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

This protocol is intended to provide strategies and resources to assist local governments, health authorities, and water system operators to assess and manage risks related to cyanobacterial bloom formations in waterbodies used for both recreational and drinking water purposes.

Health Protection Branch: August 2018

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Introduction

Cyanobacterial blooms in drinking water supplies and recreational water bodies provide a challenge to both communities and regulators. These are often recurring events; however, predicting the timing, magnitude, duration, and potential health impact of a cyanobloom is complex (Burch et al., 2016). Effective management should be based on critically appraised, reliable sources of available information. This protocol is intended to provide strategies and resources to assist local governments, health authorities, and water system operators to assess and manage risks related to cyanobacterial bloom formations in waterbodies used for both recreational and drinking water purposes. It includes strategies for engaging stakeholders, choosing appropriate evaluation methods, and protocols and actions to take to reduce risks from blooms.

Background on Cyanobacteria

Cyanobacteria, also known as blue-green algae, are naturally occurring microscopic organisms found in waterbodies. It is estimated that there are between 2000 and 8000 species of cyanobacteria worldwide (Nabout et al., 2013). In Canada, cyanobacteria can occur in waterbodies at any time of year, although rapid proliferation causing blooms (known as cyanoblooms) occurs predominantly in the summer (USCDC NCEH 2015). In many cases, cyanoblooms tend to recur in the same waterbodies year after year, although not continuously (Burch et al., 2016).

Some species of cyanobacteria can produce secondary metabolites, known as cyanotoxins. During a cyanobloom, high concentrations of cyanotoxins may occur, which can be harmful to human health (Svircev et al. 2017). Cyanoblooms can be comprised of multiple species, not all of which are capable of producing cyanotoxins, but every cyanobloom should be treated as toxic until known otherwise. There are multiple types of cyanotoxins (e.g., nodularin, saxitoxin, cylindrospermopsin etc.); however, in Canada microcystins (MC) are generally regarded as the most important from a human health perspective (Health Canada 2016). There are almost 100 different variants of MC (Qi et al. 2015), with MC-LR, the most common MC variant, being classified as Group 2B, possibly carcinogenic to humans (IARC Monographs 94, 2010).

Factors inducing the production of cyanotoxins are complex. Environmental factors, such as temperature, light, nitrogen, total phosphate, carbon availability (in the form of bicarbonate, carbonate, and carbon dioxide), and pH, can all be important (Orihel et al. 2012; Hamilton et al. 2016; Pick 2016; Levy 2017). Water column stability is also important. Collectively, these factors create an ecological niche with plentiful nutrients, warm temperatures, and low water column mixing. In this ecological niche, cyanobacteria are able to out-compete phytoplankton, and a toxic bloom may form (**Figure** 1).

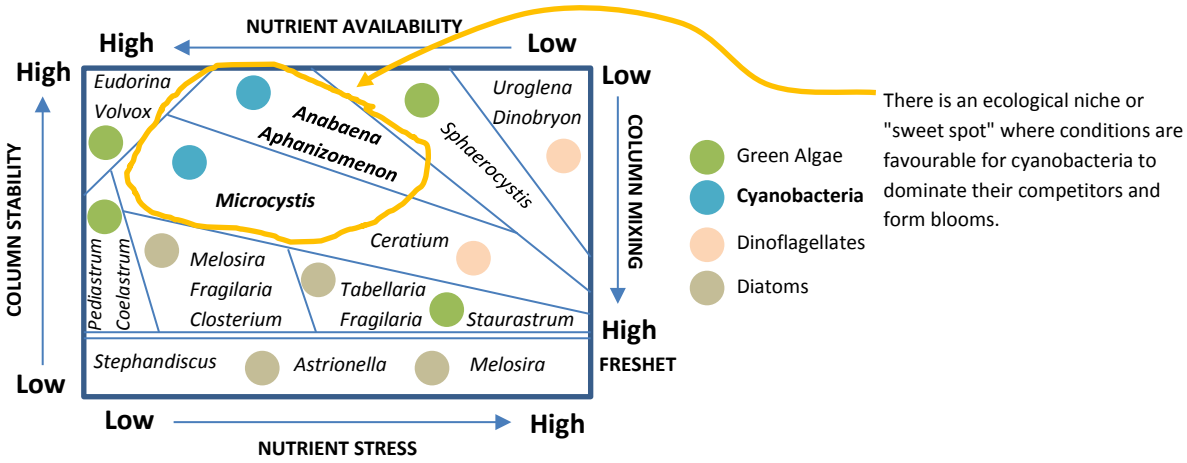


Figure 1. Dominant algal assemblages determined in terms of the relative availability of limiting nutrients and column mixing (after Reynolds, 1980)

Because toxin production varies greatly among different strains of the same species, differences in genetics, metabolic processes, and environmental conditions may also be important in the production of cyanotoxins. When present, cyanotoxin concentration can vary dramatically both spatially and temporally in the waterbody. Therefore, different parts of the same waterbody may have different concentrations, and this should be considered when deciding on testing protocols. Toxin levels do not necessarily coincide with maximum algal biomass. There can be significant variation in the amount of toxin per unit biomass of cyanobacteria over time, independent of changes in the cyanobacterial population. Cyanotoxins may persist in the aquatic environment, even after a cyanobloom has broken down and is no longer visible (Health Canada, 2016). For Microcystin, this lack of degradation may persist for 1 to 3 months, depending on the water body, initial microcystin concentration, and water temperature (Jones et al, 1994 Lahti et al., 1197b).

Cyanotoxins may be membrane bound within the cyanobacterial cells (intracellular) or occur free in the waterbody (extracellular) (Health Canada 2016). Most toxin release occurs as cells age and die, and passively leak their cellular contents; however, some active release of toxins can also occur from young, growing cells (Merel et al. 2013). It is therefore important to measure total MC due to the large number of MC variants and the possibility of both intra- and extracellular MC occurrence.

Guidance on Strategies for Evaluating and Managing Cyanobacteria and Cyanotoxins

Strategies for evaluating cyanobacterial blooms and potential cyanotoxin risk may range from simple bloom observation to comprehensive testing of cyanotoxin levels. The most appropriate management strategy for a given water body or community will depend on history, resources available, and the magnitude of potential impact on the community:

- Comprehensive sampling programs may be appropriate for waterbodies that receive high recreational use or are sources for community drinking water supply systems in areas where human, technical, and financial resources are readily available.
- Limited sampling/testing and/or reliance on qualitative observations may be appropriate for remote waterbodies, waterbodies upon which there is limited human activity, waterbodies within which bloom events are rare or unlikely due to mitigating characteristics within the waterbody, and waterbodies for which an extensive profile has been developed. In locations where blooms are recurrent problems, sampling may be of limited value other than to confirm what is already known, and resources may be better directed to implementing short or long-term mitigation measures and or communicating information to allow users to make them aware of risks so they can take steps to protect themselves and their families.

To help inform decisions on an appropriate management strategy for a particular water body, information may be gathered for consideration such as: nutrient loading and cyanobacteria species present in the watershed, geographical and seasonal trends, the population affected exposure type (route of exposure), the resources available, and potential actions available in response to evaluation.

Watershed information

Where available, watershed information such as: source water assessment studies, previous bloom events, nutrient loading (phosphorus or nitrogen) from agricultural or other land use disturbance activities, and geologic/geographic considerations may be useful in developing a profile for the water body.

