FOCUS ON

# Cyanobacterial Toxins in Recreational Freshwater

**Published: June, 2025**

## Introduction

Cyanobacteria are a diverse group of photosynthetic bacteria that naturally occur in all types of surface water environments. While commonly known as blue-green algae, this can be considered a misnomer as they are not true algae and can also appear in a variety of colours including red, brown, yellow, and pink.[1–3]

Cyanobacteria can form dense blooms. The growth and development of blooms is influenced by chemical, physical, and biological factors. Blooms can occur under a wide range of environmental conditions. High nutrient availability (such as phosphorous and nitrogen from sewage, agricultural and industrial inputs), slow-moving or still waters, elevated temperatures (such as in late summer and early fall), high light intensity, and elevated pH can encourage the formation of blooms and subsequent production of cyanotoxins. Water quality can be impacted as blooms may increase turbidity, affect taste and odour, and may result in oxygen depletion of a water source.[1,3] Depending on the type of cyanobacteria, the release of toxins into water can occur during or at the end of a bloom event.[1,3]

Toxins can also remain in waters even after a bloom has dissipated and is no longer visible.[4] These toxins have the potential to harm human health.

The most commonly encountered cyanobacteria in Ontario between 1994 and 2019 belonged to the *Dolichospermum, Microcystis* and *Aphanizomenon* generas.[5] The cyanotoxin microcystin-LR (produced by the *Microcystis* genera of cyanobacteria) is the most commonly studied cyanotoxin and is considered by Health Canada to be the most important freshwater cyanotoxin.[3] Therefore, most of the material reviewed for this Focus On is related to microcystin-LR or other microcystins.

Cyanobacterial blooms have been increasing globally, due to the accumulation of nitrogen and phosphorus in aquatic systems and is likely exacerbated by climate change.[1,2] The frequency of blooms in Ontario has increased significantly since the 1990s, presenting an increased exposure and potential associated risk to those who use recreational waters.[6]

The objective of this Focus On is to provide information on the following questions:

1. What are the human health risks, both acute and chronic, from recreational exposure to cyanobacteria?
2. What are the recreational water guidelines for cyanobacteria?
3. How do local jurisdictions respond to cyanobacterial blooms and what public messaging strategies currently exist for mitigating health risks from cyanobacteria exposure in recreational freshwaters?

This document addresses exposures via recreational freshwater. Evidence related to human health risks following cyanobacteria exposure in drinking water are discussed in Public Health Ontario's Focus On: Cyanobacterial Toxins in Drinking Water.

# Key Findings

- Cyanobacteria, commonly known as blue-green algae, are naturally occurring bacteria that can form dense blooms in water, affecting water quality and potentially producing toxins that may be harmful to human health. The most studied cyanotoxin is Microcystin-LR.

- Health effects reported from short-term (i.e., acute) recreational exposures to cyanobacteria, such as occasional swimming in murky water, are generally mild and self-limiting. These include respiratory irritation, gastrointestinal symptoms, skin irritation, and hay fever-like symptoms. In rare cases (i.e., 3 case reports from outside Canada), exposures such as falling into water containing a high concentration of cyanotoxins were associated with pneumonia, hepatotoxicosis and death. Health effects from repeated and sustained (i.e., chronic) exposures are not well-studied.

- Recreational water guideline values and precautionary response measures can be used to inform public health responses to a bloom event. Health Canada has established a health-based guideline value of 10 µg/L for total microcystins in recreational waters. Indicator-based guideline values are also available for other cyanobacteria parameters to evaluate the potential presence of cyanobacterial toxins.

- While not all cyanobacterial blooms produce toxins, when toxins are present, they may persist weeks after a bloom has dissipated. Based on the potential persistance of cyanotoxins, visual inspection alone may not confirm the presence of cyanotoxins and additional laboratory analysis may be used to confirm the presence and concentration of cyanotoxins.

- Due to the complexity of managing cyanobacterial blooms, monitoring and sampling programs vary across jurisdictions. Programs include monitoring using visual inspection and/or sampling of water bodies that are prone to blooms or complaints, and providing warnings to the public.

- Short-term response measures in the event of a cyanobacteria bloom range from public notification (e.g., posting signage and issuing swimming advisories) to temporary closures of recreational waters. Long-term responses include nutrient management, altering water chemistry and manipulating aquatic food webs. Evidence on the effectiveness of these responses is limited.

# Methods

A scoping literature search was conducted in Medline, Embase, Scopus, and Environment Complete in December 2022. The search strategy was developed by PHO Library Services and included a combination of search terms including: microcystin, cyanotoxin, cyanobacteria, harmful algal bloom, water quality, recreation, swim, beach, freshwater, lake, river, pond, health, disease, illness, exposure, and toxicity. The searches returned 446 records; titles and abstracts were screened for relevance to human health effects and cyanobacteria in recreational freshwaters. Additional articles were identified from reference lists in articles that passed screening. A grey literature search was completed in January 2023 using the same combination of search terms entered into custom search engines (targeting public health resources) and Google. Information and references identified in the grey literature search were reviewed for relevance. The full search strategy for both searches and accompanying results are available upon request.

