The NALMS **Blue-Green Initiative**

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*[**NOTE:** LakeLine is a non-peer reviewed publication of the North American Lake Management Society (NALMS), written with member interests in mind. While written for a more general readership than peer-reviewed publications, readers are expected to have a background in science, particularly in the area of water-quality. Readers will know what the abbreviation NALMS stands for and will be familiar with blue-green algae (cyanobacteria). The "Blue-Green Initiative" is the formal name of the NALMS program dealing with cyanobacteria, but the term "cyanobacteria" is generally used more frequently by NALMS. Therefore, in this text, blue-green is used to refer to the initiative, while cyanobacteria is used for general discussion. These two terms are synonymous and the use of both should not confuse the target audience of this magazine.]*

Toxic cyanobacterial (blue-green algal) blooms have been documented in North America for more than a century, but wildlife and domestic animal poisonings associated with cyanobacterial toxins (cyanotoxins) may be increasing and have caused environmental and public health concerns. Resource managers, lake associations, and local, state, and provincial governments are beginning to address problems associated with cyanobacterial blooms and potential toxicity. These organizations need easily accessible, current information to effectively make management decisions and minimize human health risks. Most of the information available about cyanotoxins in North America is diffuse and there is a need for a centralized information resource. The NALMS Blue-Green Initiative was adopted at the Board of Directors meeting in November 2004 to address this need by establishing NALMS as an information resource and furthering the understanding and management of cyanobacterial blooms through multiple session tracks at NALMS meetings and dedicated issues of *LakeLine* and *Lake and Reservoir Management*.

The November 2005 NALMS meeting in Madison, Wisconsin had the first day-long symposium on cyanotoxins, called "Toxic Freshwater Cyanobacteria – Global Perspectives on North American Occurrence and Regulation." The symposium featured 13 invited presentations by recognized experts from North America, Europe, South Africa, and Australia in the study of cyanotoxins and the ecology of toxin-producing cyanobacteria. Special issues of the NALMS magazine *LakeLine* (Volume 26[2], Summer 2006) and the peer-reviewed journal *Lake and Reservoir Management* (Volume 23[2], June 2007) featured articles based on papers presented at this symposium. In addition, presentations from this special symposium were videotaped and made available through NALMS as a three-DVD set. Since the special symposium in Madison, every NALMS meeting has included multiple session tracks on cyanobacteria and cyanotoxins, and they were the topic of the keynote address at the October 2007 meeting in Orlando, Florida.

The mission of NALMS is to forge partnerships among citizens, scientists, and professionals to foster the management and protection of lakes and reservoirs for today and tomorrow. NALMS is a unique society in that its members and leadership comprise diverse groups that have a common interest in the quality of lakes and as such, toxic cyanobacterial blooms are a topic of great concern. The annual NALMS meetings provide the unique opportunity for dialogue among these diverse groups. To seize this opportunity, round-table discussions have followed the formal sessions about cyanobacteria at three of the past four NALMS meetings. These discussions have provided the opportunity for citizens, resource managers, lake associations, local governments, scientists, and other professionals to share information and discuss research needs and ideas.

The NALMS position statement on toxic freshwater cyanobacterial blooms and the NALMS Blue-Green Initiative Webpage were a direct result of these discussions. The NALMS position statement, entitled "Toxic Cyanobacterial Blooms" (*Position Statement 8*, available online at http://www.nalms.org/resources/PDF/nalms_position_8_cyanobacteria.pdf) provides a concise summary of the issues and concerns relating to cyanotoxins and describes NALMS positions on cyanotoxins. The position statement is included in its entirety in this issue of *LakeLine* on page 13. The Webpage (http://www.nalms.org/Resources/BlueGreenInitiative/Overview.htm) provides basic information on cyanobacteria, conditions affecting blooms, cyanobacterial toxin and taste-and-odor compounds, human health effects, field sampling and analytical techniques, and links to other resources.

The November 2008 NALMS meeting at Lake Louise in Alberta, Canada featured an all-day session on cyanobacteria and cyanotoxins, with ten presentations covering a range of topics including occurrence and ecology, environmental factors influencing presence and concentration, methodology, and treatment. For the first time, a concurrent session was reserved for a formal discussion forum. Despite other presentations of interest, approximately 30 participants attended the discussion.