If the waterbody of concern has been sampled by the Ministry of Environment & Climate Change Strategy (ENV) then both historical and/or current water quality information may be available on the ENV website at https://catalogue.data.gov.bc.ca/dataset/949f2233-9612-4b06-92a9-903e817da659. Detailed information on how to use this data can be obtained through the Environmental Monitoring System (EMS) web reporting tool, also located on the ENV website http://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/environmental-monitoring-databases/ems-web-reporting. Appendix B is a list of lakes that the ENV samples as part of the Provincial Lakes Monitoring Network. These lakes are sampled twice per year (early spring and late summer). Sampling includes water chemistry, chlorophyll a, and plankton analysis for species identification and quantity. All of this information may assist in determining if any testing/sampling for cyanotoxins is necessary, and at what frequency, for a given waterbody. Provincial Lakes Network data can also act as representative of lake water quality for nearby lakes. Long-term planning, which includes the effective management of nitrogen and phosphorus sources, may enhance watershed protection and reduce the incidence of cyanoblooms in a given region.

Benefits and limitations of sampling

Sampling and testing for the presence and concentration of cyanotoxins should be considered as part of a management strategy for assessing potential impacts to human health, and where drinking water systems may need detailed information with which to fine tune their water treatment facilities. However, sampling may provide limited, or no benefit in other situations.

All toxin sampling and testing systems have limitations with regards to accuracy of results, and how precisely they represent a given bloom situation within a waterbody. Cyanobloom conditions can change rapidly, and are dependent on a number of factors, such as the weather and circulation patterns (currents) within the waterbody. However, it is important to recognize that the cyanotoxins may persist for a period of time after the bloom itself has dissipated.

Where sampling is carried out, implementing a robust sampling protocol will provide a more accurate picture than a single sample regarding the level of risk the bloom poses to public health or the waterbody ecosystem. Sampling duration, location and frequency, as well as history of the site should be carefully considered when planning sampling programs. If the decision is made to conduct sampling/testing, the decision trees for drinking water and recreational water (Appendix A) may be utilized to ensure consistent sampling and interpretation of results, and alignment with the Guidelines for Canadian Drinking Water Quality.

Community Resources

Agencies involved with the initial screening of suspect blooms, as well as cyanotoxin testing of raw and drinking water sources may include local governments, water system operators, and/or Health Authority Environmental Health Officers. Operational decisions need to be made in each community regarding which agencies are to be involved with the screening and/or cyanotoxin testing of a given water source, and the level or degree of screening/sampling required for the waterbodies of a given region (if any). For example, in certain regions it may be the health authorities who do the sampling; in other regions, local governments may take on that role. Additionally, drinking water supply system operators may take on the role of screening/sampling where it is determined to be necessary. See Appendix C for factors to consider in the preparation of a contingency plan in advance of bloom season.

Communicating With the Public

Communities should work with their local Health Authority to ensure that an effective messaging protocol is in place to inform the public about bloom events; especially when drinking water sources are affected. Local government, private industry, and the health authority may need to work together to coordinate messaging (see Appendix D) regarding recreational water sources that are at risk and where swimming should be avoided. Dogs swimming in recreational water are at risk of illness or death due to ingestion of cyanotoxins, and there is no mandatory reporting of these incidents by veterinary clinics to government agencies. However, cases received by clinics may be reported to the Ministry of Agriculture (Health Centre Veterinary Pathologist), the Public Health Veterinarian at the BCCDC, or the Ministry of Environment & Climate Change Strategy on a voluntary basis.

Sampling, Portable Test Kits, and Laboratories

Sampling agencies should make themselves familiar with this protocol and work together to develop local communication protocols prior to bloom events. Agencies should understand their respective role(s) regarding observation, sampling, and decision making for a given source of drinking or recreational water.

This protocol refers to field test kit methods and laboratory testing. Field test kits have a range of detection limits and levels of accuracy/reliability vary. To limit the potential for error when using this protocol, field testing (using test kits for MC) is intended to determine MC presence or absence *only* (versus a specific quantifiable concentration). If field tests show the presence of MC, water samples should be forwarded to an analytical laboratory to confirm the presence and determine the concentration of MC, after which next steps should be determined based on these results.

There are a number of commercial MC test kits available that are suitable for field use. These are discussed in the recent Health Canada report 'Evaluation of Field Test Kits to Detect Microcystins' (Rodriguez et al., 2015). These test kits include technologies based on ELISA, immunochromatography, and phosphatase inhibition. When choosing a portable test kit, it is important to select the one that is appropriate for the range of MC concentrations you are screening for (i.e., 0.5 µg/L to 5 µg/L for drinking water, and a higher range for recreational water). In some cases, where the test kit range is below threshold (i.e., if using a kit to test recreational water that has been designed for detecting lower concentrations) dilution of samples with fresh water may be required to provide test results within the range of interest.

Several BC laboratories are equipped to test for MC, and sampling agencies should determine, in consultation with the local Health Authority, protocols for sampling, and where and how to send samples for analysis well before any bloom event occurs. Descriptions of appropriate laboratory techniques are discussed in the supporting documentation for Health Canada's guidance on cyanobacterial toxins (Health Canada, 2016).

Stakeholder Responsibility for Sampling and Testing for Bloom Events

Responsibility for cyanobacterial sampling, testing, decision making, and risk communication should be determined prior to the occurrence of bloom events. Communication between agencies is essential to ensure that an effective 'division of labour' is agreed upon, as well as an appropriate scope of sampling and testing of a given waterbody (i.e., which lakes are to be tested and at what frequency). Accordingly, agencies should consider the level of risk for a given waterbody as it relates to the allocation of available resources.

Stakeholder Roles and Responsibilities

Organization	Roles	Example of Responsibilities*
Single family residence	Source water protection, Observer, Sampler	• Minimize loading of nutrients (nitrogen and phosphorus) to source water • Observe water and report any suspected bloom events to ENV (complaints email box or RAPP line) or local Health Authority if there are concerns around drinking water supply • Act as volunteer water sampler for laboratory or on-site analysis
Local government	Source water protection, Observer, Sampler	• Manage land use planning and sewage services to minimise nutrient loading to source water • Develop watershed protection plans in conjunction with residents, industry, NGOs, neighbouring local governments (if applicable), and Regional Health Authorities • Optionally, employ designated water quality samplers • Issue and rescind beach closures • Update local advisories via web, radio, print, bulletin board, etc
Regulated water supplier	Advocate source water protection, Provide potable water	• Collaborate with local authorities on source water protection • Observe conditions daily at intake daily non-bloom phases and more frequently during blooms • Carry out raw water monitoring program in accordance with operating permit and directions from Health Authority • Monitor water treatment processes to ensure potability • Carry out treated water monitoring program in accordance with operating permit and directions from Health Authority • Notify users in the event of drinking water advisories (Do not drink, Do not use)
Regional Health Authority	Education, Statutory decision maker under *Drinking Water Protection Act* and *Public Health Act*	• Ensure compliance with drinking water operating permits • Review water quality analyses • Provide health advice regarding drinking and recreational water quality • Participate in recreational/drinking water sampling • Issue and rescind beach closures • If necessary, require water supplier to issue drinking water advisories • Participate in provincial recreational and drinking water committees • Provide health services to users impacted by cyanobacterial toxins
Provincial Government – Ministry of Environment & Climate Change Strategy	Ambient water quality protection, Water Quality Data collection and management, Public contact for bloom identification, Statutory decision maker under *Environmental Management Act*	• Conduct ambient water quality monitoring at selected lakes • Publish data on ambient water quality to support decision makers • Respond to public reports of blooms to assess the likelihood of cyanobacteria (i.e., visual confirmation and/or local knowledge) • Participate in provincial recreational water committee
Provincial Government – Ministry of Health	Policy, Education	• Establish provincial guidance on drinking and recreational water • Participate in health authority recreational water committee and lead drinking water committee • Participate in national drinking water committee • Publish HealthLinkBC advisories

* The responsibilities of different stakeholders are not fixed, and can be renegotiated to suit the local situation as required. Contact the regional local government and health authority for more information.

