ATLANTIC CANADIAN CYANOBACTERIAL WORKSHOP 2018

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National Research Council Canada, Halifax, NS

Workshop Final Report

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Workshop Objectives

The last few summers have seen an unprecedented rise in the occurrence and impact of cyanobacterial blooms in the lakes and rivers of Atlantic Canada. These have already affected recreational waters, harmed pets and will cause ongoing issues as they reoccur in the region over the coming years.

The main goal of the Atlantic Canadian Cyanobacterial Workshop (ACCW) was to bring together the diverse group of stakeholders involved in monitoring, managing or studying cyanobacteria and their toxins in Atlantic Canada so as to build awareness of emerging needs and existing expertise in the region. By increasing awareness of common challenges and existing capabilities a foundation can be developed for ongoing discussion and collaboration that will be needed to effectively manage the issue going forward.

Workshop Summary

Attendees and presenters represented professionals working on both drinking and recreational waters across government, academia, and private sectors. Despite this diversity in background and area of expertise, a number of common themes emerged throughout the day.

It is clear from the emerging nature of the problem that the situation with respect to cyanobacteria in the region is rapidly changing. Over the past few years, freshwater algal blooms have been reported to local and provincial governments and in an increasing number of locations, both in recreational and drinking water systems. The frequency of bloom occurrence in jurisdictions without experience or expertise in cyanobacteria, makes planning an effective strategy for dealing with the problem in the future difficult when the endpoint is unknown. The dynamic nature of the problem was particularly well captured by results presented by Wendy Krkosek (Halifax Water) and Graham Gagnon (Dalhousie University). They showed how the water chemistry in reservoirs in HRM are rapidly changing towards conditions that are more favorable for the formation of algal blooms. They have called this phenomenon “lake recovery” and attributed it to remediation of industrial pollution that previously led to acid rain in Atlantic Canada since industrialization in the North Eastern United States. This same phenomenon is expected to be occurring throughout the region and, along with climate warming and anthropogenic nutrient inputs, can help explain the emerging nature of the problem.

Another common thread identified by multiple presenters was that the lack of access to local, timely and affordable testing for cyanotoxins is currently limiting the ability of many jurisdictions to carry out effective monitoring to meet national water quality guidelines. This point was raised by provincial government representatives from Prince Edward Island (Cynthia Crane, Morley Foy), Nova Scotia (Andrew Sinclair) and Newfoundland and Labrador (Kyla Brake), who also indicated that in the absence of algae/toxin analysis, provincial and local governments were heavily reliant upon reports of observed blooms and visual assessment. Currently, most regional cyanobacteria monitoring is being performed in response to observed blooms, therefore current data sets on cyanobacteria/cyanotoxin occurrence are perhaps not representative of the overall situation in the region. There is a need for both drinking water utilities and recreational water managers to have effective monitoring programs, including identification of triggers for action. However, there are numerous screening and monitoring techniques and technologies available, with more under development, and approaches to developing a monitoring framework differ between regions. There is no one-size-fits-all approach, it is largely dependent on the risk to the water body and end-users, the resources available and understanding of the situation. Organizations with a longer history of dealing with cyanotoxins such as the Ontario Ministry of the Environment (Xavier Ortiz) and the Ohio Environmental Protection Agency (Heather Raymond) have settled on a combination of different testing methods for different classes of toxins and a tiered screening/confirmation strategy. Availability of more comprehensive data sets on the occurrence of cyanobacteria and their toxins in Atlantic Canada are necessary to plan strategies for monitoring and responding to blooms across all sectors.

The situation is similar for drinking water treatment where different strategies are required for different toxins and different species of cyanobacteria, as highlighted by Arash Zamyadi (Polytechnique Montréal) and Mike Chaulk (CBCL Limited). There is a need to develop a risk profile for removal of algal toxins, as much as it is important to develop a source water monitoring framework to understand presence of algal toxins. Tools exist, like CyanoTox 2.0 that can help utilities to understand which algal toxins and at what concentrations would leave them susceptible to breakthrough. Treatment will be through a multi barrier approach as there is no single treatment process that is effective against all algal toxins.

Across all sectors, public engagement and education are important components of tackling the issue on a regional level, a point made by Hugh MacIntyre (Dalhousie) during the short panel discussion who noted that “information is the currency of interest to the public”. As progress is made in addressing this issue in the region, a framework should be established for informing and engaging the public. It was suggested that a similar approach to that taken by the Government of Nova Scotia in educating the public about tick safety (https://novascotia.ca/ticksafety/) could be appropriate – know the dangers, take recommended precautions. It was also suggested by Chris Miles (NRC) in the panel discussion that the public could be engaged to carry out sampling across the region to help fill gaps in toxin occurrence data. From a communication perspective there is also need for the use of consistent messaging across utilities, municipalities, provinces and public health officials.