# Results

## Cyanotoxins of Concern

Over 20 different genera of cyanobacteria have been identified as capable of producing toxins, some of which may be a hazard to human health during recreational exposures.[7] There are many types of cyanotoxins including microcystins, nodularins, anatoxins, cylindrospermopsin, saxitoxins, dermatotoxins and others.[3,8]

Among the cyanotoxins encountered in freshwater environments, microcystins are the greatest concern due to their frequency of occurrence and their stability in the environment.[7,9] Most of the documented human and animal poisonings by cyanobacteria in freshwater have been attributed to exposure to microcystins.[3,10] There are more than 85 different variants of microcystins, of which microcystin-LR is often reported as a dominant variant in global literature and most well studied.[10] In Ontario, the most commonly encountered microcystin variants are microcystin-LR and microcystin-LA.[11]

The highest risk of exposure to cyanotoxins is when a bloom is present which indicates a high concentration of cyanobacteria. Some risk may exist even when a bloom has visually disappeared, as cyanotoxins may continue to persist for a period time.[2,3] The length of time cyanotoxins can persist is dependent on numerous factors (e.g., dilution rate, the type of toxin, rate of degradation).[3]

A summary of the known cyanotoxins of concern are presented in Table 1, including the associated health effects and potential for exposure in the Canadian context as presented in the Health Canada Guidelines for Canadian Recreational Water Quality – Cyanobacteria and their Toxins (Ontario specific information was not available).[3]

**Table 1: Summary of acute and chronic health effects of common cyanotoxins and the potential for exposure in Canada[2,3,11,12]**

| Cyanotoxin | Health Effects | Potential for exposure in Canada |
|---|---|---|
| Microcystins | • Headache, nausea, vomiting, diarrhea, abdominal pain, muscle aches, fever, mouth ulcers, blistering of lips, sore throat, skin rashes, ear and eye irritation.<br>• Some reports of typical pneumonia (canoeing soldiers from England), liver damage (jet skier in Argentina).<br>• No known human fatalities from exposure through recreational water activities.<br>• Based on animal studies: Chronic health effects of liver toxicity following oral exposure in rodents. Microcystin-LR is possibly carcinogenic to humans (classified by the International Agency for Research Cancer (IARC) as Group 2B). | Most frequently measured cyanotoxin in Canadian recreational waters.<br><br>Most common variant encountered in Ontario are microcystin-LR and microcystin-LA. |

| Cyanotoxin | Health Effects | Potential for exposure in Canada |
|---|---|---|
| Saxitoxins | • Documented human illnesses have been associated with the ingestion of saxitoxin-contaminated seafood rather than recreational water activities.<br>• No reported human illnesses from recreational water activities.<br>• Based on animal studies: neuromuscular paralysis, respiratory failure | Detected in Canadian freshwater sources (e.g. St. Lawrence River). |
| Cylindrospermopsin | • Vomiting, malaise, headache, constipation, bloody diarrhea, liver and kidney damage.<br>• No reported human fatalities. | Infrequent in temperate fresh waters; rarely detected in Canadian surface water sources. |
| Anatoxins | • One reported human fatality from ingestion of *Anabaena* during recreational water activities in Wisconsin.<br>• Based on animal studies: tremors, convulsions, death due to respiratory failure. | Measured far less frequently than microcystins (infrequently included in testing due to difficulty in testing as it rapidly degrades). |
| Nodularins | • Based on animal studies: similar to microcystins. | No recorded occurrences in Canadian waters. |
| Dermatotoxins and other irritant toxins | • Dermatitis. | Primarily produced by marine cyanobacteria, but can also be produced by some freshwater taxa (although not well characterized). |
| Cell-surface endotoxin - Lipopolysaccharides (LPS) | • Uncertainty around the role of cyanobacterial LPS and associated health effects.<br>• Irritant or allergenic response, fever.<br>• Less toxic than LPS in other gram-negative bacteria (e.g., *Salmonella*).<br>• At least partially responsible for non-specific irritative effects. | Insufficient evidence that recreational water constitutes a significant source of exposure. |
| B-methylamino-L-alanine (BMAA) | • Insufficient information. | Insufficient evidence that recreational water constitutes a significant source of exposure. |

## Acute Human Health Effects

Exposure to cyanobacteria and cyanobacterial toxins in recreational waters can occur through accidental ingestion, dermal contact, and inhalation of aerosolized particles during water sports.[3,13,14] Health effects following cyanobacteria exposure reported in the literature, including from swimming, water skiing, sailboarding, jet skiing, and fishing, are circumstantial with only a temporal and spatial correlation between health effects and cyanobacterial blooms.[12] As well, confounders, such as other pathogens or chemicals, were rarely controlled for. Most of the cases describe acute, minor, and self-limiting effects such as hay fever-like symptoms, respiratory irritation, gastrointestinal symptoms, and skin irritation.[12]

Within Canada, Wood reviewed anecdotal and case reports on acute health illnesses in both animals and humans from exposure to cyanotoxins in fresh and brackish waters.[12] Wood identified six incidents of human morbidity between the years 1800 and 2010 associated with acute exposure to cyanotoxins; no deaths were reported.[12] All incidents occurred in Saskatchewan between 1959 and 1960, and were related to swimming. Each incident involved 1 to 10 cases (n=18 total) with five of the incidents (n=17) resulting in minor and self-resolving symptoms, primarily non-specific symptoms such as malaise and headache or gastrointestinal symptoms involving nausea, vomiting, diarrhea, and stomach cramps.[15] The sixth incident involved a male child who developed pneumonia and lost consciousness after swimming in a water hole with abundant cyanobacteria, but upon clinical examination his pneumonia was attributed to a bacterium.[12]

