Virginia Recreational Water Guidance for Microcystin and Microcystis Blooms

Provisional Guidance

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Table of Contents

List of Tables

Executive Summary

Blue-green algae, or cyanobacteria, are capable of producing several types of toxins. *Microcystis aeruginosa* is the primary algal species responsible for producing microcystin, a known liver toxin. Microcystin exposure can cause illness in people, companion animals, horses, and livestock. This document is intended to provide guidance to public health and environmental officials responding to the occurrence of a *Microcystis* algal bloom in Virginia's waters. This effort focuses on recreational exposure, which includes activities such as swimming, kayaking, wind surfing, jet skiing, and water skiing.

The Virginia Department of Health (VDH) recommends using a combination of cell counts and toxin concentrations to guide public health decision-making during harmful algal bloom events in recreational waters. When toxin results are not available, cell concentrations and other water quality parameters may be used to aid public health and environmental sampling decisions. The framework for managing toxic or potentially toxic *Microcystis* blooms in recreational water should be guided by a three-tiered approach:

5,000 to <20,000 *Microcystis* cells/mL	➢ Local agency notification; initiate bi-weekly water sampling
20,000 to 100,000 *Microcystis* cells/mL	➢ Public notification indicating a harmful algal bloom is present in recreational water; initiate weekly sampling
> 100,000 *Microcystis* cells /mL, or **> 6 *µg/L* microcystin concentration, or** **Blue-green algal "scum" or "mats" on water surface**	➢ Immediate public notification to avoid all recreational water contact where bloom is present; continue weekly sampling

More information on the three-tiered framework for managing *Microcystis* blooms is provided herein.

Note: This guidance document describes water monitoring and notification aspects to consider during a specific type of algal bloom event in recreational water. It is not a regulatory document and is not enforceable by state law.

Background

Microcystis aeruginosa is a single-celled cyanobacterium (blue-green algae) that is found in fresh and brackish waters world-wide (Graneli and Turner 2006). *M. aeruginosa*, other *Microcystis* species, and some other cyanobacteria, are capable of producing a liver toxin called microcystin. Cyanobacteria are more likely to appear during the summer months, as water temperatures increase, and to a lesser extent, the availability of nutrients such as phosphorous and nitrogen, support rapid growth. Water that appears to be green or water with green scum forming at the surface of the water is often indicative of a cyanobacterial "bloom" where microcystin may be present. The concentrations of microcystin in the water can vary during and after a bloom event. In Virginia, extensive *Microcystis* blooms have occurred in brackish (low salinity) portions of the Potomac River during the summers of 2004 and 2011. However, *Microcystis* is likely present during summer months in many other freshwater and brackish water bodies throughout the state.

Human exposure to microcystin can occur through ingestion, dermal contact or inhalation. There have been no reports to health officials of *Microcystis* or microcystin-related illnesses in Virginia. However, there have been reports of dog deaths attributed to ingestion of microcystin in neighboring states and reports of microcystin-related human illness in Australia, Canada, and some U.S. states. Companion animals, particularly dogs, should also be discouraged from making contact with recreational water during algal bloom events.

This document outlines recommended public health protection measures to be undertaken when *Microcystis* blooms occur in Virginia's recreational waters. To prevent microcystin-related illness, public health recommendations rely on a combination of routine water quality monitoring, evaluation of toxin concentrations, and consideration of *Microcystis* cell concentrations in water.

Microcystin Toxicity

Cyanobacteria can produce microcystin, which is a term that describes a toxin complex of over 80 related variations (Song et al. 2007). Microcystin variants are distinguished by amino acid substitutions at fixed points in the microcystin molecule (Watanabe et al. 1996); most toxicological data exist for a variant known as microcystin-LR, which is also the most common microcystin (WHO 1999). Both acute and chronic exposures to microcystin can pose a health risk. Microcystin is a hepatotoxin that causes liver necrosis in animals, where it may be fatal in hours to days (WHO 2003). In humans, exposure to microcystin can cause a variety of

symptoms and illnesses, including liver damage, vomiting, diarrhea, abdominal pain, malaise, and rash (CDC 2009).

Dermal contact and ingestion are the well understood routes of exposure to microcystin. Recreational activities in water bodies that experience toxin-producing cyanobacterial blooms can generate aerosolized cyanotoxins, making inhalation another potential route of exposure (Backer et al 2010).

