BRITISH COLUMBIA

DECISION PROTOCOLS FOR CYANOBACTERIAL TOXINS IN B.C. DRINKING WATER AND RECREATIONAL WATER

Purpose

The purpose of these protocols (recreational water and drinking water) is to provide standardized processes (steps) for water suppliers, local governments and health authorities to follow when monitoring cyanobacterial bloom events. Each protocol recommends actions that should be taken to address potential cyanobacterial blooms and associated microcystin issues. Examples include directing a water supplier to switch to an alternative water source, issue a "Do Not Use" notice or warn recreational water users of unacceptable water quality before it becomes a health hazard.

The decision trees in these protocols are modified from the Health Canada's *Guidelines for Canadian Drinking Water Quality: Supporting Documentation: Annex A: Stepwise Protocol for Microcystin-LR in Water Supplies Used for Human Consumption, and Cyanobacterial Toxins in Drinking Water – Document for Public Consultation* (prepared by the Federal-Provincial-Territorial Committee on Drinking Water, 2002).[1]

This document also takes into account interim drinking water advice on microcystins provided by Health Canada on June 17, 2015. This includes the addition of precautionary advice concerning infants, as a result of the collaborative assessment undertaken by Health Canada and the United States Environmental Protection Agency:

> *"A seasonal maximum acceptable concentration (seasonal MAC) of 0.0015 mg/L (1.5 µg/L) is proposed for total microcystins in drinking water. This guideline is considered to be protective of the general population, including young children. Because of the increased exposure of infants relative to body weight,* as *a precautionary approach during a cyanobacterial bloom, or when microcystins are detected in finished water, drinking water authorities should consider informing the public in the affected area that an alternate suitable source of drinking water (such as bottled water) should be used to reconstitute infant formula."*

The goal of this document is to simplify the steps in the original protocol by separating drinking water and recreational water, and incorporating additional screening indicators that may reduce the costs associated

[1] Health Canada, 2002. *Guidelines for Canadian Drinking Water Quality: Supporting Documentation, Cyanobacterial Toxins – Microcystin-LR*. Available online at http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/water-eau/cyanobacterial_toxins/cyanobacterial_toxins-eng.pdf.

with sampling. It also incorporates screening for the broader microcystin toxin as risk indicator rather than the more specific microcystin-LR that is in the current Health Canada advice. These protocols and the accompanying decision trees summarize the important factors that should be considered during bloom events and recommended actions that may be taken to address the issue.

Background Information on Cyanobacteria

The growth of cyanobacteria (also known as blue-green algae) in water bodies (generally smaller or shallow lakes, reservoirs, sloughs or dugouts) can occur throughout Canada at any time of year, but blooms happen predominantly in the summer. In many cases, blooms tend to recur within the same water bodies year after year. While most species of cyanobacteria are capable of producing nerve and liver toxins, not all do. When present, the amount of toxin can vary dramatically within the body of water and over time.

Analytical studies in dugouts and other water supplies in Manitoba, Saskatchewan and the Peace River region of Alberta indicate that cyanotoxins (i.e., microcystins) are much more common in rural water supplies than originally thought. Although there are few quantitative sources of data available, there are indications that these toxins may also be occurring in various water supplies in other provinces (e.g., Ontario, British Columbia, Quebec and PEI). This has led to increasing concern by government agencies and the public about the safety of water supplies that may be potential sources of these toxins.

The factors inducing the production of toxins by cyanobacteria are complex. Laboratory studies demonstrate that some environmental factors could be important, such as temperature, light, nitrogen concentrations, carbon availability (in the form of bicarbonate, carbonate and carbon dioxide), phosphate concentrations and pH.

As toxin production varies greatly among different strains of the same species, genetic differences and metabolic processes may also be important in the production of these secondary metabolites. Studies have shown that the ability to produce toxins can vary temporally and spatially at a particular site. Therefore, different parts of the same water body may have different concentrations, and this should be considered when deciding on testing protocols.