While rare, there are case reports of more serious acute health effects outside Canada. Three reports in Wood's review describe serious acute illnesses associated with recreational water exposure:[12] two cases of pneumonia with negative bacterial and viral tests after exposure to a water body in England where microcystin-LR was present (detected in water samples);[16] one case of pneumonia and hepatotoxicosis requiring intensive care after a jet skier fell and was immersed in a bloom where water samples reported high levels of microcystin-LR (48.6 µg/L) in Argentina;[17] and one fatality in a teenager likely due to anatoxin after swimming in an algae-scum covered pond in Wisconsin (the fatality was attributed to anatoxin by the coroner based on the toxin and toxin-producing cyanobacteria being detected in stool samples and stomach contents).[12,18]

The United States Harmful Algal Bloom-related Illness Surveillance System (HABISS) identified 176 case reports between 2007 and 2011 of human illnesses associated with exposures to cyanobacteria or algae associated with freshwater of which 157 cases were linked to recreational activities such as swimming, using personal water craft, or boating.[19] No fatalities were reported, and the primary symptoms reported were dermatologic (rash, itching, or blisters) and gastrointestinal (nausea and vomiting). Neurologic effects such as weakness and confusion and general symptoms such as fever were uncommon. The HABISS program was renamed the One Health Harmful Algal Bloom System (OHHABS) in 2011. Between 2016 and 2020, a total of 447 case reports of human illnesses reported from 18 states were captured OHHABS.[20–22] This represents an average of 111.8 human case reports per year over the four year period. Reporting to OHHABS is done voluntarily by individual state health departments and the number of participating states change slightly from year to year. Of the states bordering the Great Lakes region, participating states include Minnesota, Wisconsin, Michigan, Illinois, Ohio and Pennsylvania. Both HABISS and OHHABS do not differentiate between types of exposure to cyanotoxins (e.g., recreational water exposures versus drinking water exposures). However, based on the most recent information available from 2020, bloom-related illnesses were predominately linked to exposures at public outdoor areas (38% of reports) and beaches (30% of reports).[21]

In Australia, swimmers were surveyed and water samples analyzed as part of a 1995 prospective study on acute health effects related to cyanobacteria. Symptoms were shown to increase with cyanobacterial density and duration of water contact, but not cyanotoxin concentrations. A higher rate of symptoms was found in participants who were exposed to 5,000 cells/mL for one hour, compared to unexposed participants. Symptoms most commonly recorded were cold and flu symptoms.[23] A 2014 prospective study in Quebec on the incidence of potential symptoms associated with exposure to cyanobacteria and microcystin included eye, ear, respiratory, gastrointestinal, skin, muscle pain, headaches, and mouth ulcers. Of these symptoms, only gastrointestinal symptoms were associated with recreational contact; higher relative risk (RR) associated with higher cyanobacterial cell counts (20,000-100,000 cells/mL: RR=2.71; >100,000 cells/mL: RR=3.28).[24] No participants with symptoms in this study sought medical care. Cross-sectional studies in the United Kingdom showed no statistically significant findings for those exposed to cyanobacterial blooms compared to those unexposed.[25] In a systematic review of reports related to recreational exposure to cyanobacterial blooms and related illnesses, children were involved in the majority (80%) of cases. The authors noted that children are more sensitive to toxins from freshwater harmful algal blooms (due to their smaller size, body weight and developmental stage) and exposure is more likely due to normal risk-taking behaviours.[18]

## Chronic Human Health Effects

While animal studies have shown toxic effects from repeated dosing of microcystins, there are no data on chronic health effects in humans from recreational exposures.[26]

The International Agency for Research on Cancer (IARC) has classified microcystin-LR as a group 2B carcinogen (possibly carcinogenic to humans) based on strong evidence supporting a tumour promoting mechanism in rodents, but inadequate evidence in humans.[27] Health Canada has stated that further research is required to understand the potential carcinogencity of microcystins based on weak and contradictory results in human epidemiological studies and experimental animal studies.[7]

Non-cancer chronic health effects are seen in animal studies with exposure to microcystins. A 13-week study with mice showed gross and microscopic liver pathology and changes in blood chemistry.[28] A 28-day study with rats showed an increase in liver weight, elevation of serum liver enzymes, and evidence of liver damage on histopathology.[29] Data in humans are limited, but acute liver failure was seen in patients exposed to microcystins from contaminated dialysis fluid at a clinic in Caruara, Brazil in 1996.[12, 30]

# Recreational Water Guidelines for Cyanobacteria

Health Canada established guideline values intended to protect public health while avoiding unnecessary closure of recreational areas.[3] The guidelines for recreational waters consist of two parts: a health-based guideline value that reflects a direct measure of cyanotoxins in water, and indicators for the potential presence of cyanobacterial toxins (summarized in Table 2 below).

