North American Lake Management Society
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# Toxic Cyanobacterial Blooms

Toxin-producing cyanobacteria (commonly referred to as blue-green algae) are an increasingly common type of inland harmful algal bloom (HAB) that is a growing issue for lake managers and public health officials throughout the world. In addition to ecological (e.g. fish kills, food web impacts, low oxygen) and economic (e.g. loss or recreation, increased water treatment costs to remove T&O/toxins, and decreased property values) damage, the toxins produced by cyanobacteria (i.e., cyanotoxins) can cause illness and death of humans and domestic and wild animals. Animals exposed to potent cyanotoxins can die within hours following ingestion. Children are at greater risk than adults because of their small body size, and the way they play in the water (often ingesting water or playing with scums). Immuno-compromised individuals are at greater risk as well.

The environmental factors responsible for the formation of cyanobacterial blooms and toxicity are diverse, and bloom dynamics are complicated. Cyanobacterial blooms can be episodic or persist year-round, and often, but not always, occur in highly productive (eutrophic or hypereutrophic) waters. The eutrophication (i.e., nutrient, primarily nitrogen and phosphorus, enrichment) of North America's surface waters has led to the increasing frequency, duration, and magnitude of toxic cyanobacterial blooms. Toxic blooms are difficult to treat safely due to the risk of liberating cyanotoxins into the water.

### Which cyanobacteria produce toxins and what types of toxins are produced?

Over 50 species of cyanobacteria have been shown to produce toxins that are harmful to vertebrates. Common toxin-producing species also form blooms and include members of the genera *Microcystis*, *Dolichospermum* (formerly known as *Anabaena*), *Sphaerospermopsis*, *Planktothrix* (*Oscillatoria*), *Cylindrospermopsis*, *Aphanizomenon*, *Cuspidothrix*, *Chrysosporum*, *Plectonema* (*Lyngbya*), *Gloeotrichia*, and *Nodularia*.

Cyanotoxins fall broadly into three groups: neurotoxins, hepatotoxins and dermatoxins. All cyanobacterial toxins can affect humans. Neurotoxins include anatoxin-a, anatoxin-a(s), saxitoxin and neosaxitoxin and primarily cause neurological symptoms, including paralysis and respiratory failure. ß-*N*-methylamino-L-alanine (BMAA) is a unique amino acid widely produced by cyanobacteria. It has been linked to neurological disorders in humans, but occurrence and risk data are limited. Hepatotoxins include microcystin (100+ variants), nodularin and cylindrospermopsin acting primarily on the liver and kidneys (as well as other organs). Many cyanobacteria produce lipopolysaccharides, which cause allergic reactions, skin irritation, and rashes. The dermatoxin lynbyatoxin, most commonly produced by *Lyngbya* (*Plectonema*) also may cause gastrointestinal upset. Some data also suggest that microcystins and cylindrospermopsin can be carcinogenic (causing cancer) and teratogenic (causing birth defects). Although each of the toxins acts somewhat uniquely, initial, low-level exposure may include skin irritation and gastrointestinal upset, regardless of the specific toxin involved.

Particular problems arise from these cyanobacteria in drinking water supplies. Microcystins and cylindrospermopsin are highly heat stable (boiling will not destroy them), and they are not easily removed by conventional drinking water treatment methods such as sand filtration, if they are free (dissolved) in the water. Of the cyanotoxins, microcystin-LR, anatoxin-a, and cylindrospermopsin are on the U.S. Environmental Protection Agency (EPA) Contaminant Candidate List (CCL3) and are currently being evaluated for risk in treated drinking water. In addition, EPA established health advisory (HA) levels at or below 0.3 micrograms per liter for total microcystins and 0.7 micrograms per liter for cylindrospermopsin in finished drinking water for children pre-school age and younger (less than six years old). For school-age children through adults, the established HA levels for drinking water are at or below 1.6 micrograms per liter for total microcystins and 3.0 micrograms per liter for cylindrospermopsin. Canada has developed a drinking water quality guideline of 1.5 micrograms per liter and a recreational water quality guideline of 20 micrograms per liter for (total) microcystin. Several other countries have established drinking water guidelines for microcystins and other cyanotoxins as well.

## History and Threats Posed by Cyanotoxins

Toxic cyanobacterial blooms are not a new phenomenon. They have been documented for over two thousand years dating back to ancient Rome. Initial increases in cyanobacterial blooms in North America coincided with European colonization. Continued growth and development of population centers and agriculture resulted in substantial land use changes in watersheds and associated increases in nutrient export to surface waters over the last 200-300 years. More recently, it appears that milder winter temperatures, reduced ice cover, and warmer summers are increasing the occurrence of blooms across the United States and Canada. Additionally, resting stages (akinetes) produced by some cyanobacteria can remain viable for hundreds of years in the sediments, remaining as a 'seed bank' to initiate cyanobacterial blooms. Ecological impacts from cyanobacterial blooms include decreased algal and zooplankton diversity, lower macrophyte diversity and biomass, reduced oxygen levels, and fish and wildlife kills. Negative effects can result directly from toxins, lowered oxygen levels from reduced light penetration or degradation of the high biomass associated with HABs, or from interference with the food web.