Cyanobacterial toxins tend to be associated with cyanobacterial cells and may be membrane-bound or occur free within the cells. In laboratory studies, most of the toxin release occurs as cells age and die and passively leak their cellular contents. Some active release of toxins can also occur from young, growing cells.

Toxin levels do not necessarily coincide with maximum algal biomass. There can be a significant variation in the amount of toxin per unit biomass of cyanobacteria over time, which is independent of changes in the blue-green algal population. In one study, for example, concentrations of microcystins were higher in bloom samples taken during the day than at night. In another study, no significant difference was observed in toxin concentrations from cyanobacteria incubated for 24 hours at different depths in a reservoir.

Microcystins are relatively persistent in the aquatic environment. Studies in Australia have shown that microcystin-LR was present up to 21 days following treatment of a *Microcystin aeruginosa* bloom with an algaecide.

Sampling, Portable Test Kits and Laboratories

Agencies typically involved with cyanotoxin testing of raw and drinking water sources include the Ministry of Environment (regional offices), local governments, water system operators and health authorities' environmental health officers. These agencies should make themselves familiar with these protocols and work together to develop local communication protocols before bloom events. They should ensure each group understands their role with respect to observation, sampling and decision making for a given source of drinking or recreational water.

This document refers to field test kits methods and laboratory testing. To limit the potential for error when using the protocols, field testing for microcystins is intended to determine their presence or absence only within the sample (vs. a specific quantifiable amount), as field test kits have a range of detection limits, and levels of accuracy/reliability vary. Subsequent to field tests showing the presence of microcystins, samples should be forwarded to an analytical laboratory to confirm whether microcystin concentrations exceed the recommended thresholds.

A number of commercial microcystin tests kits suitable for field use are available. These are discussed in the recent Health Canada report *Evaluation of Field Test Kits to Detect Microcystins*.[2] They include technologies based on ELISA, immunochromatography, and phosphatase inhibition.