The indicator values are derived based on the relationship between cyanobacteria biomass and total microcystins using conservative assumptions and may be modified where site-specific information is available. The inclusion of multiple guidelines by Health Canada are intended to offer flexibility in how responsible authorities can manage cyanobacteria in their jurisdiction.[3]

**Table 2: Health Canada's recommended health-based guideline values for microcystins and general indicators of the potential for cyanobacterial bloom development in recreational waters[3]**

| Guideline or Indicator | Value | Considerations |
|---|---|---|
| **Health-based guideline:** Total microcystins | 10 μg/L | • Microcystin-LR lowest observed adverse effect level (LOAEL) of 50 μg/kg body weight per day, based on increased liver weight and slight to moderate liver lesions with hemorrhages in rats with application of an uncertainty factor of 900[29]<br>• Based on toxicity of microcystin-LR but intended to protect against exposure to other microcystin variants and cyanobacterial material based on estimated recreational exposures for children who spend more time in water than adults and are more likely to accidentally swallow water |
| **Indicator**: Total cyanobacteria cells | 50,000 cells/mL | • Cyanobacteria cell density resulting in total microcystin level of 10 μg/L based on average toxin produced by a single *Microcystis* cell |
| **Indicator**: Cyanobacteria biovolume | 4.5 $mm^3$/L | • Cyanobacterial biovolume is calculated using guideline for total cyanobacteria cells based on average cell volume of *Microcystis* cells |
| **Indicator**: Chlorophyll a | 33 μg/L | • Total chlorophyll a is calculated based on the observed ratio between microcystin and chlorophyll a in blooms.<br>• This ratio can be highly variable based on environmental conditions. This indicator is intended to be used as part of a cyanobacteria alert system to trigger further investigation and actions |

There are insufficient data for Health Canada to develop a guideline for protection from allergenic and irritative effects of cyanobacteria, as studies have not shown a consistent dose-response relationship or thresholds for irritation.[3] Evidence to derive recreational water guidelines for other cyanobacterial toxins is also considered insufficient by Health Canada.[3] Other jurisdictions have set guideline values for recreational exposure to other cyanotoxins. For instance, the United States Environmental Protection Agency (US EPA) set guideline values for cylindrospermopsin, and the state of Oregon has set values for microcystin, saxitoxin, anatoxin-a, and cynlindrospermopsin.[3,31–33]

The World Health Organization (WHO) set provisional health-based recreational water guideline for total microcystins at 24 µg/L.[34] Indicator values for cyanobacteria biovolume (8 $mm^3$/L) and chlorophyll a (24 µg/L) are also used in their alert level framework approach for early warning and to trigger short-term management responses.

# Managing cyanobacterial blooms

Cyanobacterial blooms generally occur in the late summer months, as the optimal growth temperature for all species is above 15°C. The most prevalent toxic species grow optimally at temperatures above 25°C.[15] Cyanobacterial blooms can be difficult to predict.[3] A further challenge is that not all cyanobacterial blooms produce toxins, although more than half of cyanobacterial blooms sampled globally tested positive for toxins. As visual inspection alone does not accurately assess the presence of toxins, laboratory analysis can help confirm the presence of toxins.

## Monitoring and Sampling Programs

A 2016 review of Canadian and US monitoring programs noted that there are "no standard practices for bloom monitoring and assessment, and due to limited capacity, agencies often carry out sampling on a reactive basis in response to public complaints".[10] Within the literature reviewed, no studies were found that examined optimal frequency of monitoring and sampling. As well, no studies were found that evaluated monitoring and sampling programs for reduced harms to human health.

Health Canada recommends monitoring priority areas where the body of water is more likely to form blooms and can be a source of human exposure. The frequency of monitoring can vary (e.g., weekly or bi-weekly) as appropriate, and parameters for monitoring may include visual monitoring and examining indicators and toxins.[3]

Cyanobacterial blooms can be reported to the Ontario Ministry of the Environment, Conservation and Parks (MECP) via their Spills Action Centre. The MECP has the ability to collect and analyze water samples to confirm reported cyanobacterial blooms as part of a complaints-based sampling program.[35] Results of these analyses are reported to drinking water system owner/operators, public health units and local Medical Officers of Health which is then followed by a collaborative effort to manage harmful algal blooms.[35]

The *Ontario Public Health Standards* outline requirements for recreational public beach water monitoring and bacteriological sampling in the *Operational Approaches for Recreational Water Guideline, 2018* and the *Recreational Water Protocol, 2019*.[36,37] The proactive component requires seasonal program planning to confirm the inventory of public beaches to establish a monitoring season and to document public beaches that are prone to algal blooms. The reactive component requires surveillance, where complaints or reports of adverse events related to recreational water use at public beaches (which includes cyanobacterial blooms) are to be assessed within 24 hours. The *Recreational Water Protocol* specifies the surveillance of public beaches once a week at a minimum, with variations in frequency based on a site risk assessment, while recreational camp waterfronts are to be inspected annually.[36] Monitoring for areas prone to algal blooms, occurs during these surveillance visits. The *Recreational Water Protocol* also includes a requirement for public health units to disclose results from surveillance visits for public beaches on their website in a location easily accessible to the public. Included in these reports is the public beach status (e.g., safe for swimming, precautionary, unsafe for swimming) which can include information on cyanobacterial bloom observations.

