ENVIRONMENTAL
Fact Sheet

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

29 Hazen Drive, Concord, New Hampshire 03301 • (603) 271-3503 • www.des.nh.gov

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Cyanobacteria and Drinking Water: Guidance for Public Water Systems

What are cyanobacteria?

Cyanobacteria are microscopic organisms found naturally in lakes, streams and ponds. Once known as blue-green algae, they are actually photosynthetic bacteria. Cyanobacteria may occur in all of New Hampshire's waterways. When present in low numbers they do not cause recreational or aesthetic problems; however, when conditions are optimal, high concentrations of bacterial cells may form blooms, scums or mats. Blooms sometimes appear as green or blue-green flecks scattered in the water; scums float on the surface, and mats rest on the bottom.

Why are they of concern to public water systems?

There are more than 150 different types of cyanobacteria and literally thousands of species, about 50 of which produce toxins (collectively referred to as "Cyanotoxins" or "algal toxins") that are harmful to vertebrates. These toxins may be hepatotoxins, which affect the liver and kidney, neurotoxins, which affect the central nervous system, or dermatotoxins, which are skin irritants, capable of causing both acute and chronic illnesses. The known cyanotoxin producers make toxins around 50 percent of the time. Cyanobacteria have been linked to human and animal illnesses around the world, on all continents, in connection with both recreational exposure and drinking water. The most common types of toxin-producing cyanobacteria in New Hampshire are *Anabaena*, *Aphanizomenon*, *Microcystis* and *Oscillatoria*. Cyanobacteria can also produce taste and odor problems. In a study conducted for the American Water Works Association Research Foundation, 82 percent of 243 samples of treated water testing positive for taste and odor problems also tested positive for cyanotoxins.[1] The World Health Organization has established a health-based drinking water guideline of 1.0 ppb for the most common cyanotoxin, microcystin-LR[2].

How big a problem are cyanobacteria in New Hampshire?

At this time it is not known whether cyanobacteria are a significant problem for New Hampshire water systems, other than as a source of taste and odor problems. Cyanobacterial blooms have been reported recently in at least 30 lakes, ponds, and reservoirs in the state. A survey of 44 lakes during 1999 and 2000 found microcystins (the most common class of toxins produced by cyanobacteria) in all of the lakes, both clean and high-nutrient lakes, although the latter were more likely to have high concentrations of microcystin.[3] Based on the results of that study, it is believed that potentially dangerous levels of microcystins could develop in many New Hampshire waterbodies. DES knows of

[1] American Water Works Association Research Foundation. Assessment of blue-green algal toxins in raw and finished drinking water. AwwaRF and AWWA, Denver, CO (2001).
[2] Microcystins are named according to their variable L-amino acids. Microcystin-LR contains leucine (L) and arginine (R).
[3] Haney, James F., John J. Sasner, Myoshi Ikawa and Jeffrey Schloss. Brief summary of findings of the survey of biotoxins in New Hampshire lakes. Prepared for: N.H. Department of Environmental Services, Concord, NH (February 13, 2002)

no studies of cyanotoxins in New Hampshire rivers, but cyanotoxins do occur in rivers around the world. Blooms are most noticeable in late summer and early autumn, but may occur any time of year. Although there have been several instances of confirmed blooms of toxin-producing cyanobacteria in lakes and ponds used as sources by water systems in New Hampshire, there were no protocols in place to provide for monitoring of raw or finished water for cyanotoxins.

How can you tell whether you have a problem?
There is no single predictor of which lakes will have a cyanobacteria problem and which will not, since phosphorus concentration seems to be the biggest risk factor, but low-phosphorus lakes have blooms too. While many cyanobacteria blooms are recognizable by appearance alone, the absence of an obvious bloom does not rule out significant concentrations of cyanobacteria and their toxins in the raw water. Monitoring raw and finished water is the surest way to determine whether cyanobacteria and their toxins are present in harmful concentrations. DES recommends that water systems carry out a well-designed monitoring program spanning several years to characterize the weather and water conditions (temperature, transparency, odor, appearance) and the time(s) of year that are most likely to be associated with high raw-water cyanotoxin levels, and then to focus monitoring efforts in subsequent years based on those factors. It is important to be aware that cyanobacteria concentrations tend to vary significantly with wind direction, time of day, location, and depth within a given water body. A number of microcystin test kits are available with costs ranging from $5 to $25 per test (search the internet for “algal toxin test kit”). Grants are available from the DES Local Source Water Protection Grant Program to support monitoring programs to assess the potential for cyanobacteria blooms in public water supply sources.