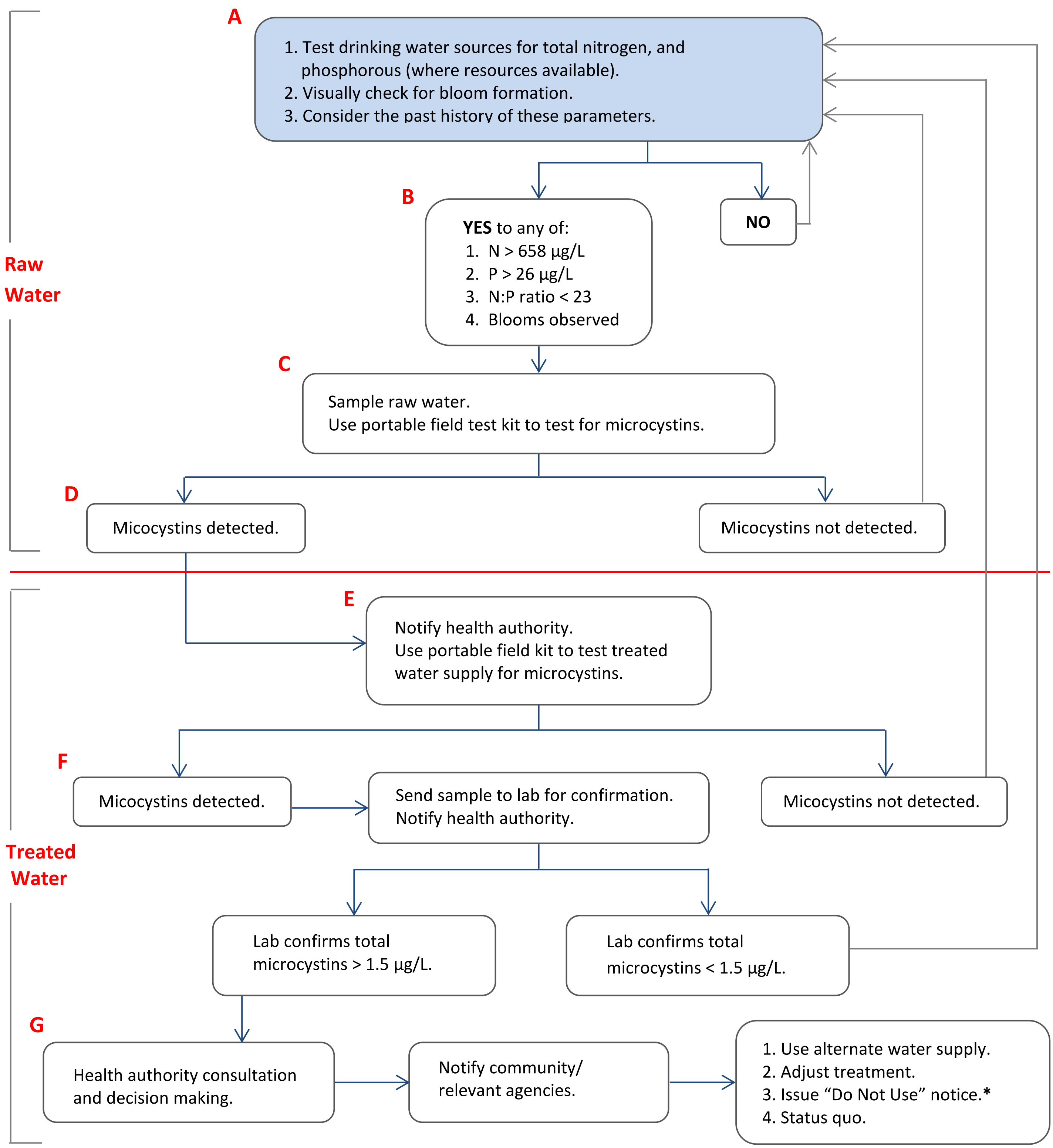
When choosing a portable test kit, it is important to pick one that is appropriate for the range of toxin concentrations being screened for (i.e., 0.5 µg/L to 5µg/L for drinking water, and a higher range for recreational water). In some cases, where the test kit range is below thresholds (as in recreational water), dilution of samples with fresh water may be required to provide results test within the range of interest.

Several B.C. laboratories are equipped to test specifically for microcystins. Sampling agencies should determine, in consultation with the local health authority, where and how to send samples for analysis well before any bloom event occurs. A description of appropriate laboratory techniques is discussed in the supporting documentation for Health Canada's guidance on cyanobacterial toxins.[3]

[2] Rodriguez, R. *Evaluation of Field Test Kits to Detect Microcystins*. Environmental Protection Agency, 2010. Available online at http://www2.epa.gov/sites/production/files/2014-08/documents/microcystins-testkit-canada.pdf.

[3] Health Canada, 2002. *Guidelines for Canadian Drinking Water Quality: Supporting Documentation, Cyanobacterial Toxins – Microcystin-LR*. Available online at http://www.hc-sc.gc.ca/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/water-eau/cyanobacterial_toxins/cyanobacterial_toxins-eng.pdf.

Decision Tree for Drinking Water: Cyanobacterial Toxins



*Advisory in effect until 2 consecutive water samples (raw & treated) tested & confirmed to be <1.5 ug/L for microcystins.