## Response Measures

Health Canada's Guidelines for Canadian Recreational Water Quality note that a swimming advisory may be issued at the discretion of the responsible authority if guideline values are exceeded, or if a cyanobacterial bloom has developed in a waterbody.[3] Water advisories should remain in place until as specified in a site's cyanobacterial management plan. The duration of an active notification can last until testing shows that the cyanobacteria toxin concentration is below the guideline value; in situations where follow-up testing is unavailable the notification/swimming advisory can be displayed for an entire season as a precautionary measure.[3]

In Ontario and globally, response measures vary from monitoring to permanent signage warning about the potential for cyanobacterial blooms, to temporary closures of recreational waters during a bloom. The framework on cyanobacteria monitoring and response in the 2021 WHO Recreational Water Guideline begins with pre-screening water-bodies followed by visual or laboratory analysis of the site.[13] The affected site is assigned a level (e.g. vigilance, alert level 1, alert level 2) with actionable responses.[13]

Previous response measures in other jurisdictions are included in a 2017 review that compares response measures in European countries, Australia, and New Zealand.[38] All reviewed countries had a three-tiered response, which generally progressed from routine monitoring to warnings to restrictions based on limit values.[39] Variability in approaches to monitoring and responding to cyanobacterial blooms globally reflects differences in perception, acceptance of risk and resources devoted to this issue.[39]

Long-term responses to cyanobacterial blooms include nutrient management, addition of phosphorus-binding clays, sediment removal, capping lake sediments, artificial mixing, and manipulating aquatic food webs.[1,40]

## Public Messaging

According to Health Canada and the US EPA, public notification of cyanobacterial blooms should include key information such as:[3,41]

- Key message – closure or warning being issued or lifted
- List of approved (e.g., boating, canoeing, kayaking) and unsafe activities (e.g., swimming, wading, fishing)
- Reason, duration and cause for notification (e.g. high levels of cyanobacteria or cyanotoxins)
- Location of recreational area affected by the notification
- Potential consequences of contact with affected area (e.g., gastrointestinal irritation)
- Actions being taken to monitor the bloom
- Contact information for additional information

The results of a jurisdictional scan on risk messaging for cyanobacteria in Canada, the US, and other international jurisdictions are summarized in Appendix A, Table 3.[41,42] The evidence base for these messages was not publicly available. The risk messages used have not been evaluated for their effectiveness to protect against all cyanobacterial-related adverse health effects or their possible negative impact in unduly restricting opportunities for water-related physical activity. However, a review on the health effects of cyanobacteria in children noted that education and signs warning of the possible presence of cyanobacteria or cyanotoxins may be less effective when compared to adults in reducing illnesses in recreational settings due to normal risk-taking behaviours among children and teenagers.[18]

# Conclusions

While cyanobacterial blooms are increasing in frequency and intensity, the most common health effects from recreational exposures are generally self-limiting and mild. For example, hay-fever like symptoms, respiratory irritation, skin irritation, and acute gastrointestinal health effects have been reported.[12] Globally, there are individual case reports of serious illness and the potential for chronic effects associated with exposure to high levels of cyanobacterial toxins.

In Ontario, protocols for recreational beach monitoring involves a proactive and reactive approach and regular surveillance of public beaches (weekly) and recreational camp waterfronts (annually). Suspected blooms observed during public beach surveillance can be reported to the MECP via their Spills Action Centre.

Exposure to cyanobacteria in recreational waters can be mitigated through strategies such as swimming advisories and signage for water bodies that exceed guideline values for total microcystins and/or cyanobacterial indicators.[3] No studies were identified that evaluated the impact of public messaging for cyanobacterial blooms. This presents a challenge in developing evidence-based programs, as the extent to which the variety of monitoring and response methods reduce health harms is not known.

# References

1. Huisman J, Codd GA, Paerl HW, Ibelings BW, Verspagen JMH, Visser PM. Cyanobacterial blooms. Nat Rev Microbiol. 2018;16:471-83. Available from: https://doi.org/10.1038/s41579-018-0040-1

2. Chorus I, Welker M, editors. Toxic cyanobacteria in water: a guide to their public health consequences, monitoring and management [Internet]. 2nd ed. London: World Health Organization; 2021 [cited 2023 Jan 23]. 858 p. Available from: https://www.who.int/publications/m/item/toxic-cyanobacteria-in-water---second-edition

3. Health Canada. Guidelines for Canadian recreational water quality - cyanobacteria and their toxins [Internet]. Ottawa, ON: Government of Canada; 2022 [cited 2023 Jan 19]. Available from: https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidance-canadian-recreational-water-quality-cyanobacteria-toxins.html

4. Centers for Disease Control and Prevention (CDC). Facts about cyanobacterial blooms for poison center professionals [Internet]. Atlanta, GA: CDC; 2022 [cited 2023 Jan 3]. Available from: https://www.cdc.gov/habs/materials/factsheet-cyanobacterial-habs.html

5. Favot EJ, Holeton C, DeSellas AM, Paterson AM. Cyanobacterial blooms in Ontario, Canada: continued increase in reports through the 21st century. Lake Reserv Manag. 2023 Jan 2;39(1):1-20. Available from: https://doi.org/10.1080/10402381.2022.2157781