Finally, all the presentations and discussions made it evident that a significant body of expertise already exists in the region, often arising from successful collaboration between municipalities, water utilities, government agencies, and academic stakeholders. A lot can also be gained from interacting with and collaborating with organizations from other jurisdictions with a longer history of addressing these issues. Continued communication between the diverse stakeholders identified during the ACCW will be important for effective management of issues surrounding cyanobacteria and their toxins in the Atlantic Provinces going forward. To this end, there was general agreement from those in attendance that a follow-up meeting should be held in 2019.

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Appendix

Presentation abstracts, workshop schedule, and attendee contact information.

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Appendix

Presentation Abstracts

08.50 Xavier Ortiz (Ontario Ministry of the Environment, Conservation and Parks, Toronto, ON)

Cyanotoxins in Ontario's Great Lakes

The Ontario Ministry of the Environment, Conservations and Parks (MECP) is the only licensed and accredited laboratory in the province for the analysis of microcystins and anatoxin-a in freshwater samples. Since 2004, MECP's Laboratory Services Branch has analyzed over a thousand samples every year to ensure the province's drinking and recreational water safety. In this presentation, an overview of the most common cyanotoxins found in Ontario's Great Lakes is provided. Most common techniques for microcystins and anatoxin-a are discussed, with special focus on ELISA and LC-MS approaches. MECP's protocol for cyanotoxins monitoring, analysis and reporting strategies are also shared with the audience. Results obtained from Ontario's Drinking Water Monitoring Program 2004-2016 are summarized. Samples from Lake Ontario (Bay of Quinte) usually presented lower concentrations of microcystins, where –LR, -RR and –LA variants were present at similar ratios. Samples from Lake Saint Clair and Lake Erie showed slightly higher concentrations, being –LA the predominant variant. Samples from Pelee Island presented a very unique microcystin fingerprint. Microcystins were detected in 59.5% of the raw samples analyzed (1775 total), but less than 0.4% presented values above Ontario's guideline for microcystin-LR (1.5 µg/L). After the drinking water treatment, less than a 0.2% of the analyzed samples (465) presented detectable microcystins, where in all cases these values were clearly below the guidelines.
Several research projects are also briefly showcased:

- MECP's automated method for cyanotoxins analysis based on in-line SPE LC-MS was able to increase the laboratory's capacity by a factor of x5, and lower the emergency response from 4 days to 3 hours.
- The untargeted method for microcystin analysis based on Data Dependant Acquisition by QTOF-MS was able to detect and characterize microcystin variants not previously reported.
- The developed method for the analysis of free microcystins in fish evidenced that 1) these toxins were mainly present in liver samples; 2) concentrations in walleye were an order of magnitude higher than in yellow perch; 3) –LA was the most common variant in fish liver, which was also the most common variant in the water samples from where the fish were caught.

09.30 Graham Gagnon, Lindsay Anderson, Amina Stoddart (Dalhousie University, Halifax, NS), **Wendy Krkosek** (Halifax Water, Halifax, NS)

Understanding lake recovery impacts in Nova Scotia and the reality of this change for drinking water utilities

Many surface waters in Atlantic Canada are sensitive to acid deposition (acid rain) attributed to the long-range transport of SO_x emitted by power generating processes in Eastern Canada and the United States. Accordingly, acid rain control programs have resulted in substantial reductions in SO_2 emissions and SO_4 deposition in surface waters has also decreased. Thus, some lakes throughout Atlantic Canada have shown signs of recovery from acidification as evidenced by increasing pH and natural organic matter (NOM) concentration with no corresponding increase in nutrient loading. For example, average monthly color concentrations in certain Halifax water supplies have increased by up to 3.8x, while total organic carbon (TOC) has increased by approximately 1 mg/L since 1999 (Anderson et al., 2017). A similar phenomenon has been observed in some Scandinavian countries, where levels of dissolved organic carbon (DOC) have increased by up to 0.15 mg/L/year.

Changing source water quality from lake recovery and climate change are affecting the drinking water supplies for Halifax Water. In addition to increased chemical costs to manage the increased TOC, Halifax Water has also experienced biological changes in source waters. 2012 brought the sudden appearance of geosmin, a taste and odour compound, which is now a seasonal issue. In 2016, Microcystin LR was first detected in the source water of a small water treatment plant. In 2018, a diatom bloom in one of the water supplies posed significant treatment challenges for a source water that has never before experienced a noticeable algal bloom. With an unknown end point to source water quality changes, Halifax Water is working on developing a monitoring and response plan for algal blooms, including cyanobacteria and algal toxins. Challenges include selection of appropriate monitoring tools, regional analytical capacity, development of effective communications and analysis of treatment feasibility for algal toxins.