Decision Tree for Drinking Water: Cyanobacterial Toxins – Step Descriptions

***STEP A:* Initial screening for suspected blooms: Examine the water for one or more of total nitrogen and phosphorus. Check for bloom formation.**

- Test for nitrogen/phosphorus:
  - Spring turnover typically results in an increase in water nutrients cycled to the surface. This nutrient cycling coupled with increased sunlight and temperature can provide the conditions that lead to an algae bloom. Testing for phosphorous and/or nitrogen may serve as an alert for impending algal blooms and increasing the frequency of visual checks.
- Visually check for bloom formation:
  - As blooms tend to recur in the same water supplies, water bodies that have historically exhibited algal blooms should be visually monitored for bloom formation. As well, water bodies that experience changes in variables such as temperature, size, water depth and nutrient content may be susceptible to algal blooms and should be considered for increased monitoring. Public enquiries/complaints may also serve as a flag to check for blooms.
  - A visual bloom is identified by the appearance of "soupy" water. Colours can range from grey or tan, to blue-green or bright blue, to reddish. The appearance of blooms may also be described as fine grass clippings or small clumps. Changes in secchi (cloudiness/turbidity) depth readings may be a sign of an impending bloom.

***STEP B:* If yes to any of: nitrogen (N)>658 µg/L; phosphorus (P)> 26µg/L; an N:P ratio < 23; changes in secchi depth; or blooms observed, go to Step C. If no, return to Step A.**

- High levels of nitrogen and phosphorus, as well as low ratio of nitrogen to phosphorous, can contribute to algal blooms and the presence of microcystins.
- According to Orihel et al., 95% percent of the cases where microcystin concentrations exceed the WHO drinking water guideline occur with phosphorus concentrations above 26 µg/L and nitrogen concentrations above 658 µg/L. Maximum concentrations of microcystins occur in hypereutrophic lakes at mass ratios of N:P below 23. The probability of microcystin concentrations exceeding all toxin thresholds is highest when N:P ratios are less than 20, and drop to near zero above N:P ratio of 40.[4]
- As growth conditions and nutrient content of each water body are unique, these numbers are provided as a screening reference for anticipating the risk of a bloom. They are not intended to be exact thresholds.
- For a rationale on bloom observation, see step A, second bullet (above).

***STEP C:* Sample the raw water. Use a portable field kit to test for the presence of microcystins.**

- Raw water samples should be collected before any treatment. Sampling from a reservoir should be done as close to the inlet/shore and/or the bloom formation as possible. When choosing a sampling location, be aware that cyanobacterial species/cell abundance and biomass vary spatially within a water body (e.g., cells may be transported by wind currents).

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[4] Orihel, Diane M. "High microcystin concentrations occur only at low nitrogen-to-phosphorus ratios in nutrient-rich Canadian lakes." *Canadian Journal of Fisheries and Aquatic Sciences*. NRC Research Press, August 14, 2012.

- For the purpose of this decision protocol, the presence of microcystins means >1.0µg/L using a portable test kit. See *Evaluation of Field Test Kits to Detect Microcystins* regarding how to select a portable test kit.[5]
- Be aware that toxins may persist following the collapse of blooms. This can happen particularly in the late summer and early fall, when colder temperatures and a decrease in light intensity result in decreased rates of toxin degradation. This may indicate a need for sampling for toxins during and after collapse of the bloom.
- Further sampling (optional) for algal identification may also be helpful. Species identification, especially from sites positive for toxin, can provide additional information regarding the source, conditions and type of other toxins that might be present.

***STEP D:* If the presence of microcystins is detected (>1.0µg/L) with a field test kit, go to step E, and alert the health authority of a potential issue. If microcystins are absent, return to step A.**

***STEP E:* Use a portable test kit to test the treated water supply for microcystins.**

- Samples should be taken at a tap located after treatment from the water plant or from within the distribution system.

***STEP F:* If the portable test kit indicates microcystins are present (>1.0µg/L) in the treated water, send a sample to the lab for confirmation and immediately notify the health authority.**

- The presence of microcystins indicates there is a potential concern for infants who use formula reconstituted from that water. Consult the health authority about informing the public that an alternate source of drinking water should be used for reconstituting infant formula.
- Contact the health authority to confirm an appropriate laboratory for microcystin testing.
- Samples for lab analysis should be collected in glass containers or as directed by the lab, as studies indicate that the toxin, if present, can be adsorbed to plastic.