Cyanobacterial blooms occur in all freshwater systems, from man-made dugouts and natural ponds to rivers, lakes, and reservoirs. Though they tend to occur at the height of summer and early fall, some can persist well into late fall or winter. Some cyanobacteria (e.g. *Planktothrix sp.*) cause blooms under ice, which can be extremely toxic and may persist through spring ice-out. Most bloom-forming cyanobacteria (*Microcystis*, *Dolichospermum* and *Aphanizomenon*) accumulate in characteristic scums that initially look like blue-green paint or slicks on the water surface, and later develop into bubbly masses up to a meter thick, and their color can range from yellows and browns to bright blue. Wind often concentrates these scums near boat docks and shores. Not all toxin-producing cyanobacteria form scums. *Cylindrospermopsis* and *Aphanizomenon gracile* do not concentrate at the surface, remaining more evenly distributed in the subsurface waters. Some species of *Planktothrix* concentrate at depths where light intensities are much reduced. As in under-ice blooms, these metalimnetic blooms (blooms at depth) can contain very high microcystin concentrations.

Exposure routes to cyanobacterial toxins include insufficiently treated drinking water and casual recreational water contact from swimming, fishing, and water skiing. Recreational exposure includes skin contact, ingestion, or inhalation. As mentioned above, children are at greater risk, as are family pets (e.g., dogs), which may receive high doses of toxins when wading or swimming in bloom-infested water. Exposure also may occur through consumption of fish and popular food supplements containing cyanobacteria such as *Spirulina* and *Aphanizomenon*.

Most U.S. states, Canadian provinces and Mexico have documented toxic cyanobacterial blooms. The extent and impacts of toxic cyanobacteria blooms in Mexico are less well known. Toxic cyanobacteria alerts are now routinely issued in many states and provinces that have bloom-monitoring programs. State-specific information on toxic cyanobacteria monitoring and alerts can be found at http://www.nalms.org/home/programs/inland-hab-program/inland-hab-program.cmsx. There is no standard program or approach for monitoring or reporting toxic cyanobacterial blooms, and most go undocumented. The reauthorization of the Harmful Algal Blooms and Hypoxia Research and Control Act in 2014 (HABHRCA 2014, Public Law 113-124) extended federal HAB efforts to include freshwaters

### Issues and Concerns Relating to Cyanotoxins in North America

1. Lack of regulation
   a. There are no U.S. or Mexican regulatory policies and practices that address freshwater cyanobacterial blooms or toxins in drinking water supplies, although the USEPA has established a health advisory guideline for finished drinking water. In Canada, a federal drinking-water guideline for total microcystin (based on microcystin-LR toxicity equivalents) has been adopted by the provinces and territories.
   b. Neither the U.S. nor Mexico have established recreational policies or practices regarding toxic cyanobacteria. Health Canada set recreational and drinking water guidelines for microcystin and cyanobacteria cells counts in 2012, which many provinces have adopted http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/guide_water-2012-guide_eau/index-eng.php
2. Inadequate monitoring and management
   a. Adequate monitoring programs do not exist in most systems, and there is little infrastructure in place to notify populations at risk from developing or fully developed cyanobacterial blooms.
   b. Prevention, monitoring and control must be coordinated at the local, state, provincial, and national levels. Protection and mitigation efforts are poorly supported in most cases.
3. Lack of information regarding impacts on human and animal health
   a. The human health impacts of toxic cyanobacterial blooms can be profound and long term, including potential carcinogenic and teratogenic risks later in life.
   b. Almost all laboratory exposure data are based on mice and rats, with limited replication of complete studies, and few other appropriate mammalian models.
   c. Although there is more awareness of the potential adverse effects of toxic cyanobacteria in drinking and recreational waters, translation of risk to water users is often missing or unclear, resulting in confusion about water safety and appropriate uses during blooms.
   d. Known toxins are not yet fully characterized, and new toxins are still being discovered.
4. Ecosystem- and food web-level impacts of toxic cyanobacterial blooms have been understudied.
   a. The ecological and economic impacts of toxic cyanobacterial blooms can be very high.

b. Documented impacts include chronic low-dissolved oxygen issues and decreased juvenile fish recruitment, and food web impacts.

## NALMS Positions on Cyanotoxins

1. NALMS supports the development of national standards on the cyanotoxins primarily encountered in drinking and recreational waters (microcystins, anatoxin-a, cylindrospermopsin, and saxitoxin) and to expand the focus beyond microcystin-LR.
2. NALMS encourages research on developing appropriate analytical methodologies for better and more rapid identification and quantification of cyanotoxins, especially microcystins.
3. NALMS encourages effective and consistent messaging be developed that conveys to the public the relative risks of exposure to cyanobacteria blooms at varying abundance levels.
4. NALMS supports international, national, provincial, and state efforts to monitor, control and mitigate freshwater cyanobacterial blooms.
5. NALMS supports expanding the focus of monitoring programs to include all major classes of cyanotoxins (microcystins, anatoxin-a, cylindrospermopsin, and saxitoxin).
6. NALMS encourages the development of consistent, coordinated approaches to monitoring and management of toxic blooms at the local, state, and regional levels to yield more efficient utilization of resources and standardization of the response.
7. NALMS supports more research towards understanding both:
   a. The factors that control blooms.
   b. Quantifying the effects of cyanotoxins on humans.
8. NALMS encourages and supports local efforts to protect and restore lakes, and thereby limit cyanobacterial blooms. This includes public education, monitoring, watershed management and mitigation programs, and effective nutrient source control including agricultural sources.
9. NALMS strongly recommends that U.S. EPA reinstate national funding and support for both lake restoration and watershed management to enhance ecosystem functions and protect human health. NALMS promotes the engagement of national/international agriculture agencies (i.e. the USDA and AAFC-(Agriculture and Agri-Food Canada) in the monitoring and control of cyanotoxins as a matter of agricultural nutrient management and livestock health.

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