10.25 Cindy Crane, Morley Foy (Department of Communities, Land and Environment, PE)

Tracking of cyanobacterial blooms in Prince Edward Island

Cyanobacteria blooms are not common in PEI. Nine blooms have been documented in surface waters in the last fourteen years. Surface water is not used as source drinking water in the province so the concern is for recreational contact, livestock and pets. Initially, PEI developed a protocol to deal with blooms using cell counts and formations of surface scums as triggers for postings. In more recent years, a precautionary approach has been adopted with all blooms considered as having the potential to be toxic. Staff with the Water and Air Monitoring section of the PEI Department of Communities, Land and Environment are responsible for identifying blooms, monitoring them, and providing advice to staff of the Environmental Health Section of the Chief Public Health Office (PEI Department of Health and Wellness). Bloom identification is also assisted by members of community watershed enhancement groups and the general public. For guidance cyanobacteria blooms are included in the well-advertised provincial “What’s in the Water” webpage (https://www.princeedwardisland.ca/en/information/communities-land-and-environment/red-green-and-brown-whats-water). Environmental Health takes responsibility for posting notices in areas outside of the National Park. Ponds with blooms are typically posted for as long as the bloom lasts, closing them for activities such as swimming, boating and fishing and advising the public to keep livestock and pets away from the water. Parks Canada staff post separately, using similar signage, inside of the National Park.

In 2018 a cyanobacteria bloom occurred in one cell of the facultative lagoon in the Town of O’Leary in western PEI. Concerns from this bloom include worker safety, water quality in the lagoon, the potential for release to the environment, and impacts on effluent quality. Potential management options include sludge removal for nutrient reduction, use of coverings to limit light, use of chemical algaecides and physical removal of scums.

It is our hope that attending this workshop will assist us in establishing contacts across the region that can provide advice and support. We are also interested in regionally accessible assessment tools including taxonomic expertise and timely and affordable toxicological analysis.

10.40 Gordon Yamazaki, Meghann Bruce, R. Allen Curry (Canadian Rivers Institute, University of New Brunswick)

Relevant historical and ongoing studies of the Saint John River by the Canadian Rivers Institute

The Mactaquac Generating Station (MGS) on the Saint John River (SJR), New Brunswick, is the largest dam in the world ever to undergo the decision-making process of dam renewal. New Brunswick Power (NB Power) entered into a 5-year partnership with the Canadian Rivers Institute (CRI), centered at the University of New Brunswick, to provide the science in support of both the decision and the subsequent EIA. The resulting Mactaquac Aquatic Ecosystem Study (MAES) is a staged whole-ecosystem approach to establish biological baseline conditions, model the current physical state of the river, and develop an environmental flows program for future operation. Many of the studies undertaken as part of MAES are relevant and useful to ongoing and future studies of cyanobacteria and their toxins within the SJR. In addition, the CRI maintains a sizeable staff and assets in their Fredericton location that can be available to undertake field work in support of cyanobacteria studies.

The presentation provided a high-level overview of the following potentially-relevant biological studies: fish species assemblage and distribution, macrophytes, benthos, and plankton. Potentially relevant physical metrics included: water quality, river and reservoir bathymetry, hydrodynamics data and modelling, post-inundation sediment thickness, and sediment quality/contamination. The study results will eventually be made public and many of the results are already available via their ArcGIS online portal at http://canadarivers-gis.maps.arcgis.com/apps/webappviewer/index.html?id=f4d83a4f66104c36bece0a221d17f832. Many additional studies were also undertaken and interested parties are encouraged to contact Meghann Bruce (meghann.bruce@unb.ca) for more information.