***STEP G:* If the lab results indicate the seasonal MAC of 1.5µg/L has been exceeded, immediately contact the health authority for consultation and decision making.**

Where lab analysis indicates that levels of microcystin are near or exceed the seasonal MAC of 1.5µg/L, the health authority should be consulted to determine a short-term and long-term course of action. Health agencies, municipal councils and water supply system operators should be included in these discussions.

Factors to consider may include the site history, size and location of the bloom, available treatment technology, uses of the source water (recreational vs. domestic uses) and monitoring of the environmental conditions that might affect the bloom (e.g., wind). Water system operators may be able to provide information about the historical occurrence of blooms/microcystins for a given system.

In response, the water supplier may need to do one or more of the following:

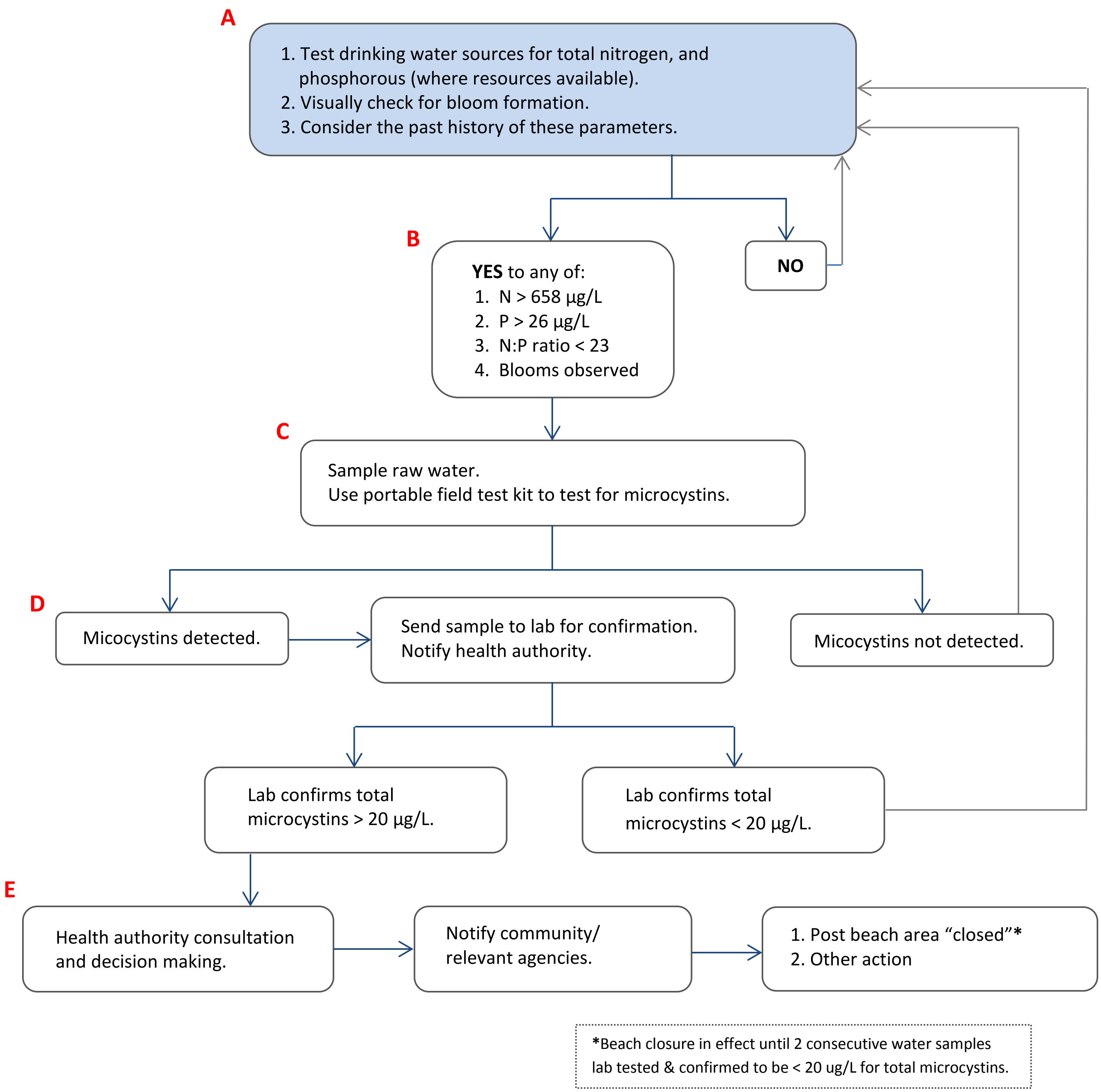
- Resample the treated water supply using a field kit or laboratory, or do other monitoring.