Appendix A - Protocol Decision Trees

The Protocol Decision Trees (for Drinking Water and Recreational Water) are standardized (stepwise) processes to follow when monitoring cyanobacterial bloom events. Each protocol recommends actions to address potential cyanobacterial blooms and associated cyanotoxin issues. Examples include directing a water supplier to switch to an alternative water source, issuing a 'Do Not Use Notice', or warning recreational water users of unacceptable water quality before it becomes a health hazard. The decision trees presented are modified from 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 and 2016 respectively).*

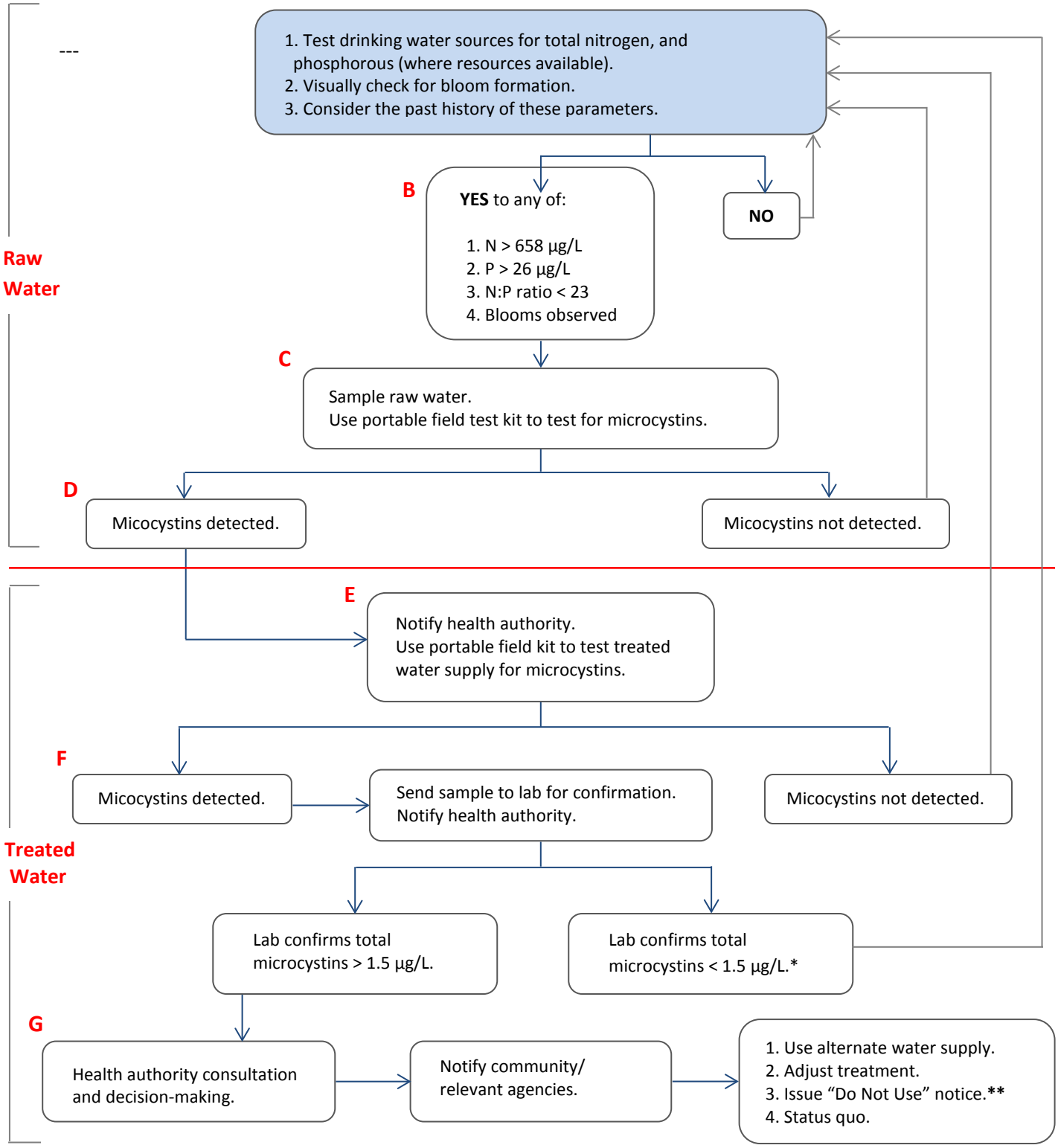
The Drinking Water Decision Tree Protocol also takes into account interim drinking water advice on MC provided by Health Canada in June 2015, which includes the addition of precautionary advice for infants as a result of the collaborative assessment undertaken by Health Canada and the United States Environmental Protection Agency as follows:

> *"A seasonal maximum acceptable concentration (seasonal MAC) of 0.0015 mg/L (1.5 μg/L) is proposed for total microcystin 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 microcystin 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 the decision tree protocols is to simplify the steps by separating drinking water (Decision Tree Part A) and recreational water (Decision Tree Part B), and to incorporate additional screening indicators that may reduce the costs associated with toxin sampling. The protocols also incorporate screening for total MC as a risk indicator rather than just MC-LR. These protocols provide a summary of the important factors that should be considered during bloom events and recommended actions that may be taken to address the issue.

Part A

Procedure for Screening/Quantitative Analysis for Communities Engaging in Sampling/Testing for Cyanobacteria Toxins in Drinking Water ('Decision Tree')



***** If microcystins are detected in treated 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.

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

Drinking Water Decision Tree for Cyanobacteria (Part A) – Step Descriptions

Step A: Initial screening for suspected blooms. Examine water for total nitrogen and/or phosphorus, and visually 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 ideal conditions for a cyanobloom. Testing for phosphorous and/or nitrogen may serve as an alert for impending cyanobloom, indicating a need for increased frequency of visual checks.

- Visually check for cyanobloom formation.

  As cyanoblooms tend to recur in the same water supplies, waterbodies that have historically exhibited cyanoblooms should be visually monitored for bloom formation. Additionally, waterbodies that experience changes in variables such as temperature, size, water depth, and nutrient content, may be susceptible to cyanoblooms and should be considered for increased monitoring. Public inquiries/complaints may also serve as a flag to inspect for cyanoblooms.

  A cyanobloom is identified by the appearance of 'soupy' water. Colours can range from grey, tan, blue-green, or bright blue, to reddish. The appearance of cyanoblooms may also be described as resembling fine grass clippings or small clumps. Changes in Secchi depth readings (i.e., cloudiness/turbidity) may be a sign of an impending cyanobloom (see Appendix E for more on cyanobloom algae identification).