A wide range of topics were covered from general information on recent news and research to knowledge gaps and tools required to further the state of the science. The key focus of the discussion was how NALMS can better integrate and disseminate information to lake managers, policy makers, citizens, and other interested parties. This issue of *LakeLine*, the second devoted to cyanobacteria and cyanotoxins, is one result of the discussion. The discussion also resulted in four additional ideas that are being explored and developed:

1. Further development of the Blue-Green Initiative Web pages.
2. Writing a white paper describing the state of the science for cyanotoxins.
3. Working through the Policy and Government Affairs Committees to use our science and collective experience to assist those agencies working towards developing drinking-water and recreational guidelines for cyanotoxins.
4. Development of a user-driven North American occurrence database where cyanotoxin testing results and poisoning incidents could be reported.

It was the consensus of the group that the Blue-Green Initiative Webpage is a valuable resource, and that NALMS should continue to work on developing the Webpage and focus on the compilation and dissemination of the most up-to-date information on cyanobacterial toxins. The long-term vision for the Blue-Green Initiative Webpage is an Internet-based network where information about cyanotoxins, risk assessment, monitoring programs, and management options can be obtained and shared. Ultimately, the information content and utility of this Webpage will depend on the ideas and contributions of all NALMS members. Keep your eyes posted for requests for information, input, and feedback in NALMS Notes and *LakeLine* as NALMS continues to develop the Blue-Green Initiative Webpage. If you would like to be involved in the development of the Webpage or any of the other ideas discussed above, contact Ann St. Amand (astamand@phycotech.com). NALMS can always use more volunteers. Cyanobacteria and cyanotoxins will continue to be the focus of session tracks at future NALMS meetings, and another full day of presentations followed by a discussion forum is being planned for the October 2009 meeting in Hartford, Connecticut. We look forward to seeing all of you there!

Position Statement 8: Toxic Cyanobacterial Blooms

Toxin-producing cyanobacteria (commonly referred to as blue-green algae) are an emerging issue for lake managers throughout the world. Cyanotoxins have caused the death of domestic and wild animals and have been implicated in illness and even death in humans. They also have negative impacts on fish and other aquatic biota, and can have economic impacts on water uses and property values. Thus there is a critical need for objective scientific information regarding bloom occurrence and impacts, so that responsible agencies can set guidelines and limits where necessary to protect humans, livestock, pets and natural resources.

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 (overfertilization) of North America's surface waters has lead to the increasing frequency, duration and magnitude of toxic cyanobacterial blooms. Toxic blooms are difficult to treat safely due to the risk of liberating the toxins into the water.

Which cyanobacteria produce toxins and what types of toxins are produced?
Approximately 50 species of cyanobacteria have been shown to produce toxins that are harmful to vertebrates. Common bloom-forming species include members of the genera *Microcystis, Anabaena, Planktothrix (Oscillatoria), Cylindrospermopsis, Aphanizomenon, Plectonema (Lyngbya)* and *Nodularia*. All cyanobacterial toxins can affect humans. Cyanotoxins fall broadly into three groups: neurotoxins, hepatotoxins, and dermatoxins. 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 or risk data are limited. Hepatotoxins include microcystin (80+ variants), nodularin and cylindrospermopsin acting primarily on the liver and kidneys (as well as other organs). The most common dermatoxin is lyngbyatoxin produced by *Plectonema (Lyngbya) wollei*, primarily causing skin irritation, rashes and 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 may 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, although they are destroyed by strong oxidants like chlorine. Of these cyanotoxins, microcystin (-LR, -RR, -YR, -LA variants), cylindrospermopsin, and anatoxin-a

are on the US EPA Contaminant Candidate List (CCL2) and are currently being evaluated for risk in treated drinking water. Canada and several other countries have already established drinking water guidelines for microcystin-LR.

History and Threats Posed by Cyanotoxins

Toxic cyanobacterial blooms are not a new phenomenon. They have been documented for over 2,000 years dating back to ancient Rome. Initial increases in cyanobacterial blooms in North America coincided with European colonization of the continent, resulting in continued growth and development of population centers and substantial land use changes in watersheds and associated increases in nutrient export 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 toxin-producing cyanobacteria can remain viable for hundreds of years in the sediments, remaining as a "seed bank" to initiate cyanobacterial blooms.