11.00 Steven Scott (Government of New Brunswick, Fredericton, NB)

Anatoxin related dog deaths on the Saint John River, New Brunswick

An Australian Shepherd dog died shortly after swimming in the Saint John River about 10 km west of Fredericton, New Brunswick, on July 20, 2018. On July 22, 2018, two more dogs, a Shih Tzu and a Papillion, died after swimming briefly in the river, playing on the shoreline and eating mats of vegetation at Fredericton, about 10 km downstream from the initial mortality site. The Australian Shepherd and Shih Tzu were submitted to the New Brunswick Provincial Veterinary Laboratory for necropsy examination, which revealed no significant lesions. The Australian Shepherd's stomach contained abundant brown digesta and small amounts of vegetation, while the Shih Tzu's stomach contained a small amount of leaves and grass. Although no visible cyanobacterial blooms were reported at either site, exposure to cyanobacterial anatoxins was suspected given the common history of sudden death shortly after being in or around the river, combined with the prolonged hot summer temperatures, low water levels, and absence of significant lesions on necropsy. Stomach contents and vomitus from the dogs that died, and water and algal mats from both sites were submitted to the Biotoxin Metrology research facility, National Research Council, Halifax. Samples were examined for cyanobacteria and screened for all major classes of cyanotoxins including anatoxins, microcystins, cylindrospermopsins, and saxitoxins. Filaments of Phormidium sp., a known anatoxin producer, were observed in the water and algal samples. Anatoxins were detected at variably high levels in the stomach contents, vomitus, vegetation mats and algal mats and were the only cyanotoxin present. These findings, in combination with the history and clinical signs, help conclude that anatoxins were the most reasonable cause of death. In August, there were several additional reports of dogs dying after swimming in various bodies of water in New Brunswick but only one of these dogs was submitted for necropsy. This dog died from internal bleeding due to a ruptured splenic tumour. Cyanotoxins were not detected in the stomach contents of this dog and they were not detected in water samples collected at sites where mortalities were reported to have occurred in August. Necropsy examinations should be done to investigate the possibility of cyanobacterial toxicity in dogs that die shortly after swimming, being at a beach and/or consuming mats of aquatic vegetation.

11.10 Sara Rumbolt, Andrew Sinclair and Krysta Montreuil (Nova Scotia Environment, Halifax, NS)

Cyanobacteria management and procedures in Nova Scotia

The Government of Nova Scotia applies a multi-departmental approach (Environment; Health and Wellness) to managing cyanobacteria blooms in surface water systems. There are two procedures applied to manage blooms, which differ based on whether the water body is used for a public drinking water supply or recreation.

If the surface water body is used for a municipal or registered public drinking water supply, the owner of the system first contacts their regional Nova Scotia Environment (NSE) office to report a suspected bloom. An NSE inspector visits the site to confirm visual presence, identify potential sources of nutrient inputs and impacted users. This information is communicated to staff in the NSE Sustainability & Applied Science (SAS) Division. SAS staff evaluate the treatment system and associated risk to public health, and make a recommendation to the Medical Officer of Health (MOH) regarding the necessity of a 'Do Not Consume' advisory. The information is reviewed by the MOH who ultimately makes the decision to issue the advisory. The decision and any follow-up actions are relayed to the owner of the supply which may include notifying the users, continued visual monitoring and sampling for total microcystins. For registered supplies, the advisory is removed by the MOH when the bloom is no longer visible and sampling confirms the absence of total microcystins. In contrast, municipal supplies are required to sample the raw and treated water for total microcystins to support removal of an advisory or continued monitoring based on a decision by government staff.

For recreational waters, the Canadian Recreational Water Quality Guidelines are applied to determine when an advisory is issued. When NSE receives a report of a bloom, an inspector conducts a site visit to collect information on the users of the water body to assist with the public health risk assessment. If an advisory is issued, a media communique is sent out by the government.

NSE also conducts long-term lake water quality monitoring in the province, and is a partner in active studies in the Carleton River and Mattatall Lake watersheds which have experienced cyanobacteria blooms occurring over two or more years. The Government of Nova Scotia continues to actively review and revise its cyanobacteria management procedures, including improving regional monitoring, risk assessment capacities, and public education resources.

11.30 Heather Fraser (City of Moncton, Moncton, NB)

Monitoring for blue – green algae in Moncton's reservoirs

City of Moncton Water Sampling Program Began in 2000 looking at recreational water bodies, City Parks and in 2010 added the Turtle Creek Reservoir (TCR) and in 2014 added the newly built Tower Road Reservoir (TRR).

Current work : Four different reservoirs are being monitored annually including the Irishtown Nature Park (INP) reservoir a recreational water body; McLaughlin reservoir back up drinking water supply not used since the year 2000, Turtle Creek (TCR) and Tower Road Reservoirs (TRR) drinking water reservoirs for the Tri-Community of Moncton, Riverview and Dieppe. This monitoring and research program is in partnership with many local universities due to algae being discovered in the INP.

More than 600 samples have been taken in different categories (*nutrient, taxonomy, toxicity, physical and biological data*) in the water column along with soil samples in each watershed. These samples have been carefully analyzed and evaluated in the labs at Dalhousie University, University of Moncton and in the RPC lab in Moncton.