Step B: If 'yes' to any of nitrogen (N) >658 µg/L; phosphorus (P) > 26 µg/L; an N:P ratio <23; changes in secchi depth; or cyanoblooms observed (see appendix E for bloom identification) – go to Step C. If "no", return to Step A.

- High levels of nitrogen and phosphorus, as well as a low ratio of nitrogen:phosphorous (N:P) can contribute to cyanoblooms and consequently the presence of MC if MC-forming species are present.

- According to Orihel et al. (2012), 95% percent of the cases where MC concentrations exceed the WHO drinking water guideline occur when phosphorus concentrations are above 26 µg/L and nitrogen concentrations are above 658 µg/L (Orihel et al., 2012). Maximum concentrations of MC occur in hypereutrophic lakes at mass ratios of N:P < 23. The probability of MC concentrations exceeding all toxin thresholds is highest when N:P ratios are < 20, and drop to near zero above an N:P ratio of 40 (Orihel et al., 2012).

- As growth conditions and nutrient content of each waterbody is unique, these numbers are provided as a screening reference for anticipating the risk of a bloom, and are not intended to be exact thresholds. For rationale on cyanobloom observation, See step A above.

Step C: Sample raw water. Use a portable field kit to test for presence of MC.

- Raw water samples should be collected prior to any treatment. Sampling from a reservoir should be done as close to the inlet 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).
- For the purpose of this decision document, presence of MC means > 1.0 µg/L using a portable test kit. See Rodriguez et al. (2015) on selecting a portable test kit. Be aware that toxins may persist following the collapse of blooms, particularly in the late summer and early fall, when the onset of colder temperatures and decrease in light intensity result in decreased rates of cyanotoxin degradation. This reduced degradation may indicate a need for sampling for cyanotoxins during and after the collapse of a bloom.

Step D: If MC are detected (> 1.0 µg/L) with a field test kit, go to step E, and alert the Health Authority of a potential issue. If MC are <1.0 µg/L, return to step A.

Step E: Use a portable test kit to test the <u>treated water</u> supply for MC.

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

Step F: If the portable test kit indicates MC are present (> 1.0 µg/L) in the treated water, send a sample to a laboratory equipped to analyse for MC for confirmation, and immediately notify the local Health Authority.

- **<u>The presence of MC indicates that there is a potential concern for infants who use formula reconstituted from that water. Consult the Health Authority regarding informing the public that an alternate source of drinking water should be used for reconstituting infant formula.</u>**
- Contact the Health Authority to confirm an appropriate laboratory for microcystin testing. Samples should be sent (in coolers) to the laboratory for analysis. Specific protocols for sampling and storing water samples *en route* to the laboratory should be identified in consultation with the laboratory, prior to a cyanobloom occurring to ensure accuracy of analyses.

Step G: If lab results indicate the seasonal MAC of 1.5 µg/L has been exceeded, the Health Authority should be contacted immediately for consultation and decision making.

Where laboratory analysis indicates that MC concentrations are near or exceed the seasonal MAC of 1.5 µg/L, the Health Authority should be consulted to determine a short 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 history of the site, the size and location of the bloom, available treatment technology, uses of the source water (recreational vs domestic) and monitoring of environmental conditions that might affect the bloom (e.g., wind). Water system operators may be able to provide information regarding the historical occurrence of cyanoblooms/MC for a given system.

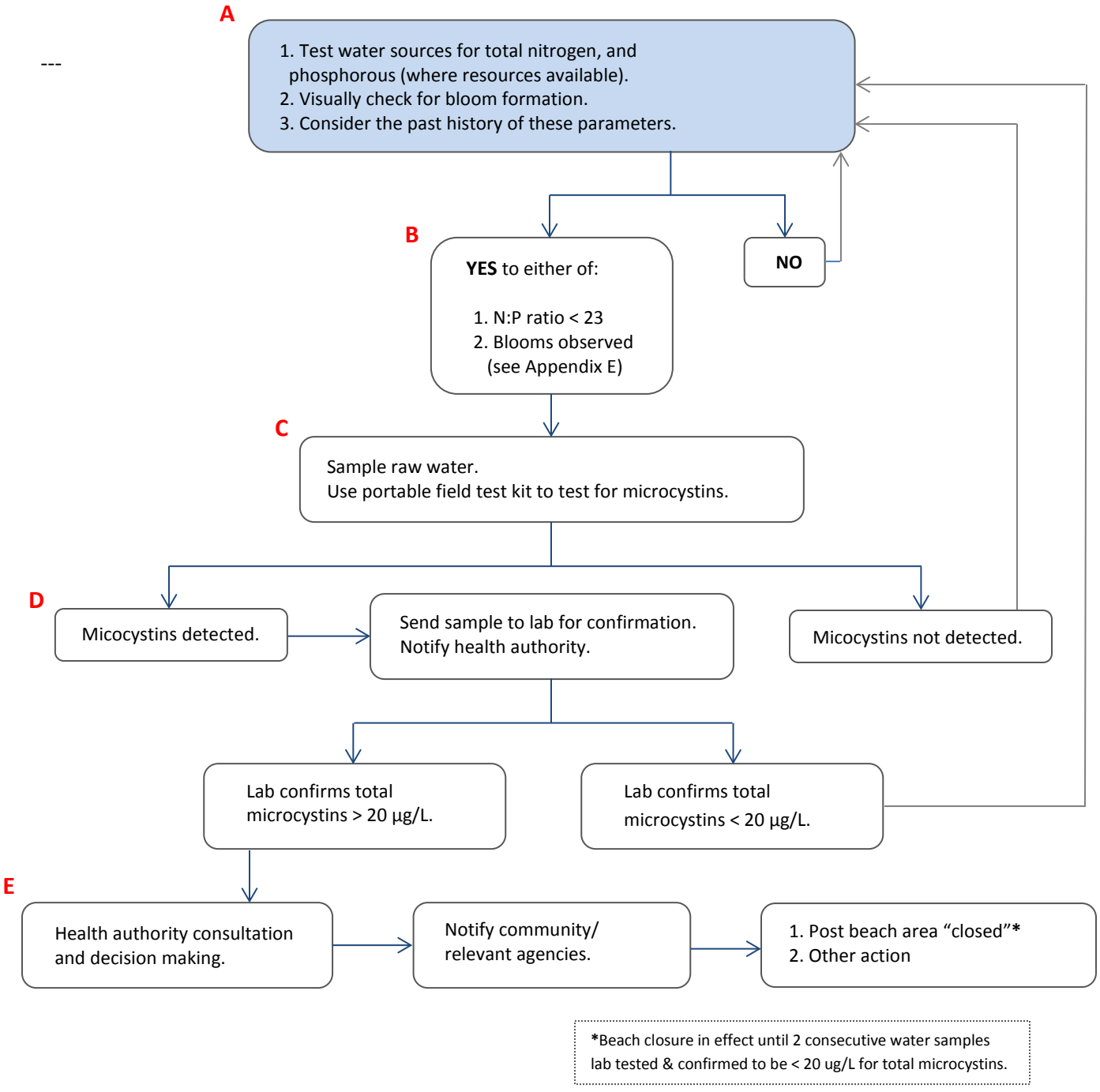
In response, the water supplier may need to do one or more of the following:

- Re-sample the treated water supply using field kit or laboratory analyses; conduct other monitoring.
- Use alternate water source or supply.
    - Discussions regarding alternative supplies should be reviewed with the Health Authority.
- Adjust treatment (if doing so will be effective in removing MC).
    - Discussions regarding treatment adjustments should be reviewed with the Health Authority.
- Issue 'do not use' advisory (see Appendix D 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' advisory be issued, and that consumers seek alternative supplies of safe drinking water until the risk passes.
    - Any 'do not use' advisory should remain in effect until two consecutive water samples within 48 hours (for both raw and treated supplies) are tested and confirmed to be less than their respective thresholds for MC.
- Maintain the status quo (continue monitoring).
- Other actions as required by the Health Authority.