[5] Rodriguez, R. *Evaluation of Field Test Kits to Detect Microcystins*. Environmental Protection Agency, 2010. Available online at http://www2.epa.gov/sites/production/files/2014-08/documents/microcystins-testkit-canada.pdf.

- Use an alternate water source or supply.
    - Discussions regarding alternative supplies should be reviewed with the health authority.
- Adjust treatment (if doing so will be effective).
    - Discussions regarding treatment adjustments should be reviewed with the health authority.
- Issue a “Do Not Use” notice. See Appendix B for suggested messaging.
    - As blooms may be of short duration (ranging from days to weeks), the health authority may recommend that a “Do Not Use” notice be issued, and that consumers seek alternative supplies of safe drinking water until the risk passes.
    - Any “Do Not Use” notice should remain in effect until two consecutive water samples (for both raw and treated supplies) are tested and confirmed to be less than their respective thresholds for microcystins.
- Maintain the status quo (continue monitoring).
- Take other actions as required by the health authority.

Long-term issues and/or recurrence of cyanobacteria blooms may require planning to incorporate specific treatment to correct the problem, and the use of an alternate source of water in the interim.

Decision Tree for Recreational Water: Cyanobacterial Toxins



Decision Tree for Recreational Water: Cyanobacterial Toxins – Step Descriptions

***STEP A:* Initial screening for suspected blooms: Examine the water for one or more of total nitrogen and phosphorus. Check for bloom formation.**

- Test for nitrogen/phosphorus:
  - Spring turnover typically results in an increase in water nutrients cycled to the surface. This nutrient cycling coupled with increased sunlight and temperature can provide the conditions that lead to an algae bloom. Testing for phosphorous and/or nitrogen may serve as an alert for impending algal blooms and increasing the frequency of visual checks.
- Visually check for bloom formation:
  - As blooms tend to recur in the same water supplies, water bodies that have historically exhibited algal blooms should be visually monitored for bloom formation. As well, water bodies that experience changes in variables such as temperature, size, water depth and nutrient content may be susceptible to algal blooms and should be considered for increased monitoring. Public enquiries/complaints may also serve as a flag to check for blooms.
  - A visual bloom is identified by the appearance of "soupy" water. Colours can range from grey or tan, to blue-green or bright blue, to reddish. The appearance of blooms may also be described as fine grass clippings or small clumps. Changes in secchi (cloudiness/turbidity) depth readings may be a sign of an impending bloom.
  - Be aware that toxins may persist following the collapse of blooms. This can happen particularly in the late summer and early fall, when colder temperatures and a decrease in light intensity result in decreased rates of toxin degradation. This may indicate a need for sampling for toxins during and after collapse of the bloom.