Dermal exposure to *Microcystis* cells in water can cause rash (Pilotto et al. 1997, in WHO 1999). Pilotto et al. (in WHO 1999) conducted a recreational water study in Australia in 1995 which attributed skin irritation and rashes to *Microcystis* blooms. Reports of rash and skin irritation started when *Microcystis* concentrations reached 5,000 cell/mL in water. WHO (2003) reports that skin irritation at these cell concentrations was limited to sensitive individuals, as most dermatologic symptoms were reported when cell concentrations were between 20,000 and 100,000 cells/mL. More people in the study reported dermatologic symptoms when *Microcystis* cell concentrations exceeded 100,000 cells/mL.

Ingesting water containing microcystin is a complete exposure pathway. Levels of concern, or guidance values, are determined using toxicological methodology that evaluates toxin concentration, exposure, and risk of adverse health effects associated with differing levels of exposure. Derivation of guidance values for microcystin exposure in recreational water is discussed below.

WHO concluded that sufficient research was not available to describe a benchmark health risk from inhalation exposure to *Microcystis* or microcystins. It should be noted, however, that the potential for respiratory irritation to occur from aerosolized microcystin may be present during bloom events.

Existing Microcystin Guidelines

In the U.S., there is no federally established guideline value or criteria value for microcystin in either drinking or recreational water. The U.S. Environmental Protection Agency (EPA) has included microcystin in its "contaminant of concern list," or CCL, for further evaluation during consideration of drinking water quality standard revisions. While EPA (2006) has drafted a microcystin review document, which lists a reference dose or tolerable daily intake (TDI) of 0.006 *µg/kg*/day, this TDI has not been adopted by EPA.

State governments have adopted various microcystin guidance values for recreational waters. Many states use WHO's TDI value of 0.04 *µg/kg*/day in calculations, but use varying assumptions regarding daily intake and body weights to derive guidance values. Washington

State guidance (1998) uses a TDI of 0.04 µg microcystin/kg/day and a body weight of 15 kg to arrive at a microcystin guidance value of 6 *µg/L* microcystin. Massachusetts' guidance value is 14 *µg/L* microcystin, which assumes a 35kg body weight. Both Vermont and Australia use guidance values of 6 *µg/L* and 10 *µg/L* microcystin, respectively (cited in Massachusetts guidance).

Adopted Guidance Value for Virginia

The suggested guidance value for microcystin in Virginia is based upon assumed toxin concentration and associated exposure health risks. Microcystin toxicity, exposure factors including concentration and water volume ingested, and body weight, are used to determine a TDI that corresponds to an acceptable risk level. The acceptable risk is assumed to be a no observable adverse effect level (NOAEL), which is considered a non-harmful level of acute or chronic exposure. Virginia's microcystin guidance value is intended to be protective of at-risk populations, thus the average body weight of a small child is used to calculate the guidance value. Finally, water consumption during recreation is assumed to occur from incidental ingestion during swimming or other recreational water activities such as kayaking, wind surfing, jet skiing, or water skiing.

The guidance value for recreational water in Virginia is calculated as follows (WHO 1999, WHO 2003):

$$\text{Guidance Value (GV)} = \frac{\text{TDI} \times \text{BW}}{\text{IR}}$$

Where:

TDI (tolerable daily intake) = 0.04 ug microcystin/kg/day

BW (body weight) = 15 kg child

IR (ingestion rate) = 0.1 L/day, assuming 1 hour swimming per day

The resulting guidance value for recreational exposure is 6 *µg/L*. This value is based on a NOAEL from chronic microcystin exposure in children. If children were to be excluded, adult exposure guidelines would be higher (28 *µg/L* assuming an adult weight of 70 kg). As a precautionary measure, all users of recreational water should be discouraged from making any water contact when microcystin levels exceed 6 *µg/L*.

VDH Public Health Guidance: Microcystin and *Microcystis* cell counts

The Virginia Department of Environmental Quality (DEQ) and VDH have a well-established operational plan for staff response to suspected harmful algal bloom events. All suspected harmful algal blooms are referred to an initial responder during the bloom season, which typically runs from May through October. Once a water sample is collected by an initial responder, VDH recommends avoiding contact with recreational water when the microcystin concentration in a single sample exceeds 6 *µg/L*.

Bi-weekly sampling for microcystin and *Microcystis* cell counts is recommended when cell counts reach or exceed 5,000 cells/mL. Because cyanobacteria multiply quickly to produce intense blooms, especially when the weather is hot and dry, VDH recommends bi-weekly monitoring to detect if and when a *Microcystis* bloom may be intensifying. When cell counts equal or exceed 20,000 cells/mL, VDH recommends public notification, advising that harmful algae are present in the water body.