Long-term issues and/or recurrence of cyanoblooms may require planning to incorporate specific treatment to correct the problem, and the use of an alternate water source in the interim**.** See Appendix F for more information on cyanobacteria management strategies for unregulated water systems. Note that the treatment process for mycrocystins may result in changes to other chemical parameters of the water.

Part B

Procedure for Screening/Quantitative Analysis for Communities Engaging in Sampling/Testing for Cyanobacteria Toxins in Recreational Water ('Decision Tree')



Recreational Water Decision Tree for Cyanobacteria (Part B) – Step Descriptions

Step A: Initial screening for suspected blooms. Examine water for total nitrogen and/or phosphorus; visually 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 a cyanobloom. Testing for phosphorous and/or nitrogen may serve as an alert for impending cyanoblooms, indicating a need for increased frequency of visual checks.

- Visually check for bloom formation:

  As cyanoblooms tend to recur in the same water supplies, waterbodies that have historically exhibited cyanoblooms should be visually monitored for bloom formation. As well, waterbodies that experience changes in variables such as temperature, size, water depth, and nutrient content, may be susceptible to cyanoblooms and should be considered for increased monitoring. Public inquiries/complaints may also serve as a flag to check for cyanoblooms.

  A cyanobloom is identified by the appearance of 'soupy' water. Colours can range from grey, tan, to blue-green, bright blue, or reddish. The appearance of cyanoblooms may also be described as resembling fine grass clippings or small clumps. Changes in secchi depth readings (i.e., cloudiness/turbidity) may be a sign of an impending cyanobloom (see Appendix E for more on cyanobloom algae identification).

  Be aware that cyanotoxins may persist following the collapse of a cyanobloom, particularly in the late summer and early fall, when the onset of colder temperatures and decrease in light intensity results in decreased rates of cyanotoxin degradation, which may indicate a need for sampling for cyanotoxins during and after collapse of the bloom.

Step B: If 'yes' to any of a N:P ratio < 23; or cyanoblooms observed (see Appendix E for bloom identification) – go to Step C. If "no", return to Step A.

- High levels of nitrogen and phosphorus, as well as a low ratio of nitrogen:phosphorous (N:P) can contribute to cyanoblooms and the presence of MC if MC-forming species are present.

- According to Orihel et al. (2012), concentrations of MC occur in hypereutrophic lakes at mass ratios of N:P < 23. The probability of MC concentrations exceeding all toxin thresholds is highest when N:P ratios are < 20, and drop to near zero above an N:P ratio of 40.

- As growth conditions and nutrient content of each waterbody is unique, these numbers are provided as a screening reference for anticipating the risk of a bloom, and are not intended to be exact thresholds.

- For rationale on bloom observation, see step 'A' above.

Step C: Sample raw water. Use a portable field kit to test for MC.

- 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 MC, as cyanobacterial biomass varies spatially within a waterbody (i.e., cells may be transported by wind currents).
- See Rodriguez et al. (2015) on selecting a portable test kit.

Step D: If MC is detected with a field test kit (> 20 µg/L), send a sample to laboratory for quantitative analysis.

- For the purpose of this decision document, presence of MC means > 20 µg/L using a portable test kit.
- Contact Health Authority to confirm an appropriate laboratory for MC testing capability.
- Samples should be sent (in coolers) to the laboratory for analysis. Specific protocols for sampling and storing water samples *en route* to the laboratory should be identified in consultation with the laboratory, prior to a cyanobloom occurring to ensure accuracy of analyses.

Step E: Health Authority consultation and decision making.

Where laboratory analysis indicates that levels of MC are near or exceeding the threshold of 20 µg/L, the Health Authority should be consulted to determine a short 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 uses of the site (i.e., swimming), the size and location of the bloom, the environmental conditions that might affect the bloom (e.g., wind), and the history of the water body.

The authority responsible for the recreational water body may need to do one or more of:

- Resample water immediately, and send to laboratory for confirmation of result.
- Take appropriate action(s), which may include:
  - Post beach area and notify community
    - See attached template (appendix D) for wording.
    - The HealthlinkBC fact sheet on cyanobacteria blooms is available at http://www.healthlinkbc.ca/healthfiles/hfile47.stm to help convey information to communities.
    - Any beach closure should remain in effect until two consecutive water samples within 48 hours are tested and confirmed to be less than 20 µg/L for total MC.
- Notify local water supply operator that toxins have been found in their area.
- Other actions recommended by Health Authority.

Appendix B - Provincial Lakes Network

The following is a list of lakes that are samples by ENV as part of the Provincial Lakes Network. Lakes are sampled twice per year in early spring and late summer. Sampling includes water chemistry, chlorophyll a, Secchi disk, and plankton analysis for species composition and quantity.