6. Pick FR. Blooming algae: a Canadian perspective on the rise of toxic cyanobacteria. Can J Fish Aquat Sci. 2016;73(7):1149-58. Available from: https://doi.org/10.1139/cjfas-2015-0470

7. Health Canada. Guidelines for Canadian drinking water quality: guideline technical document – cyanobacterial toxins [Internet]. Ottawa, ON: Government of Canada; 2018 [cited 2022 Nov 17]. Available from: https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidelines-canadian-drinking-water-quality-guideline-technical-document-cyanobacterial-toxins-document.html

8. Rastogi RP, Sinha RP. The cyanotoxin-microcystins: current overview. Rev Environ Sci Biotechnol. 2014;13:215-49. Available from: https://doi.org/10.1007/s11157-014-9334-6

9. Massey IY, Al osman M, Yang F. An overview on cyanobacterial blooms and toxins production: their occurrence and influencing factors. Toxin Rev. 2022;41(1):326-46. Available from: https://doi.org/10.1080/15569543.2020.1843060

10. Carmichael WW, Boyer GL. Health impacts from cyanobacteria harmful algae blooms: implications for the North American Great Lakes. Harmful Algae. 2016;54:194-212. Available from: https://doi.org/10.1016/j.hal.2016.02.002

11. Taranu Z, Pick F, Creed I, Zastepa A, Watson S. Meteorological and nutrient conditions influence microcystin congeners in freshwaters. Toxins. 2019;11(11):620. Available from: https://doi.org/10.3390/toxins11110620

12. Wood R. Acute animal and human poisonings from cyanotoxin exposure — a review of the literature. Environ Int. 2016;91:276-82. Available from: https://doi.org/10.1016/j.envint.2016.02.026

13. World Health Organization (WHO). WHO guidelines on recreational water quality: volume 1: coastal and fresh waters [Internet]. Geneva: WHO; 2021 [cited 2023 Jan 13]. xxii, 138 p. Available from: https://apps.who.int/iris/handle/10665/342625

14. United States. Environmental Protection Agency (EPA). Exposure to CyanoHABs [Internet]. New York, NY: EPA; 2018 [cited 2023 Jan 23]. Available from: https://www.epa.gov/cyanohabs/exposure-cyanohabs

15. Dillenberg HO, Dehnel MK. Toxic waterbloom in Saskatchewan, 1959. Can Med Assoc J. 1960;83(22):1151-4.

16. Turner PC, Gammie AJ, Hollinrake K, Codd GA. Pneumonia associated with contact with cyanobacteria. BMJ. 1990;300(6737):1440-1. Available from: https://doi.org/10.1136/bmj.300.6737.1440

17. Giannuzzi L, Sedan D, Echenique R, Andrinolo D. An acute case of intoxication with cyanobacteria and cyanotoxins in recreational water in Salto Grande Dam, Argentina. Mar Drugs. 2011;9(11):2164-75. Available from: https://doi.org/10.3390/md9112164

18. Weirich CA, Miller TR. Freshwater harmful algal blooms: toxins and children's health. Curr Probl Pediatr Adolesc Health Care. 2014;44(1):2-24. Available from: https://doi.org/10.1016/j.cppeds.2013.10.007

19. Backer LC, Manassaram-Baptiste D, LePrell R, Bolton B. Cyanobacteria and algae blooms: review of health and environmental data from the Harmful Algal Bloom-related Illness Surveillance System (HABISS) 2007–2011. Toxins. 2015;7(4):1048-64. Available from: https://doi.org/10.3390/toxins7041048

20. Roberts VA, Vigar M, Backer L. Surveillance for harmful algal bloom events and associated human and animal illnesses — One Health Harmful Algal Bloom System, United States, 2016–2018. MMWR Morb Mortal Wkly Rep. 2020;69(50):1889-94. Available from: https://www.cdc.gov/mmwr/volumes/69/wr/mm6950a2.htm?s_cid=mm6950a2_w

21. Centers for Disease Control and Prevention (CDC). Summary report – One Health Harmful Algal Bloom System (OHHABS), United States, 2020 [Internet]. Atlanta, GA: CDC; 2022 [cited 2023 Mar 21]. Available from: https://www.cdc.gov/habs/data/2020-ohhabs-data-summary.html

22. Centers for Disease Control and Prevention (CDC). Summary report – One Health Harmful Algal Bloom System (OHHABS), United States, 2019 [Internet]. Atlanta, GA: CDC; 2022 [cited 2023 Mar 21]. Available from: https://www.cdc.gov/habs/data/2019-ohhabs-data-summary.html

23. Pilotto LS, Douglas RM, Burch MD, Cameron S, Beers M, Rouch GJ, et al. Health effects of exposure to cyanobacteria (blue–green algae) during recreational water–related activities. Aust N Z J Public Health. 1997;21(6):562-6. Available from: https://doi.org/10.1111/j.1467-842X.1997.tb01755.x

24. Lévesque B, Gervais MC, Chevalier P, Gauvin D, Anassour-Laouan-Sidi E, Gingras S, et al. Prospective study of acute health effects in relation to exposure to cyanobacteria. Sci Total Environ. 2014;466-467:397-403. Available from: https://doi.org/10.1016/j.scitotenv.2013.07.045