What can water systems do to manage the problem?

Source Water Protection
Factors contributing to blooms include nutrient availability, sunlight, and temperature. Water suppliers can help keep cyanobacteria blooms from forming through source water protection efforts that limit phosphorus and sediment loads to source waters. Controlling phosphorus and sediment loads can also help minimize problems with taste and odor and disinfection byproducts.

Monitoring
As noted above, it is recommended that water systems using surface sources – especially lakes, ponds, or reservoirs that have taste and odor issues or have shown indications of cyanobacterial blooms – implement monitoring programs to characterize cyanobacteria and cyanotoxin trends in raw water and, when indicated, in finished water.

Monitoring methods represent a rapidly changing aspect of cyanobacteria management. Cell counts have long been used as an indicator of cyanobacteria growth trends, but are not necessarily related to cyanotoxin production. Fluorescence sensors that measure the algal and cyanobacterial pigments chlorophyll-a and phycocyanin are currently being evaluated. The presence of cyanotoxin-producing genes is emerging as a promising indicator of potential cyanotoxin production. However, as noted above, it is now possible to measure concentrations of cyanotoxins in real time with moderately-priced test kits.

Develop a Response Procedure
If you find that your source is susceptible to cyanobacteria blooms, develop a protocol that describes how you plan to respond to events such as moderate to high concentrations of cyanotoxins in your raw water. An example of a tiered response framework can be found in the Canadian document referenced below.

In-Reservoir Strategies

While not practical for all sources, some systems can reduce the concentrations of cyanobacteria and toxins reaching their intakes by drawing water from locations or depths with lower concentrations of cyanobacteria and by diverting surface scums away from the intake. In-reservoir techniques that focus on manipulating the conditions that affect cyanobacteria growth include destratification (vertical mixing), aeration, and sediment removal or covering. A number of water systems have had success using algaecide before blooms occur, but using this technique successfully with a minimal amount of algaecide depends on an appropriate monitoring program. Copper sulfate or other algaecides should be used with caution, *prior to bloom formation, if at all*. Concerns associated with algaecide use include the potential release of toxins by cyanobacterial cells and unpredictable ecological effects, such as nutrient release leading to subsequent algae blooms. A permit from DES would be required prior to the use of algaecide in a water body.

Manage Treatment Processes to Optimize Removal of Cells and Toxins

The best overall strategy is to optimize the removal of intact cyanobacteria cells through coagulation and filtration, *and* removal or destruction of the dissolved toxin through adsorption and/or post-filtration oxidation. Conventional surface water treatment plants, using coagulation, clarification, and filtration, are effective at removing cyanobacterial cells, although rapid filtration without coagulation and clarification is generally **not** satisfactory at removing cells. With respect to removal or oxidation of the dissolved toxin, plants that meet Stage 1 and Stage 2 requirements for Disinfectants and Disinfection Byproducts Removal (D/DBPR) by using ozone and/or granular activated carbon (GAC) have relatively high protection against many cyanotoxins with reference to the WHO guideline value of 1.0 ug/L microcystin-LR. Oxidation with ozone, if the dissolved organic compounds demand is satisfied, potassium permanganate (1 mg/L for 30 min), or chlorine (contact time of at least 15 mg-min/L at pH <8) is largely effective at destroying most cyanotoxins. *Oxidation with chloramines, chlorine dioxide, hydrogen peroxide, or ultraviolet radiation does* **not** *seem to be effective at removing cyanotoxins.* Both powdered and granular activated carbon can be effective at removing cyanotoxins, but competition from other organic compounds (such as humic substances, which are common in Northeast lakes) can reduce their effectiveness. For more information on treatment options, consult the references listed below.