Region	Okanagan	Vancouver Island	South Coast	Kootenay	Skeena	Omineca-Peace	Thompson	Cariboo
	CHRISTINA L @ CHRISTINA	COWICHAN LAKE STATION # 1	DEER LAKE AT CENTRE	COLUMBIA LAKE	LAKELSE LAKE	NADSILNICH (WEST) L	SHUSWAP LK OPPOSITE MARBLE P	WILLIAMS LAKE
	CHRISTINA LAKE NORTH BASIN	COWICHAN LAKE STATION # 2	ALTA LAKE	WINDERMERE L	DIANA LAKE	TABOR L	SHUSWAP LK WEST OF SORRENTO	CHIMNEY LAKE
	KALAMALKA L SOUTH	COWICHAN LAKE STATION # 3	BROHM LAKE; MIDLAKE	MOYIE LAKE, NORTH	MORICE LAKE, CENTER	CLUCULZ L EAST ARM	SHUSWAP LK OFF BROKEN PT	DRAGON LK
	KALAMALKA LAKE DEEP BASIN	ELK LAKE, CENTER	Chilliwack Lake	MOYIE LAKE, SOUTH	BURNS L	CLUCULZ LAKE WEST	SHUSWAP LK OFF ENCOUNTER PT	HORSE LK
	KALAMALKA LAKE SOUTH END	LANGFORD LAKE	Sasamat Lake	SLOCAN LAKE, N. END	BURNS LAKE, DEEP STN #2	FRASER L MIDDLE	SHUSWAP LK OFF ARMSTRONG PT	PUNTZI LAKE
	MABEL L @ SOUTH END (PE00173)	QUAMICHAN LAKE	Como Lake	SLOCAN LAKE, S. END	BABINE LAKE, CENTER	FRASER L WEST BASIN	SHUSWAP LK OFF CANOE PT	BOWRON LAKE
	MABEL L @ TSUIUS CREEK	BAINBRIDGE LAKE, DEEP STN	BURNABY LAKE	PREMIER LAKE	BABINE LAKE, STN. 2	STUART LK EAST	ADAMS LAKE, CENTER	BIG LAKE
	MARA SOUTH	BRANNEN LAKE	ALPHA L CENTRE	TROUT LAKE	BABINE LAKE, STN. 4	MOBERLY LAKE	PENNASK LK NEAR CENTER	BRIDGE LAKE
	MARA LAKE OPPOSITE FOSSETT	LIZARD LAKE	NITA LAKE	WHITESWAN LAKE	KATHLYN LAKE	SWAN L	STUMP LK AT CENTER	HORN LAKE
	OKANAGAN L CENTRAL	QUATSE LAKE	LOST LAKE, CENTRE	ST. MARY`S LAKE	TYHEE LAKE @ DEEP STN	CHARLIE L	NICOLA LK AT DEEPEST PT.	LAC LA HACHE
	OKANAGAN L D/S KELOWNA	SHAWNIGAN LAKE, #1	GREEN LAKE CENTRE	SUMMIT LAKE	FRANCOIS LAKE CENTRE	CHARLIE North arm	WHITE LAKE	MCLEESE L.
	OKANAGAN L NORTH	SHAWNIGAN LAKE, #2	SAKINAW LAKE	JIMSMITH LAKE	FRANCOIS LAKE EAST END	ONE ISLAND LAKE	MONTE LAKE AT CENTER	SPANISH LAKE
	OKANAGAN L SOUTH	SHAWNIGAN LAKE, #3	LOIS LAKE, CENTER	TIE LAKE	FRANCOIS LAKE WEST END	NALTESBY (Bobtail) LK.	ROCHE LAKE AT CENTRE	TATLA LAKE
	OSOYOOS L OPP. MONASHEE CO-OP	SHAWNIGAN LAKE, WEST ARM	Buntzen Lake	WASA LAKE	DECKER LAKE	PURDEN LK DEEP STN.	Peter Hope	CANIM LAKE WEST END
	OSOYOOS L SOUTH BASIN	COMOX LAKE INLET BASIN			ROUND LAKE, DEEP STN	SUMMIT LK	BIG BAR LK AT CENTER	CANIM LAKE S. OF BOSS CK.
	OSOYOOS LAKE CENTRAL BASIN	COMOX LAKE MAIN BASIN			SEYMOUR LAKE, CENTER	CARP L	BONAPARTE LK WEST END	
	SKAHA L OPP. GILLIES	COMOX LAKE OUTLET BASIN					PAUL LAKE AT CENTER	
	SKAHA L SOUTH BASIN	SPROAT LAKE - FABER ARM					GUN LAKE AT CENTER	
	SKAHA L WEST	SPROAT LAKE - STIRLING ARM					HEFFLEY LAKE AT CENTRE	
	SUGAR L @ SITKUM CR.	SPROAT LAKE - TAYLOR ARM					LAC LE JEUNE AT DEEPEST PT	
	WOOD LAKE DEEP BASIN	SPROAT LAKE - WEINER ARM					LOON LK AT ROCK BLUFF	
	ELLISON LAKE CENTRAL						DUTCH LK OFF ISLAND	
	Green=shallow <10m (epi only)							
	Blue= intermediate depth 10- 20m							
	Black= deep (epi & hypo samples)							
	Brown shaded = Defer to 2018 or later							

Appendix C - Cyanobacteria Preparation Checklist and Contact List Template

Preparation is crucial to an effective response to cyanobacterial blooms. The process will go more smoothly if preparations are made in advance, and collecting and analysing samples are practiced in advance. Water supplier and/or local governments should develop and establish a plan prior to bloom season for both recreational and drinking water sources that are or may be vulnerable to cyanobacterial blooms. This plan should lay out what to do if a cyanobacterial bloom is visually detected in the water source. It should:

- identify the 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 re-sampling when MC is detected;
- identify the analytical laboratory or laboratories that can do MC analysis;
- outline individual responsibilities for how to collect and deliver samples to the laboratory, and ensure specific sampling protocols for the selected laboratory are known and followed;
- specify the method(s) of MC detection/analysis that can be used with the laboratory;
- identify the appropriate contact people to receive laboratory results and who they must notify if MC is detected;
- identify which authority/authorities are responsible for deciding further notifications/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 notification, including when an advisory is issued or rescinded, and what situation calls for which messaging;
- include sample messages and questions/answers to deal with different situations (e.g., MC detected above guideline; MC detected below guideline level but still of concern for infants) and provide clear guidance to the public;
- identify corrective actions (e.g., water treatment adjustments) and triggers for such actions;
- ensure steps are in place for different situations (e.g., long-lasting as opposed to short-lived blooms; and
- identify closing procedures and follow up (e.g., keep a record of the bloom: start and end date of cyanobloom and cyanotoxin detection, species identified, cyanotoxins present, actions taken, authorities involved, and lessons learned).

The following is an example contact list of relevant agencies:

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

Appendix D - Suggested Messaging

1. **Microcystins detected in drinking water:**

Notice: Do Not Use Water for Reconstituting Infant Formula
Issued By:_____

Use format of Appendix 21 of the Drinking Water Officers Guide (https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/how-drinking-water-is-protected-in-bc/appendices.pdf)

Suggested Messaging:

This notice is being issued because blooms of cyanobacteria (blue green algae) have been detected in the water supply.

The Drinking Water Officer, in consultation with the Medical Health Officer, advises that the seasonal maximum acceptable microcystin 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, as a precaution, an alternate suitable source of drinking water (such as bottled water) should be used to reconstitute infant formula. **Boiling is not effective** in reducing or removing these toxins. Exposure to toxins produced by cyanobacteria may cause nausea, vomiting, diarrhea, or fever.

2. **Do not use water notice:**

Notice: Do Not Use Water

Issued By:_____

Use format of Appendix 21 of the Drinking Water Officers Guide (https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/how-drinking-water-is-protected-in-bc/appendices.pdf)

Suggested Messaging:

- This notice is being issued because blooms of cyanobacteria (blue green algae) 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.*
- Exposure to toxins produced by cyanobacteria may cause nausea, vomiting, diarrhea, or fever in humans and pets.
- Consumers should seek alternative 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 health fact sheet on microcystin (It's your health: Blue green algae (cyanobacteria) and their toxins) is available at http://www.healthlinkbc.ca/healthfiles/hfile47.stm

3. Recreational Water

Notice: Beach Closed

*Issued By:*_____

Suggested Messaging:

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

4. Communication Best Practices

Best Practice	**Application in Water Advisory Notice**
1. Tell them who you are.	The community drinking water provider (utility name).
2. Establish that you care.	To protect your health.
3. State the action they need to take.	The tap is currently only safe for external use. Do not boil the water, because boiling makes it worse.
4. Share the potential consequences.	If you swallow the water, you may experience nausea, diarrhea, vomiting, or liver and kidney damage (note: message depends on the MC concentrations detected and should be developed in consultation with the Health authority).
5. Provide the date	FROM [DATE].
6. Point to more information	For more information and advice please [CONTACT INFO].

Appendix E – Algae Identification and Testing

Algae identification – Impact Assessment Biologists with ENV may be able to identify the algae to the genus or species level but for definitive identification samples will need to be sent to a lab. Photos of the bloom (with a request for identification) can be sent to ENV at EnvironmentalComplaints@gov.bc.ca

Field Tests:

Both the jar test and the stick test can help to identify algae; however they may not be able to identify when multiple species are present.