25. Stewart I, Webb PM, Schluter PJ, Shaw GR. Recreational and occupational field exposure to freshwater cyanobacteria – a review of anecdotal and case reports, epidemiological studies and the challenges for epidemiologic assessment. Environ Health. 2006;5(1):6. Available from: https://doi.org/10.1186/1476-069X-5-6

26. Otten TG, Paerl HW. Health effects of toxic cyanobacteria in U.S. drinking and recreational waters: our current understanding and proposed direction. Curr Environ Health Rep. 2015;2(1):75-84. Available from: https://doi.org/10.1007/s40572-014-0041-9

27. International Agency for Research on Cancer (IARC); World Health Organization (WHO). IARC monographs on the evaluation of carcinogenic risk to humans: volume 94 ingested nitrate and nitrite, and cyanobacterial peptide toxins [Internet]. Lyon: IARC; 2010 [cited 2022 Nov 17]. Available from: https://monographs.iarc.who.int/wp-content/uploads/2018/06/mono94.pdf

28. Fawell JK, Mitchell RE, Everett DJ, Hill RE. The toxicity of cyanobacterial toxins in the mouse: I microcystin-LR. Hum Exp Toxicol. 1999;18(3):162-7. Available from: https://doi.org/10.1177/096032719901800305

29. Heinze R. Toxicity of the cyanobacterial toxin microcystin-LR to rats after 28 days intake with the drinking water. Environ Toxicol. 1999;14(1):57-60. Available from: https://doi.org/10.1002/(SICI)1522-7278(199902)14:1%3c57::AID-TOX9%3e3.0.CO;2-J

30. Falconer I, Humpage A. Health risk assessment of cyanobacterial (blue-green algal) toxins in drinking water. Int J Environ Res Public Health. 2005;2(1):43-50. Available from: https://doi.org/10.3390/ijerph2005010043

31. Farrer D, Counter M, Hillwig R, Cude C. Health-based cyanotoxin guideline values allow for cyanotoxin-based monitoring and efficient public health response to cyanobacterial blooms. Toxins. 2015;7(2):457-77. Available from: https://doi.org/10.3390/toxins7020457

32. United States. Environmental Protection Agency (EPA). Recommended human health recreational ambient water quality criteria or swimming advisories for microcystins and cylindrospermopsin. [Internet]. New York, NY: EPA; 2019 [cited 2023 Apr 11]. Available from: https://www.epa.gov/sites/default/files/2019-05/documents/hh-rec-criteria-habs-document-2019.pdf

33. Oregon Health Authority. Oregon harmful algae bloom surveillance (HABS) program: recreational use public health advisory guidelines - cyanobacterial blooms in freshwater bodies. [Internet]. Salem, OR: Oregon Health Authority; 2019 [cited 2023 Apr 11]. Available from: https://www.oregon.gov/oha/PH/HEALTHYENVIRONMENTS/RECREATION/HARMFULALGAEBLOOMS/Documents/Advisory-Guidelines-Harmful-Cyanobacterial-Blooms-Recreational-Waters.pdf

34. World Health Organization (WHO). Cyanobacterial toxins: microcystins [Internet]. Geneva: WHO; 2020 [cited 2022 Nov 17]. Available from: https://apps.who.int/iris/bitstream/handle/10665/338066/WHO-HEP-ECH-WSH-2020.6-eng.pdf

35. Ontario. Ministry of the Environment, Conservation and Parks. Blue-green algae [Internet]. Toronto, ON: King's Printer for Ontario; 2022 [cited 2022 Nov 17]. Available from: http://www.ontario.ca/page/blue-green-algae

36. Ontario. Ministry of Health and Long-Term Care. Recreational water protocol, 2019 [Internet]. Toronto, ON: Queen's Printer for Ontario; 2019 [cited 2022 Aug 9]. Available from: https://www.health.gov.on.ca/en/pro/programs/publichealth/oph_standards/docs/protocols_guidelines/Recreational_Water%20Protocol_2019_en.pdf

37. Ontario. Ministry of Health and Long-Term Care. Operational approaches for recreational water guideline, 2018 [Internet]. Toronto, ON: Queen's Printer for Ontario; 2018 [cited 2018 Oct 10]. Available from: https://health.gov.on.ca/en/pro/programs/publichealth/oph_standards/docs/protocols_guidelines/Operational_Approaches_to_Rec_Water_Guideline_2018_en.pdf

38. Funari E, Manganelli M, Buratti FM, Testai E. Cyanobacteria blooms in water: Italian guidelines to assess and manage the risk associated to bathing and recreational activities. Sci Total Environ. 2017;598:867-80. Available from: https://doi.org/10.1016/j.scitotenv.2017.03.232

39. Ibelings BW, Backer LC, Kardinaal WEA, Chorus I. Current approaches to cyanotoxin risk assessment and risk management around the globe. Harmful Algae. 2014;40:63-74. Available from: https://doi.org/10.1016/j.hal.2014.10.002

40. Ibelings BW, Kurmayer R, Azevedo SMFO, Wood SA, Chorus I, Welker M. Understanding the occurrence of cyanobacteria and cyanotoxins. In: Chorus I, Welker M, editors. Toxic Cyanobacteria in Water. 2nd ed. Boca Raton, FL: CRC Press; 2021. Available from: https://www.taylorfrancis.com/chapters/oa-edit/10.1201/9781003081449-4/understanding-occurrence-cyanobacteria-cyanotoxins-bastiaan-ibelings-rainer-kurmayer-sandra-azevedo-susanna-wood-ingrid-chorus-martin-welker