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 cause blooms under ice which can result in the build-up of toxins, and blooms may persist through spring ice-out. Cyanobacteria may bloom all year long in tropical to sub-tropical regions, creating a persistent threat.

Most bloom-forming cyanobacteria (*Microcystis, Anabaena,* and *Aphanizomenon*) accumulate in characteristic scums that initially look like blue-green paint chips or slicks on the water surface, and can develop into bubbly masses up to a meter thick. Their color can range from yellows and browns to bright blue. Wind often concentrates these scums near boat docks or shores. However, not all toxin-producing cyanobacteria form scums. *Cylindrospermopsis* does 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 concentrations of microcystin.

Exposure routes to cyanobacterial toxins include ineffectively treated drinking water and casual recreational water contact from swimming, fishing, and water skiing. Recreational exposure includes skin contact, ingestion or inhalation. Children appear to be at greater risk, as a function of lower body mass and the way they play in the water, often ingesting water or playing with scums. Family pets (especially dogs) experience elevated risk, as they often consume the water intentionally. Human exposure can also occur via popular food supplements containing *Aphanizomenon flos-aquae* and *Spirulina* collected from lakes, which in some cases have been found to contain cyanotoxins. Animals exposed to potent toxic cyanobacterial blooms can die within minutes following ingestion. Effects on humans can be acute or chronic; deaths related to cyanobacterial toxins have occurred, and a number of chronic effects have been implicated but not yet adequately studied.

Most US states and Canadian provinces have documented toxic cyanobacterial blooms. Toxic cyanobacteria alerts are now routinely issued in those states (e.g., Minnesota, Nebraska, Iowa, Oregon) and provinces (e.g., Alberta and Manitoba) that have monitoring programs. Unfortunately, there is no standard program or approach for monitoring toxic cyanobacterial blooms, and most go undocumented.

Issues and Concerns Relating to Cyanotoxins

1. There are no US or Mexican policies and practices to deal with freshwater cyanobacterial blooms or toxins in drinking water supplies. In Canada, a federal drinking water guideline for microcystin-LR has been adopted by the provinces and territories.
2. North American countries have no federal recreational polices or practices regarding toxic blooms.
3. 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.
4. 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.
5. New toxins are being discovered, while known toxins still need to be fully characterized.
6. The public remains mostly ignorant of potential exposure routes for toxins present in cyanobacterial blooms.
7. Children, dogs, and livestock appear to be at greatest risk among terrestrial vertebrates. Chronic impacts seem more likely for adult humans, with a risk of carcinogenic and teratogenic effects, but deaths have occurred.
8. Almost all laboratory exposure data are based on mice and rats, with limited replication of complete studies, and few other appropriate mammalian models, restricting our knowledge of human impacts.
9. The human health, ecological, and economic impacts of toxic cyanobacterial blooms can be very high.

NALMS Positions on Cyanotoxins

1. NALMS supports international, national, provincial, and state efforts to monitor, control, and mitigate freshwater cyanobacterial blooms.
2. NALMS supports more research toward understanding the factors that control blooms and quantifying the effects of cyanotoxins on humans.
3. NALMS encourages and supports local efforts to protect lakes, and thereby limit cyanobacterial blooms. This includes public education, monitoring, and mitigation programs.
4. NALMS supports the development of scientifically supported and appropriately protective limits on the primary toxins in drinking and recreational waters (microcystins, anatoxin-a, cylindrospermopsin) at the national level.

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Jean Jacoby, Ph.D., is an associate dean in the College of Science & Engineering and a professor in the Department of Civil & Environmental Engineering at Seattle University. Her research emphasis has been on the causes and controls of nuisance and toxic algae in lakes and rivers. She is currently serving as the NALMS Region 10 Director (2006-2009) and an associate editor of *Lake & Reservoir Management* (1995-present).

Ann St. Amand has been involved in managing lakes across the United States since 1990, as President of PhycoTech, Inc. and is a Certified Lake Professional. St. Amand has processed over 27,000 algal and zooplankton samples in her career, and has co-chaired a workshop on Algal Identification at the annual NALMS symposium since 1991. She serves on various blue-green algae, water quality, and education committees both within and outside of NALMS.