Jar Test - Cyanobacteria float to the top or remain suspended in the water column

Stick Test – long strands are probably NOT cyanobacteria

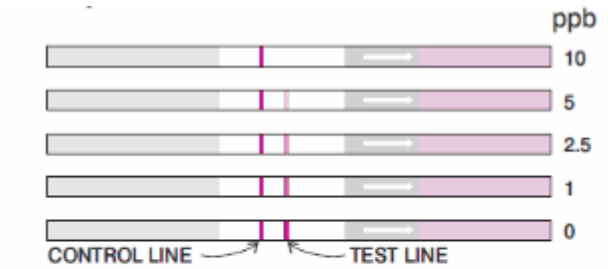
GREEN ALGAE BLUE-GREEN ALGAE

Reference for Jar Test: Dani, 2016

Microcystins

Quantitative – the field test kits can test for ranges of microcystins present but for greater accuracy, a sample should to be sent to a lab.

Presence/ Absence – field test kits are ideal for presence/ absence tests and often can give a range of values.



INTERPRET TEST

CONTROL LINE	TEST LINE	INTERPRETATION
NO CONTROL LINE PRESENT	NO TEST LINE PRESENT	INVALID RESULT
CONTROL LINE PRESENT	NO TEST LINE PRESENT	>10 ppb
CONTROL LINE PRESENT	MODERATE INTENSITY TEST LINE PRESENT	BETWEEN 0 AND 10 ppb

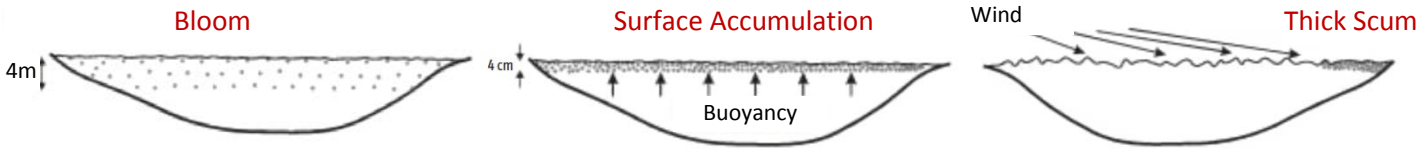
Sample field test interpretation from an Abraxis test kit.

Appendix F - Cyanobacteria Decision Support for Unregulated Water Systems

All surface water should be treated with filtration and disinfection to control pathogens. This is often referred to as 43210 treatment, meaning 99.99% reduction in viruses, 99.9% reduction in cysts, 2 independent treatment devices, 1 turbidity unit maximum, and 0 coliform bacteria in treated water - see 'Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in BC' on the Ministry of Health website (https://www2.gov.bc.ca/assets/gov/environment/air-land-water/surfacewater-treatment-objectives.pdf).

Algae and cyanobacteria are always present in ponds and lakes. Algae are microscopic plants. Algae can cause aesthetic problems with taste, odour and turbidity in drinking water. The presence of algae does not imply an environmental or human hazard as long as the cells remain thinly dispersed. Cyanobacteria are naturally occurring microscopic organisms found in waterbodies, and are different to algae. By contrast, cyanobacteria can produce toxins that may be harmful to human and animal health. Visible blooms, whether algae or cyanobacteria, should be considered potentially harmful when cells are visible throughout the water column or surface accumulations or thick scum are present, until testing has been conducted.

Cyanobacteria are present at low levels in most lakes. Environmental conditions can concentrate them up to 1000 times.



Cyanobacteria can sometimes produce dangerous toxins that may damage the liver and brain if ingested or inhaled (droplets) in high concentrations. You can avoid these potential health risks by using bottled water (or another safe source) for all ingestion (cooking and drinking) during bloom events. Also, try baths rather than showers during blooms, and avoid swimming in any bloom. Contact with cyanotoxins also causes skin irritation in some people, but this causes no lasting harm.

If there is a visible build-up of algae (a bloom) seen, the *first step* is to try to **determine if it is** cyanobacteria **(**blue-green algae) Photos of a suspected bloom can be emailed to EnvironmentalComplaints@gov.bc.ca with a request for assistance to identify the algae. An alternative is to call the RAPP line 1-877-952-7277.

Filamentous green plant algae bloom.
→ Not likely dangerous

Planktonic cyanobacteria bloom.
→ Possibly dangerous

During active plant algae blooms, the water is at low risk of containing significant cyanotoxins, but algae is known to cause aesthetic taste and odour problems. Aesthetic issues are not hazardous to human health, but may affect how you feel about drinking the water. You may prefer to use an alternate drinking water source during these non-hazardous blooms.

During active cyanobacteria (blue-green algae) blooms, the safest approach is to use an alternate source of water for drinking, washing, and preparing food, and brushing teeth, such as bottled water, potable water hauled to a storage tank (cistern), or well water. Because of the increased sensitivity of infants, it is especially important to adopt a precautionary approach and use safe (e.g., bottled) water to reconstitute infant formula.

If the water intake is outside of the active cyanobacteria bloom, water may be used for potable uses as long as extra monitoring and precautions are used – check filter frequently for signs of cyanobacteria and replace or backwash as needed. Granular activated carbon and/or reverse osmosis is recommended to remove dissolved cyanotoxins if the bloom is widespread. **Boiling water does not remove cyanotoxins – it concentrates them.**

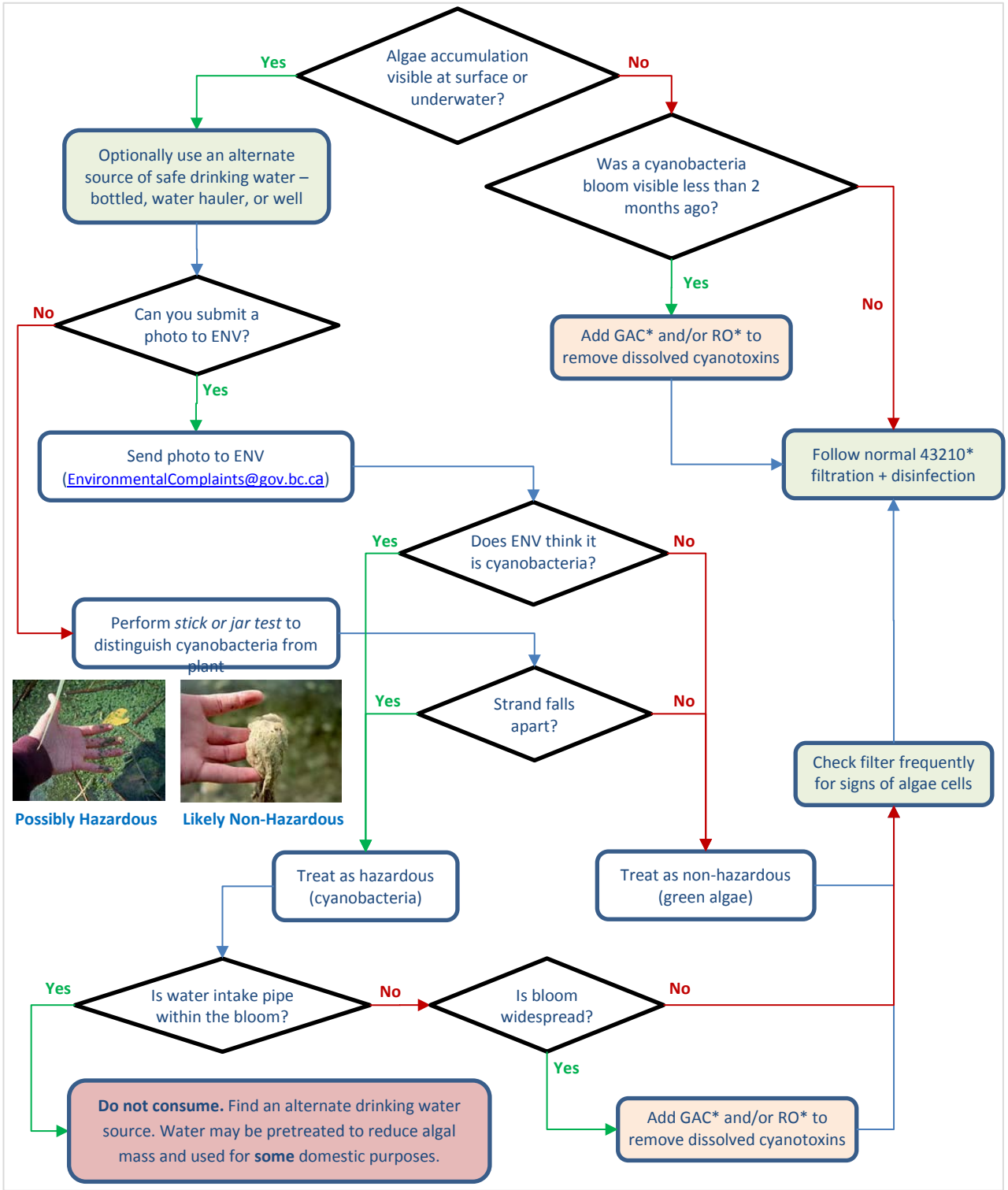
If the water intake is within any active bloom (whether cyanobacteria or plant algae), the mass of algae will likely overwhelm most filtration systems. If possible, move the intake away from the bloom or to >4 metres depth. If the intake cannot be moved, another source of drinking water must be found. Microfiltration, activated carbon, and reverse osmosis should be bypassed. With coarse pre-filtration (20 to 5 micron) to reduce algal mass, water drawn from an active bloom may be used for non-contact purposes such as toilet flushing.