Optimal cell and toxin removal entails the following steps *where practical*:

1. Avoid rupturing the cells before they can be removed; consequently, keep pre-oxidation to a minimum. (Pre-ozonation is less likely to rupture the cells than pre-chlorination.) The importance of this step will depend on whether the total toxin concentration is low enough to be adequately addressed by adsorption and/or oxidation.
2. Increase the frequency of sludge removal and backwashing in order to reduce the time the intact cells spend in contact with the water, since the cells will eventually rupture and release their toxins. Do not recycle the backwash water.
3. Optimize ozone and chlorine doses following filtration. (See Westrick (2008) for chlorine CT values for reducing microcystin-LR.)
4. Use powdered activated carbon (PAC) if oxidation alone will not be sufficient to reduce toxin concentrations. Jar-testing is recommended to determine the appropriate type and dose of PAC.

What are the regulatory requirements for public water systems?

Cyanotoxins are not currently regulated as contaminants under federal or state rules. They are, however, considered candidates for regulation in the future.

For more information

Recognizing a cyanobacteria bloom and getting help from DES: See in particular the **Ecology** and **Images** sections at http://des.nh.gov/organization/divisions/water/wmb/beaches/cyano_bacteria.htm

An overview of cyanobacteria, their toxins, treatment effectiveness, and a tiered response framework for water systems: Federal-Provincial-Territorial Committee on Drinking Water (Canada) (2002) "Cyanobacterial Toxins – Microcystin-LR" in *Guidelines for Canadian Drinking Water Quality: Supporting Documentation*. Available at http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/water-eau/cyanobacterial_toxins/cyanobacterial_toxins-eng.pdf.

Source water protection: Piehler, Michael F. (2008) "Watershed management strategies to prevent and control cyanobacterial harmful algal blooms," in Hudnell, H. Kenneth (ed.), *Cyanobacterial Harmful Algae Blooms: State of the Science and Research Needs*. Available at: http://www.epa.gov/cyano_habs_symposium/monograph/Ch12.pdf

More information regarding treatment:

Chorus, Ingrid and Jamie Bartram. (1999) Toxic Cyanobacteria in Water: A guide to their public health consequences, monitoring and management. World Health Organization.

Newcombe, Gayle and Mike Burch. (2003) Toxic Blue-Green Algae: Coming to a Neighborhood Near You? *OpFlow*, May 2003.

Westrick, Judy A. (2003) Everything a Manager Should Know About Algal Toxins but Was Afraid to Ask. *Journal AWWA*, September 2003.

Westrick, Judy A. (2008) "Cyanobacteria toxin removal in drinking water treatment processes and recreational waters," in Hudnell, H. Kenneth (ed.), *Cyanobacterial Harmful Algae Blooms: State of the Science and Research Needs*. Available at: http://www.epa.gov/cyano_habs_symposium/monograph/Ch13.pdf

Designing a monitoring program for cyanotoxins: U.S. Geological Survey (2008) Guidelines for Design and Sampling for Cyanobacterial Toxin and Taste-and-Odor Studies in Lakes and Reservoirs (SIR 2008-5038). Available at: http://pubs.usgs.gov/sir/2008/5038/pdf/SIR2008-5038.pdf

USEPA stance on regulating cyanotoxins: USEPA – Office of Ground Water and Drinking Water (June 2008) Regulatory Determinations Support Document for Selected Contaminants from the Second Drinking Water Contaminant Candidate List (CCL 2). (EPA 815-R-08-012) (pp 14-15). Available at: http://www.epa.gov/ogwdw/ccl/pdfs/reg_determine2/report_ccl2-reg2_supportdocument_full.pdf

DES Local Source Water Protection Grant Program:
http://des.nh.gov/organization/divisions/water/dwgb/dwspp/lswp_grants.htm