A new weather station was installed at the TRR to collect the weather data such as light intensity, rainfall and wind parameters. Datasets for these locations are currently being analyzed for the 2018 sampling season, no blooms in Moncton's drinking water systems TCR and TRR.

2017 Issues: The weather of the summer 2017 was very dry little wind and rain, there were no algal blooms in two reservoirs McLaughlin and Irishtown. However, the toxic algal blooms prominently (*Anabaena planctonica*) appeared in the Tower Road reservoir, upstream of Turtle Creek reservoir from the beginning of September 2017 and lasted until early November.

Therefore the focus and effort in sampling was put on TCR and TRR for the 2018 sampling period. Moncton is looking at a biological control for BGA at various locations in both watersheds using vegetation mats as a way to control nutrients coming into the drinking water system. A chemical control along with treatment options at the water treatment plant are being explored as well.

11.50 Kyla Brake (Department of Municipal Affairs and Environment, St. John's, NL)

Monitoring and occurrence of cyanobacteria in Newfoundland (via WEBEX)

Newfoundland and Labrador's first confirmed blue-green algae (BGA) bloom was observed during late summer in 2007 at waterbodies throughout the Paddy's Pond watershed, just outside of St. John's. Measured values of microcystin reached 0.36 µg/L and the bloom was dominated by *Anabaena sp.* While a cause of the bloom could not be determined, it was speculated that a tropical storm which brought 100mm of rain to the area several weeks before the bloom occurred may have contributed by increasing runoff (in particular, nutrients) from the surrounding area.

Since 2007, the province has investigated whenever suspected BGA blooms are reported by the public. The same few locations (Miller's Pond, Great Pond, Grand Pond, Paddy's Pond) have repeatedly supported blooms. All are located in sub-urban or rural areas near St. John's. No blooms have been observed in highly urbanized water bodies or public drinking water supplies.

While increasing the public's knowledge of BGA is an advantage, increased awareness can also lead to increased false reports, in turn leading to lost resources spent in investigating the reports. For this reason, the province created a 'Weird Stuff in Water' website to help the public differentiate between all the odd things we sometimes see in our lakes and rivers (https://www.mae.gov.nl.ca/waterres/outreach/water_weird.html). In addition, Canada's Lake Pulse research team conducted extensive sampling at two of the ponds which repeatedly support BGA blooms during the summer. The results of this program may yield some answers as to why these ponds are affected by BGA and not others.

Monitoring of BGA continues on a public complaint case by case basis. More information on BGA in NL can be found here:
https://www.mae.gov.nl.ca/waterres/quality/background/bgalgae.html

13.00 Daniel Beach; Chris Miles, Krista Thomas, Cheryl Rafuse, Michael Quilliam, Pearse McCarron (National Research Council Canada, Halifax, NS)

Analytical methods for cyanobacterial toxins

Determining the type cyanotoxins present in a sample and the concentration is significantly more challenging than other typical environmental contaminants (e.g. trace metals). Cyanotoxins occur in several different classes including microcystins (MCs), anatoxins (ATXs), cylindrospermopsins (CYNs) and saxitoxins (STXs). Each of these differ significantly in chemical structure, properties and mode of toxicity requiring the use of multiple different methods for comprehensive analysis. Within each of these classes there can be hundreds of different chemicals that must be detected including new chemicals that have not yet been identified. Because the density and composition of harmful algal blooms can vary significantly over relatively small changes in space and time, representative sampling of surface waters is also challenging. The wide range of techniques available for cyanotoxin analysis, each measuring something different and having different figures of merit, makes it challenging to choose the appropriate technique in any given situation. Finally, it can be unclear which analytical method is most appropriate to best apply to changing guidelines and regulations for cyanotoxins. For example, the new Health Canada drinking water guidelines released in September 2018 are based on "total microcystin" which is currently poorly defined with respect to the quantity being measured and which methods are suitable for making the measurement.

This presentation reviews the capabilities of the full range of methods available for monitoring for the presence of toxic cyanobacteria from simple visual monitoring of a waterbody all the way to sophisticated research techniques such as untargeted liquid chromatography-high resolution mass spectrometry (LC-HRMS) methods currently under development at NRC Halifax. Of these, immunoassays represent the most commonly used routine monitoring tool, but different assays are required for each class of toxin and each must be carefully validated for a particular application to avoid false positive or false negative results. Also commonly applied are targeted LC-tandem mass spectrometry (LC-MS/MS) methods for commonly known cyanotoxins. These are appropriate for the sensitive, selective and accurate quantitation of toxins for which chemical standards are available, but have a potential to produce false negatives from samples containing unknown toxins when used alone. Genetic methods are emerging as an effective routine monitoring and early warning tool, though they measure the presence of toxin producing genes, rather than toxins themselves.