***STEP B:* If yes to any of: nitrogen (N)>658 µg/L; phosphorus (P)> 26µg/L; an N:P ratio < 23; changes in secchi depth; or blooms observed, go to Step C. If no, return to Step A.**

- High levels of nitrogen and phosphorus, as well as a low ratio of nitrogen to phosphorous, can contribute to algal blooms and the presence of microcystins.
- According to Orihel et al., 95% percent of the cases where microcystin concentrations exceed the WHO drinking water guideline occur with phosphorus concentrations above 26 µg/L and nitrogen concentrations above 658 µg/L. Maximum concentrations of microcystins occur in hypereutrophic lakes at mass ratios of N:P below 23. The probability of microcystin concentrations exceeding all toxin thresholds is highest when N:P ratios are less than 20, and drop to near zero above N:P ratio of 40.[6]
- As growth conditions and nutrient content of each water body are unique, these numbers are provided as a screening reference for anticipating the risk of a bloom. They are not intended to be exact thresholds.
- For a rationale on bloom observation, See step A, second bullet (above).

[6] Orihel, Diane M. "High microcystin concentrations occur only at low nitrogen-to-phosphorus ratios in nutrient-rich Canadian lakes." *Canadian Journal of Fisheries and Aquatic Sciences*. NRC Research Press, August 14, 2012.

***STEP C:* Sample raw water. Use a portable field kit to test for microcystins.**

- Samples should be taken as close to beaches or recreational sites as possible. However, if sampling agency resources are available, it is suggested that samples from several sites be taken and tested for the presence of microcystins, as cyanobacterial biomass varies spatially within a water body (e.g., cells may be transported by wind currents).
- *See Evaluation of Field Test Kits to Detect Microcystins* regarding how to select a portable test kit.[7]
- Further (optional) sampling for algal species identification may also be helpful. Species identification – especially from sites positive for toxin identification – can provide additional information about the source, conditions and type of other toxins that might be present.

***STEP D:* If the presence of microcystins is detected with a field test kit (>1µg/L), send a sample to the lab for quantitative analysis.**

- For the purpose of this protocol, presence of microcystins means >1.0µg/L using a portable test kit.
- See *Evaluation of Field Test Kits to Detect Microcystins* regarding how to select a portable test kit.
- Contact the health authority to confirm an appropriate laboratory for microcystin testing capability.
- Samples should be sent (in coolers) to the laboratory for analysis and collected in glass containers or as directed by the lab, as studies indicate that the toxin, if present, can be adsorbed to plastic.

***STEP E:* Health authority consultation and decision making.**

- Where the laboratory analysis indicates that levels of microcystins are near or exceeding the threshold of 20 µg/L, the health authority should be consulted to determine a short-term and long-term course of action.
- Health agencies, municipal councils and water supply system operators should be included in these discussions. Factors to consider may include the site uses (e.g., swimming), size and location of the bloom, environmental conditions (e.g., wind) and history of the water body.
- The authority responsible for the recreational water body may need to do one or more of the following:
  - Resample the water immediately and send the resample to lab for confirmation of result.
  - Take appropriate action(s), which may include:
    - Post "Beach Closed" and notify the community. See Appendix B for suggested messaging.
    - Making available the BC HealthLink fact sheet entitled *Blue-green Algae (Cyanobacteria) Blooms* to provide communities with information.. It is available online at http://www.healthlinkbc.ca/healthfiles/hfile47.stm.
    - Any beach closure should remain in effect until two consecutive water samples are tested and confirmed to be less than 20 µg/L for total microcystins.
  - Notify the local water supply operator that toxins have been found in the area.
  - Take any other actions recommended by the health authority.

[7] Rodriguez, R. *Evaluation of Field Test Kits to Detect Microcystins*. Environmental Protection Agency, 2010. Available online at http://www2.epa.gov/sites/production/files/2014-08/documents/microcystins-testkit-canada.pdf.