Regulated water suppliers or individuals who cannot switch to an alternate source should contact the Regional Health Authority for more information on options to maintain service during cyanobacteria blooms.

Any test is indicative of water quality only at the time and location of sampling. During an active bloom, water conditions can vary dramatically from place to place and even hour to hour. Testing kits for cyanotoxins give same-day results for detecting the presence or absence of cyanotoxins. Packs of 20 tests cost about $600 (e.g., *Abraxis*). These may be useful to ensure a water treatment system is removing toxins, or to ensure significant levels of toxins are not present in lake water between bloom events. Quantitative laboratory tests for cyanotoxins ($120) or to identify and enumerate algae species ($80) are also available. Results take one to two weeks (e.g., *MB Laboratories* in Sidney, BC).

Homeowners should be cautious about relying on pull test and field test kit results to make decisions about cyanobacteria (blue-green algae) health risks. If in doubt, use bottled water or another safe water source for all ingestion (drinking and food preparation) during and up 1 to 3 months after cyanobacteria blooms disappear.

The following flowchart can help homeowners manage algae in their unregulated water systems.



*Note that cyanoblooms often have a septic/musty odor, and sensitive individuals may experience tearing near wind-accumulated areas. Dipping bare hands into a potential bloom is not advised.

Example scenarios for blue-green algae (cyanobacteria) occurrence, recommended water uses, and treatment.

Scenario	Total Microcystins (µg/L)	Recommended Use for Water	Treatment Objective	Example Processes	Comments
No recent bloom, no evidence of cyanobacteria in lake, or isolated bloom far from intake	< 1.5	Potable	Pathogen control (43210)	Pre-filtration + Microfiltration + { Chlorination, UltraViolet, Reverse Osmosis, or Boiling }	Base case disinfection
Bloom close to intake or 1 to 3 months post-bloom*	Possibly > 1.5	Potable	Pathogen control (43210) + cyanotoxin removal	As above, but add: Activated Carbon and/or Reverse Osmosis	Check filters and replace or backwash frequently for signs of algae. Replace activated carbon frequently.
		Non-potable**	Reduction of suspended solids and turbidity	Pre-filtration + Optional Chlorination	Check filter and replace or backwash frequently for signs of algae. Optional chlorination may reduce skin irritation.
Intake in algae bloom*	Possibly >> 1.5	Non-potable **	Reduction of algae mass	Bypass potable filtration systems. Pre-filtration + Optional Chlorination	Algae will overwhelm and clog filtration system. Optional chlorination may reduce skin irritation.

* If possible, move intake to deeper water (>4m deep) after bloom has passed.

** Use alternate source of potable water (eg bottled).

Description of water treatment processes [*applicable certification standard for treatment devices*]

- **43210**. Treatment achieving 99.99% reduction in viruses, 99.9% reduction in cysts, 2 independent treatment devices, 1 turbidity unit maximum, and 0 bacteria.
- Microfiltration (**MF**). MF uses pore sizes from 0.1 µm to 1 µm-absolute to remove parasitic protozoan cysts [*NSF 53 for cysts*].
- Ultrafiltration (**UF**). UF uses pore sizes from 0.01 µm to 0.1 µm to remove parasitic protozoan cysts and bacteria.
- Chlorination (**Cl_2**) uses unscented bleach as a disinfectant to kill pathogenic bacteria and enteric viruses. 1 ppm × 15 min contact time [*NSF 60 optional*].
- UltraViolet (**UV**) disinfection uses strong UV light to inactivate bacteria, viruses and cysts [*NSF 55 Class A or equivalent*].
- Reverse Osmosis (**RO**) pushes water through an incredibly fine membrane to remove almost all impurities, including cyanotoxins. RO is usually only installed on one or two drinking water taps in the home (point-of-use) [*NSF 58 or equivalent*].
- **Boiling** uses temperatures above 70°C to kill bacteria, viruses and cysts, but ***does not remove cyanotoxins***.
- (Granular) Activated Carbon (**GAC**) uses carbon to adsorb organic chemicals, including cyanotoxins [*NSF 42 or equivalent*].
- **Pre-filtration** uses coarse membranes or a back washable sand filter (effective pore size 5 to 20 µm) to reduce the mass of large particles [*NSF 61*].

Appendix G - Regulatory Agency Contacts for Reporting Bloom Events

***When contacting regulatory agencies, use the word 'algae' in subject line describing the concern. Include the name of the lake or water body, along with the general area or name of the nearest community.**

Northern Health Authority

Email: php@northernhealth.ca

Regional Offices:

Northwest (Terrace) 250-631-4222
Northern Interior (Prince George) 250-565-2150
Northeast (Fort St John) 250-263-6000

Island Health Authority

Email: Gateway_office@viha.ca
Tel: 250-519-3401 (Rory Beise) or 250-737-2010 (Heather Florence)

Interior Health Authority

Regional Offices:

Kootenay 250-420-2220
Okanagan 250-549-5714
Thompson 250-851-7340

Fraser Health Authority

Email: feedback@fraserhealth.ca
Tel: 604-870-7903

Vancouver Coastal Health Authority

Email: HealthProtectionCG@vch.ca
Tel: 604-885-5164

First Nations Health Authority

Environmental Health: 1-844-666-0711123

Ministry of Environment & Climate Change Strategy, Environmental Protection

Email: EnvironmentalComplaints@gov.bc.ca
Tel: RAPP line 1-877-952-7277

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