In general, knowledge of which types of cyanobacteria and cyanotoxins that can occur in a region is helpful in determining the most appropriate analytical strategy. True comprehensive monitoring most often requires a combination of techniques such as rapid initial screening by ELISA or PCR followed by mass spectrometry based methods for quantitative confirmation.

13.20 Janice Lawrence, Adrian Reyes-Prieto, Kristen Hawkes, Jordan Brown, Rossella Calvaruso (Biology Department, University of New Brunswick, Fredericton, NB)

Genetic approaches for studying toxic cyanobacterial populations

The characteristics and capabilities of living organisms are encoded in sequences of DNA called genes, which are passed down from parent to offspring. As such, related organisms have very similar genes, and therefore similar characteristics and capabilities. We can detect characteristics of interest, such as the ability of an organism to produce toxins, by identifying the presence of genes involved in toxin production.

We can also identify which particular organism in a complex community is responsible for toxin production by detecting the toxin-production genes in its DNA.
We have been using genetic approaches to detect the presence of cyanobacterial genes involved in toxin production in diverse freshwater environments around New Brunswick. We are able to detect the *mcy*E gene, which is involved in the biosynthesis of the hepatotoxin microcystin, and to determine if the source organism is from the cyanobacterial genus *Microcystis, Anabaena,* or *Planktothrix*. We are also able to detect the presence of *ana*C gene, key part in the biosynthesis of the neurotoxin anatoxin-a. We are using deep-DNA sequencing and phylogenetic approaches to determine which organisms contain the *ana*C gene.
Our preliminary studies indicate that microcystin and anatoxin-a biosynthesis genes are widespread in New Brunswick waterbodies, and that planktonic and benthic/epiphytic communities may harbor toxin producers. The application of genetic approaches has provided important information regarding toxin-production potential, and has revealed that cyanobacteria armed with genes for toxin biosynthesis are part of complex and diverse microbial communities.

13.40 Tri Nguyen-Quang (Dalhousie University, Truro, NS)

Monitoring freshwater Harmful Algal Blooms in Nova Scotia and New Brunswick: current situation and future perspectives

Since 2014, Biofluids and Biosystems Modeling Lab (BBML-Truro, NS) has been involved in a monitoring program for freshwater resources Harmful Algal Blooms (HABs) including thirteen lakes in Nova Scotia (Torment, Sherbrooke, Ogden, Fanning, Nowlans, Armstrong, Hourglass, Chain, Blair, Half-moon, Parr, Raynards, Vaughan, and Mattatall) and four Moncton recreational and drinking water reservoirs in New Brunswick (McLaughlin, Irishtown, Tower Road, and Turtle Creek).
There are many important reasons why the monitoring program is considered valuable and processed throughout the past several years within BBML: 1) to build a robust dataset of physiological, chemical, and biological parameters leading to mathematical models for bloom predicting and threshold determination; 2) to attempt to elucidate the relationships between the involved parameters in the bloom patterns and between the waterbody and related watershed; 3) to determine the dominant species as well as their toxin variants and concentrations released in the waterbodies; 4) Finally, information obtained from monitoring program could be provided to the involved stakeholders and governmental agencies to create an early warning system and water management plan vis-a-vis HAB issues.
For the toxicity detection, ELISA tests (ADDA and HAPTEN) for Microcystins and Anatoxin-a were used in BBML. A collaborative research project with The National Research Council –Halifax is processed to validate and strengthen our ELISA tests by the Liquid Chromatography-Mass Spectrometry approach.

14.00 Rob Jamieson, Lindsay Johnston, Rick Scott, Jenny Hayward, Audrey Hiscock, Meggie Letman (Dalhousie University, Halifax, NS)

Development of watershed and lake assessment tools to identify and manage lakes at risk for Harmful Algae Blooms