Appendix A - Cyanobacteria Preparation Checklist and Sample Contact List

Cyanobacterial Bloom Preparation Checklist

Preparation is key to an effective response to cyanobacterial blooms. Establishing relationships with other agencies and practising collecting and analyzing samples are important. Water suppliers and/or local governments should establish a plan for recreational and drinking water sources that may be vulnerable to cyanobacterial blooms, before the anticipated bloom season. This plan should lay out what to do in case a cyanobacterial bloom is visually detected in the water source. It should:

- Identify agencies responsible for sampling (establish clear responsibility for water sources requiring sampling).
- Describe the sampling strategy (parameters, frequency, timing, locations) to be followed for the duration of the bloom with respect to both routine sampling and resampling when microcystins are detected.
- Identify the analytical laboratory or laboratories that can do microcystin analysis.
- Ensure that agreement(s) and protocol(s) are in place with lab(s) for receiving and processing samples in a timely manner, and for communicating results from the lab to the appropriate contact people.
- Outline individual responsibilities for how samples will be collected and delivered to the laboratory.
- Specify the method(s) of microcystin detection/analysis that can be used.
- Identify the appropriate contact people to receive the results from the lab and who they must notify if microcystins are detected.
- Identify which authority or authorities are responsible to decide further notifications and actions.
- Identify which authority will take the lead role in notifying communities and other appropriate agencies or authorities.
- Set out a communications plan describing the circumstances and target groups for notifications, including when an advisory is issued or rescinded.
- Include sample messages and Qs & As to deal with different situations (e.g., microcystins level above guideline, microcystins detected below guideline level but still of concern for infants) and provide clear guidance to the public.
- Identify any corrective actions (e.g., treatment adjustments) and the triggers for such actions.

Sample Contact List of Relevant Agencies

Organization	**Role**	**Contact Name**	**Phone**	**Email**
Health Authority				
Water Supplier				
MoE				
Local Government				
Laboratory				
Media				

Appendix B: Suggested Messaging

Microcystins Detected in Drinking Water

Notice: *Do Not Use Water for Reconstituting Infant Formula*

- Use the format of Appendix 21 of the *Drinking Water Officers Guide*.[8]

Suggested Messaging

- This notice is being issued because blooms of blue-green algae (cyanobacteria) have been detected in the water supply.
- The Drinking Water Officer, in consultation with the Medical Health Officer, advises that the seasonal maximum acceptable concentration of 0.0015 mg/L (1.5 µg/L) has not been exceeded, and there is no reason for a health warning for the general population, including young children.
- However, because of the increased exposure of infants relative to body weight, another suitable source of drinking water (e.g., bottled water) should be used to reconstitute infant formula.

"Do Not Use" Notice

Notice: *Do Not Use Water*

- Use the format of Appendix 21 of the *Drinking Water Officers Guide* (referenced in footnote below).

Suggested Messaging

- This notice is being issued because blooms of blue-green algae (cyanobacteria) have been detected in the water supply, and the seasonal maximum acceptable concentration of 0.0015 mg/L (1.5 µg/L) has been exceeded.
- Consumers should seek other supplies of safe drinking water.
- Boiling is not effective in reducing or removing these toxins, although some point-of-use devices may be effective.
- Dialysis treatment units in the community should also be notified, especially if it is a first-time occurrence for blooms on this supply.
- A HealthLinkBC fact sheet entitled *Blue-green Algae (Cyanobacteria) Blooms* is available online at http://www.healthlinkbc.ca/healthfiles/hfile47.stm.

Recreational Water

Notice: *Beach Closed,* *Issued by: ______________*

Suggested Messaging:

- This notice is being issued because blooms of blue-green algae (cyanobacteria) have been detected in the water supply, and the recommended Health Canada guideline of 20µg/L for recreational water has been exceeded.
- Exposure to blue-green algae may cause nausea, vomiting, diarrhea and/or fever in humans and pets.
- People and pets should not drink or swim in the water until further notice.
- Anyone who comes in contact with blue-green algae should rinse off with fresh water.

[8] Government of British Columbia. *Drinking Water Officers Guide: Appendices*. 2015.