quota.

Contributing Factors and Consequences

- “Under certain environmental conditions, such as elevated levels of nutrients, warmer temperatures, still water, and plentiful sunlight, cyanobacteria can rapidly multiply to form harmful algal blooms (HABs)”. (EPA. EPA 822-F-19-001. 2019)
- As the cyanobacteria multiply, some of the cells can produce toxic compounds, known as cyanotoxins, which can be harmful to human and animal health.” (EPA. EPA 822-F-19-001. 2019)

<sup>3</sup> EPA 822-R-19-001, 2019

The major recognized factors that **increase** HABs are:<sup>4</sup>

- High Phosphorus (or Nitrogen in specific cases)
- Low Nitrogen, inorganic and organic (when the cyanobacterium is a Nitrogen fixer)
- Low N:P ratios
- Low flow/stagnant waters
- High sunlight levels
- Warm temperatures (optimally above 25 °C/77 °F)
- High organic matter in water
- Sufficient Iron and trace metals
- Low grazing of cyanobacteria (typically due to cyanotoxins)

Some factors that **decrease** HABs are:<sup>5</sup>

- High Nitrogen (for Nitrogen fixers)
- Low Phosphorus
- High N:P ratios
- High turbulence (and vertical mixing of the water column in lakes)
- High flow/flowing water
- Low light
- Cool temperatures
- Low organic matter in water
- Low Iron and trace metals
- High cyanobacteria grazing rates
- Viruses (cyanophages)

## 5a. What Causes HABs?: Cyanotoxins

Microbes, such as zooplankton, eat/**graze** cyanobacteria, which keeps the ecosystem in balance. However, when conditions allow toxigenic cyanobacteria to produce enough toxins these grazers

### Microbial Interactions

“The microbial community can be complex and variable. It can consist of multiple different species and strains of cyanobacteria and other microbes. Microbial interactions can occur within blooms, such as competition and adaptation between toxic and nontoxic cyanobacterial strains, as well as impacts from viruses and zooplankton grazers like *Daphnia* (large generalist grazers), copepods, and cladocerans (Ger et al. 2014). Each of these microbial-related factors can cause fluctuations in bloom development and composition.” (EPA. EPA 822-R-19-001. 2019)

<sup>4</sup> EPA 822-R-19-001, 2019

<sup>5</sup> EPA 822-R-19-001, 2019

may be inhibited, allowing cyanobacteria to bloom.

Not all cyanobacteria can produce toxins, and toxigenic cells vary widely between bloom events. The amount of toxins produced by a toxigenic cell is the **cell quota**. It is not the case that quota is correlated with cell density, because a bloom can contain both toxigenic and non-toxic cells in

varying locations, or no toxigenic cells at all.<sup>6</sup> Toxins may even settle in sediments, allowing them to stay in the ecosystem for months after a HAB.

Cyanotoxins can be dangerous and even fatal to humans, livestock, aquatic animals, and pets. The risks to human health and animals from HABs are outlined in more detail later in this workbook, starting on page 6 with an overview of different cyanotoxins.

## 5b. What Causes HABs?: Nutrients

Nutrients in water typically refer to dissolved phosphorus and nitrogen, which are essential for plants and cyanobacteria. In the right nutrient ratios, certain cyanobacteria proliferate, especially with low N:P ratios.

Cyanobacteria that are **nitrogen-fixing**<sup>7</sup> thrive with low nitrogen and high phosphorus. Nitrogen fixing refers to taking nitrogen out of the air to help meet the plant's nitrogen needs. Adequate amounts of nitrogen don't need to be present in the soil or water nitrogen fixing bacteria are living in, they can simply thrive without it while other organisms die off. Non-nitrogen-fixing

**Mobility**

- “Microcystins may adsorb onto naturally suspended solids and dried crusts of cyanobacteria. They can precipitate out of the water column and reside in sediments for months (Falconer 1998; Han et al. 2012).” (EPA. EPA 822-R-19-001. 2019)
- “In sediments, cylindrospermopsin exhibits some adsorption to organic carbon, with little adsorption observed on sandy and silt sediments (Klitzke et al. 2011). The low adsorption of cylindrospermopsin reduces its residence time in sediments, thus reducing the opportunity for microbial degradation.” (EPA. EPA 822-R-19-001. 2019)

**Nutrients and Cyanobacteria (slide 4)**

- “Ottens et al. (2012) reported higher average microcystin concentrations and a higher prevalence of toxigenic *Microcystis* biomass at sites that had narrower TN:TP ratios (<20) in Lake Taihu, China.” (EPA. EPA 822-R-19-001. 2019)
- “Fortin et al. (2015) demonstrated that the dominance of *Microcystis* depended on the ratio of nitrogen to phosphorus, with a (mass) ratio of 11:1 resulting in the highest abundance of *Microcystis*...” (EPA. EPA 822-R-19-001. 2019)

<sup>6</sup> EPA 822-R-19-001, 2019

<sup>7</sup> Nitrogen-fixing bacteria can return nitrogen to the atmosphere.

cyanobacteria, such as *Microcystis*, thrive in the opposite case, where there is low phosphorus and high nitrogen ratios.

### **5c. What Causes HABs?: Temperature & Sunlight**

Cyanobacteria are well-understood to prefer higher temperatures because their maximum growth rates occur at temperatures ranging from 30 to 35 °C (86 to 95 °F).<sup>8</sup> This is why most algal blooms occur in the summer months. Exacerbating that effect, most eukaryotic organisms and other aquatic organisms such as phytoplankton decline with warmer temperatures, allowing cyanobacteria to take over the ecosystem.

Cyanobacteria are photosynthetic, so in the hot summer months when sunlight is more intense, species of cyanobacteria that rely on this function may dominate over others.

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<sup>8</sup> Giannuzzi 2018; Reynolds 2006; Roberts and Zohary 1987; WHO 2003; EPA 822-R-19-001. 2019