The occurrence of cyanobacteria blooms in several lakes in Nova Scotia in recent years has generated significant public awareness and concern. The apparent increasing frequency in cyanobacteria blooms could be due to a number of factors, including climate change and decreased levels of acid deposition. However, increased nutrient loading is still recognized as a central factor influencing potential for blooms. Phosphorus (P) is typically the limiting nutrient in freshwater systems, and identification and control of P sources within the lake watershed is a critical first step in preventing cyanobacteria blooms. A recent analysis of water quality data collected from 58 lakes in the Halifax Regional Municipality has demonstrated that P is still a strong predictor of trophic state, and should continue to be a focus of watershed management efforts. This presentation provided an overview of an on-going CWRS research program focused on understanding and modeling P dynamics within lake-watershed systems. Much of these efforts have been centred on the development and refinement of the Nova Scotia Phosphorus Model, which is a mass balance model designed to predict P concentrations in lakes as a function of watershed land-use and hydrology, and lake morphology. The CWRS has conducted extensive research over the past two decades to refine model inputs for Nova Scotia, and has added model components to better represent key potential sources of P, such as on-site wastewater systems. The modeling approach has been applied in both urban and rural watersheds throughout NS, and has been used to identify causes of cyanobacteria blooms, and primary sources of P driving these processes. The CWRS is currently partnering with NS Environment to adapt this modeling approach so that it can be applied at a regional scale as a screening tool. This type of risk assessment tool would aid in generating regional or province-wide risk assessments of lake eutrophication. The identification of high-priority lake watersheds would allow the province to efficiently prioritize their resources for managing lakes across the province. The risk assessment tool would also guide municipalities and watershed stewardship groups in establishing monitoring programs and land-use management plans in watersheds of interest.

14.20 Mike Chaulk, Melissa Fraser (CBCL Limited, Halifax, NS)

Assessment of cyanobacteria treatment options: An Atlantic Canadian perspective

The incidence of documented cyanobacteria (blue green algae) blooms in fresh water bodies across North America has been steadily increasing. These blooms have the potential to produce toxins, taste and odour by-products, and biomass that can inhibit the ability of drinking water treatment facilities to produce acceptable quantities and quality of safe drinking water. In Atlantic Canada, several regional municipalities, including Halifax and Moncton, have recently experienced algal blooms or algal bloom by-products in drinking water sources that have impacted downstream treatment processes. These events, while not severe in magnitude, provide an impetus for other municipalities to consider source water risks for algal blooms and treatment process resiliency. The majority of municipal drinking water systems in Atlantic Canada provide customers with surface water treated using multiple unit processes. Common unit processes include oxidation, coagulation, flocculation, clarification, filtration and disinfection. Depending on the type of bloom that occurs in a source, treatment requirements may include various classes of toxins, bacteria, or taste and odour compounds. Chlorination is effective for some toxin removal and oxidation with permanganate is effective for others. The method of clarification in a treatment plant can affect the ability of a process to remove biomass (bacteria), with Dissolved Air Flotation followed by filtration having demonstrated good performance elsewhere. Each drinking water treatment system should consider site specific process features to identify risk and vulnerabilities for constituents associated with cyanobacteria blooms, and understand the maximum concentration of toxins or biomass that could be effectively treated. These treatment limitations should then be considered against the risk of occurrence in source water beyond the limitations, with additional measures added as needed.

15.00 Arash Zamyadi (Polytechnique Montréal, Montréal, QC)

Management of harmful algal blooms: Lessons learned from water treatment plants at low and high risk of bloom events

A wide range of cyanobacterial species and their harmful metabolites are increasingly detected in water bodies worldwide including in Canada, exacerbated by climate change and human activities. The resulting conditions and production of harmful compounds represent significant challenges to production of safe drinking water therefore their removal is a priority to ensure public safety. While current microscopic taxonomy identification methods provide valuable information about cell numbers during treatment, these methods are incapable of providing real-time information about the fate of cells during treatment. The objectives of this study were to (1) identify the critical control points for breakthrough and accumulation of cells by investigating the fate of cells during treatment processes using a combination of taxonomy, real-time fluorescence measurement, cell integrity and next-generation sequencing, and (2) assess the impact of pre-treatment processes on breakthrough prevention at critical control points, and the benefits of these analysis for improved management purposes. This talk presents the results of an unprecedented cyanobacterial monitoring program conducted in Canadian and Australian full scale water treatment plant at high and low risk of bloom events. Cyanobacterial cell integrity and accumulation during operation process were assessed for the first time using next generation of gene sequencing methods. Next-generation sequencing analysis led to detection of cyanobacterial and melainabacteria orders in water samples that were not identified by microscopy. 80 ± 5% of cells were completely lysed post pre-oxidation (for both ozone and potassium permanganate). However unlike pre-ozonation, the remaining cells were undamaged post-$KMnO_4$ treatment, particularly in clarifier sludge. To effectively monitor water quality, this study presents a synergistic approach coupling new and traditional analytical methods and demonstrates the importance of identifying critical points for managing accumulation of cyanobacteria within plants.

15:30 Heather Raymond (Ohio Environmental Protection Agency, Columbus, OH, USA)

Ohio EPA HAB response and lessons learned

Ohio EPA began sampling public water systems (PWSs) for cyanotoxins in 2010, after results from USEPA's National Lakes Assessment showed presence of cyanotoxins in Ohio source waters above national averages. Ohio EPA's sampling is guided by the State of Ohio PWS HAB Response Strategy, which was first developed in 2011 and updated annually thereafter. Ohio EPA's sampling was initially incident-response based, but Ohio EPA established rules in 2016 requiring routine microcystins monitoring and reporting (MC-ADDA ELISA method) and qPCR-based cyanobacteria screening.