41. United States. Environmental Protection Agency (EPA). Communicating about cyanobacterial blooms and toxins in recreational waters [Internet]. New York, NY: EPA; 2022 [cited 2023 Jan 25]. Available from: https://www.epa.gov/cyanohabs/communicating-about-cyanobacterial-blooms-and-toxins-recreational-waters

42. Chung R, Leung A, Copes R. Cyanobacteria: understanding the toxicology to communicate risks and support decision-making. Poster presented at: The Ontario Public Health Convention. 2019 Mar 27; Toronto, ON.

43. Windsor-Essex County Health Unit. Blue-green algae bloom [Internet]. Windsor, ON: Windsor-Essex County Health Unit; 2015 [cited 2023 Jan 18]. Available from: https://www.wechu.org/drinking-water-small-drinking-water-systems-beaches-pools-and-spas/blue-green-algae-bloom

44. Wilson P. Blue-green algae found in Lake Nosbonsing [Internet]. North Bay Nugget [Internet], 2018 Aug 13 [cited 2022 Nov 21]; Local News. Available from: https://nugget.ca/news/local-news/blue-green-algae-found-in-lake-nosbonsing

45. Timiskaming Health Unit. Blue-green algae bloom [Internet]. New Liskeard, ON: Timiskaming Health Unit; 2021 [cited 2023 Jan 18]. Available from: https://timiskaminghu.com/351/blue-green-algae-bloom

# Appendix A – Sample Public Messaging

This appendix includes sample public messaging specific to cyanobacteria in recreational freshwater, which were developed by Health Canada and O Public Health Units in Ontario. The risk messages used have not been evaluated in terms of their effectiveness to protect against all cyanobacterial-related adverse health effects or their possible negative impact in unduly restricting opportunities for water-related physical activity.

Public messaging used by Health Canada and public health units include a combination of themes summarized in Table 3. Clear visuals on the signs are used to warn recreational water users of risks and precautions.[43,44]

**Table 3: - Select risk messaging examples for cyanobacteria[3,41,42]**

| Risk Messaging Themes | Select Risk Messaging Examples |
|---|---|
| Awareness | • All persons are warned that potentially toxic cyanobacteria are present in this water body and may affect the health of persons and animals coming into contact with the water.<br>• Avoid entering or playing in bodies of water that:<br>  ◦ smell bad<br>  ◦ look discolored (e.g. greenish/bluish tinge)<br>  ◦ have foam, scum, or algal mats on the surface<br>  ◦ contain or are near dead fish or other dead animals |
| Advisory and Restrictions | • People are discouraged from having full body contact with water (e.g., swimming, wading, skiing, etc.) or allowing pets to drink or swim in the water; however, boating and fishing are permitted.<br>• Anyone who comes in contact with blue-green algae should rinse themselves off with fresh water, as well as any items that may have come into contact with the cyanobacterial material, as soon as is practical upon exiting the water.<br>• Livestock should not contact or ingest the water. |
| Symptoms | • Exposure to blue-green algae may cause nausea, sore throats, vomiting, diarrhea or abdominal pain and/or fever in humans and pets.<br>• Swimming, sailing, water skiing, or any other activity involving body contact with the water may cause skin and eye irritation.<br>• Drinking or accidentally swallowing water may result in illness.<br>• If experiencing adverse health effects from recreational water activity, consult a medical professional and, if necessary, alert the appropriate local public health authorities. |
| Fish Consumption | • Toxins can accumulate in the internal organs of fish and shellfish. Remove the internal organs of fish before cooking and avoid eating shellfish. |
| Water Use | • If water from the lake is used for irrigation, people should avoid the spray, thoroughly wash fruits or vegetables in clean water, and not allow livestock to drink irrigation water.<br>• Do not boil or treat the water with bleach, disinfectant prior to use.[43,45] |

# Citation

Ontario Agency for Health Protection and Promotion (Public Health Ontario). Cyanobacterial toxins in recreational freshwater. Toronto, ON: King's Printer for Ontario; 2025.


# Acknowledgements

The authors wish to express their sincere appreciation to our colleagues at Simcoe Muskoka District Health Unit, York Region Public Health, and the Ministry of the Environment Conservation and Parks for their peer review.


# Disclaimer

This document was developed by Public Health Ontario (PHO). PHO provides scientific and technical advice to Ontario's government, public health organizations and health care providers. PHO's work is guided by the current best available evidence at the time of publication. The application and use of this document is the responsibility of the user. PHO assumes no liability resulting from any such application or use. This document may be reproduced without permission for non-commercial purposes only and provided that appropriate credit is given to PHO. No changes and/or modifications may be made to this document without express written permission from PHO.

# Public Health Ontario

Public Health Ontario is an agency of the Government of Ontario dedicated to protecting and promoting the health of all Ontarians and reducing inequities in health. Public Health Ontario links public health practitioners, front-line health workers and researchers to the best scientific intelligence and knowledge from around the world.

For more information about PHO, visit: publichealthontario.ca.

Ontario