When cyanobacteria scum forms on the water surface or cell counts reach or exceed 100,000 cells/mL, health officials should advise the public *to avoid contact* with the water body. Messages should also include a warning against livestock, horses, and companion animals, particularly dogs, coming into contact with water under algal bloom conditions. Pet owners should be advised to keep their animals out of water with surface scum or green discoloration to prevent pet illness or death. Pets should be prevented from licking their coats after entering water with a harmful bloom and should be thoroughly washed to remove any microcystin or harmful algae from their coats for the same reason.

Table 1. Water Conditions and Corresponding Notification

Water Quality Condition	Public Health Response	Basis
5,000 to <20,000 *Microcystis* cells/mL	Notify local health district and DEQ; initiate bi-weekly water sampling.	WHO (2003)
20,000 to 100,000 *Microcystis* cells/mL	Notify public through press release and/or signage. Advise people and pet-owners that harmful algae are present. Initiate weekly water sampling.	Massachusetts and Washington Health Dept guidance, WHO (2003)
> 100,000 *Microcystis* cells /mL, or > 6 *µg/L* microcystin concentration, or blue-green algal "scum" or "mats" on water surface	Notify public through press release and/or signage. Advise against any recreational activity that may involve water contact for people and pets; continue weekly monitoring until bloom and/or microcystin dissipates.	Washington Health Department guidance, WHO (2003)

Environmental Conditions and Monitoring Considerations

Several ecological variables contribute to *Microcystis* blooms and cause variation in bloom intensity, duration, area, and toxin concentrations from bloom to bloom. Factors affecting the likelihood of a *Microcystis* bloom are thought to be primarily water temperature and nutrient availability. Temperatures between 15 and 30° C (between 59 and 86° F) tend to support *Microcystis* growth, while elevated water temperatures between 25 and 30° C (between 77 and 86° F) seem to be conducive to blooms (Davis et al. 2009). Blooms may be anticipated when fresh and brackish waters warm during the summer months, but especially when water temperatures are between 25 and 30° C.

Microcystis blooms do not uniformly yield toxin concentrations in response to their environment. Temperature and nutrient availability differences between water bodies and within the same water body at different times during the year may be responsible for differences in microcystin levels in algal blooms with the same cell concentrations (Orr and Jones 1998). Elevated temperatures may result in elevated toxin production as well (Song et al. 2007). It is possible that increases in water temperature result in greater within-cell concentrations of microcystin when compared to blooms formed during cooler conditions (Davis et al. 2009). Water quality monitors and managers should respond to reports of cyanobacteria blooms because microcystin concentrations may not directly correspond to the intensity of the bloom. In addition, microcystin is stable in the environment and is resistant to light-induced breakdown. Breakdown occurs fastest in acidic water (low pH), in the presence of bacteria that can metabolize the toxin (Song et al. 2007).

Physically, cell concentrations are likely to be variable within a water body, due to the variable concentrating effects of water flow, tide (in estuaries), wind, and wave activity in some areas versus others (WHO 2003). This means, for example, that a recreational water body may have dense concentrations of cells where wind pushes onshore, while the remainder of the water body may show no scum or water discoloration. Bloom monitoring response for preventing recreational water illness should focus on parts of the water body that people are likely to use (e.g., designated beach areas) with the understanding that between-sample cell or toxin concentrations may vary. Depending on the size of the water body and the intensity of the bloom, it may be appropriate to advise against water contact in one area and not in another. When a partial water body advisory is issued due to a bloom, the undesignated area should remain under observation for the spread of blooms into new areas.

Table 2. Recommendations for Water Monitoring in Recreational Waters

Environmental Condition	Monitoring suggestions
Warm water temperatures during summer months	Be aware that *Microcystis* blooms are a potential concern in fresh and brackish waters
Evidence of a bloom (water discoloration, fish kill, etc.)	First responder collects water samples for algae identification and enumeration. If possible, collect water samples for microcystin concentration analysis. Collect temperature and pH data if possible. Ideally, collect several samples to characterize the extent of a bloom. If sampling resources are limited, concentrate on areas where people or pets are likely to come into contact with water.
5,000 cells/mL to < 20,000 *Microcystis* cells/mL	Monitor water quality in anticipation of an intensifying bloom, especially in hot, dry weather. Sampling frequency should be based on water use, with bi-weekly sampling in areas that are heavily used for recreation.
20,000 cells/mL to 100,000 *Microcystis* cells/mL	Weekly sampling in areas that are heavily used for recreation.
> 100,000 *Microcystis* cells /mL	Continue weekly sampling in order to characterize the extent and growth or dissipation of the bloom.
Bloom is dissipating or has dissipated	Discontinue bloom-response sampling after two sampling events, a week apart, show low or no cell / toxin concentrations

Public Health Communication

The public should be advised to limit or avoid direct contact with the identified recreational water body during various stages of a bloom event. Use of advisory signs (Appendix A) and media releases (Appendix B) should be considered when harmful algal blooms are present. Before a media release occurs, a pre-release discussion with jurisdictional leadership and other key stakeholders should take place. Any media release that contains a public health warning should be shared with elected officials. The VDH website should be updated to reflect accurate and timely information on the algal bloom event. Finally, social networking tools should be considered to communicate with the general public and gather information during widespread algal bloom events.

People should be warned that dogs are particularly susceptible to injury or death when a bloom is occurring. Pets may consume water at greater volumes per bodyweight than humans and toxin ingestion can occur when dogs lick their coats after coming into contact with *Microcystis*.

Additionally, the public should be advised that even after a bloom has dissipated, there is still risk of microcystin exposure. While counter-intuitive, microcystin levels may rise as a bloom dies off. Microcystin is not excreted by algal cells but rather is contained within cells (Jones and Orr 1994). During a bloom die-off, cell concentrations, along with visible signs of a bloom (e.g., green water discoloration), are not necessarily correlated with toxin concentrations.

The public should be advised that it is safe to swim or conduct other recreational water activities when sampling results show microcystin levels are below 6 $\mu g/L$. If direct testing for microcystin is not practical, advisories should remain in effect for a period of 9 – 15 days (Song et al.2007) after the bloom is no longer visibly present.

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Appendix A. Sample Signs

BE AWARE:

HARMFUL ALGAE MAY BE PRESENT IN WATER. PEOPLE AND PETS SHOULD AVOID AREAS WHERE ALGAE OR SCUM ARE PRESENT.

For More Information Call [the responsible authority] or the VDH HAB HOTLINE: 888-238-6154.

VDH VIRGINIA DEPARTMENT OF HEALTH
Protecting You and Your Environment

WARNING:

HARMFUL ALGAE ARE PRESENT IN WATER. AVOID ALL WATER CONTACT UNTIL FURTHER NOTICE.

For More Information Call [the responsible authority] or the VDH HAB HOTLINE: 888-238-6154.

VDH VIRGINIA DEPARTMENT OF HEALTH
Protecting You and Your Environment

Appendix B. Sample Harmful Algal Bloom Press Release

VDH VIRGINIA DEPARTMENT OF HEALTH
Protecting You and Your Environment

News Release

109 Governor Street, Richmond, Virginia 23219 ● **www.vdh.virginia.gov**

FOR IMMEDIATE RELEASE **Month, XX, 2010**

For More Information Contact **Release #**

Contact name and number (and title if not a PIO--PIO contact preferred)

TOXIC HARMFUL ALGAL BLOOM OCCURING IN X LAKE

Public advised to avoid water contact

(RICHMOND, Va.)— High levels of toxic algae have been found in X Lake. A harmful algal bloom of *Microcystis aeruginosa* is occurring in the lake. This blue – green algae produces a toxin that can cause rashes and other illness. The Virginia Department of Health is warning lake-goers to stay out of the water and to keep their pets and children out as well. Due to low body weight, children and pets are at greater risk of severe illness if lake water is ingested.

Harmful algal blooms occur when warm water and nutrients combine to make conditions favorable for algae growth. The algae become so abundant that they can turn the water green and eventually produce a toxin. Microcystin, one of the types of toxins, can develop in green clumps on the surface of the water. It may also look like thick, green paint in the lake.

"The Department of Environmental Quality and the Department of Health will continue to monitor water quality in X Lake during the harmful algal bloom," said a VDH representative.

To prevent illness, people should:

- Avoid contact with any area of the lake where water is green or an advisory sign is posted
- Keep children and pets out of affected areas too, and quickly wash them off with soap and water after coming into contact with algae
- If you experience symptoms after swimming in or near an algal bloom, seek medical care
- Call the Virginia Harmful Algal Bloom Hotline at 1-888-238-6154 for more information