Ohio EPA selected the ELISA method for inclusion in rules after conducting an independent microcystins method comparison study: ELISA-MC-ADDA, LC-MS/MS individual variant (14), LC-MS MMPB, LC-UV, and LC-scan (used in tandem with LC-UV for unknown variants). Samples from eleven different source waters, representing a range of source water types, varying seasonal occurrence, and multiple locations within individual source water, were analyzed using each method and the results were compared. Some of the interesting findings were: MC-LR was detected at less than half the sites; the demethylated variants were some of the most frequently-detected variants (but not included in USEPA LC-MS/MS method); the LC-UV method was prone to interferences and had both false positives and negatives; the LC-MS/MS-MMPB method had a very good correlation (0.98) with the MC-ADDA ELISA method and the individual variant method appeared to under-report total microcystins, as compared to LC-MS/MS-MMPB, ELISA, and LC-MS scan results. We also worked with Abraxis and USEPA to further evaluate potential for matrix effects with the MC-ADDA ELISA method.

To evaluate the CyanoDTec qPCR assay, which quantifies total cyanobacteria (16S rDNA), and microcystin (mcyE), saxitoxins (sxtA), and cylindrospermopsin (cyrA) genes, Ohio EPA collected biweekly samples year-round at 118 public water system source waters (paired with MC-ADDA ELISA analysis). Saxitoxins and cylindrospermopsin were analyzed if sxtA or cyrA were detected. In addition, all three cyanotoxins were analyzed and paired with phytoplankton enumeration at select inland lakes. mcyE was detected in source waters for 57 PWSs and six inland lakes and microcystins were detected at 45 PWSs and five inland lakes. The number of samples positive for microcystins but negative for mcyE was low (2% for PWS). At several sites, detection of mcyE preceded microcystins detections by 1-4 weeks. sxtA was detected at 33 PWSs and 14 inland lakes, and saxitoxins were detected at 15 PWSs and 10 inland lakes. Less than 1% of PWS and 2% of inland lake samples had saxitoxins detections without corresponding stxA detections. Samples with cyanotoxin detections that lacked corresponding gene detections often occurred following bloom senescence and cyanotoxin concentrations were low. At one PWS, mcyE, sxtA, and cyrA were all detected, demonstrating multi-plex assay functionality. An interlab method comparison was also conducted on a subset of samples and showed no significant difference in results. qPCR results out-performed cyanobacteria cell counts as a predictor for inland lake cyanotoxin production. 16S rDNA sequencing analyses linked most cyanotoxin positive samples to *Planktothrix* or *Microcytis* species, although in a few samples dominant species were *Aphanizomenon, Dolichospermum*, *Cylindrospermopsis*, *Phormidium*, and *Leptolyngbya*.

Overall, some of the major Ohio HAB lessons learned include: HABs are not always visually apparent; HABs can occur year-round with peak cyanotoxin concentrations at some systems occurring in the late fall or early winter; saxitoxins are an emerging issue for Ohio and provide treatment challenges; there is no perfect method for detecting total microcystins and the analysis method should match the objectives of the monitoring; early warning monitoring can be helpful; and qPCR is an effective screening tool for cyanotoxins.

ATLANTIC CANADIAN CYANOBACTERIAL WORKSHOP 2018

National Research Council Canada, Halifax, NS

SCHEDULE

TUESDAY, NOVEMBER 20th

08.00	***Arrival and Registration*** *Speakers please load talks during this time*
08.40	**Pearse McCarron** (National Research Council Canada, Halifax, NS) *Welcome and opening remarks*
08.50	**Xavier Ortiz** (Ontario Ministry of the Environment, Conservation and Parks, Toronto, ON) *Cyanotoxins in Ontario's Great Lakes*
09.30	**Graham Gagnon** (Dalhousie University, Halifax, NS) **Wendy Krkosek** (Halifax Water, Halifax, NS) *Understanding lake recovery impacts in Nova Scotia and the reality of this change for drinking water utilities*
10.00	***Coffee, Nutrition and Networking***
10.25	**Cynthia Crane** (Government of Prince Edward Island, Charlottetown, PE) *Tracking of cyanobacterial blooms in Prince Edward Island*
10.40	**Gordon Yamazaki** (Canadian Rivers Institute, University of New Brunswick) *Relevant historical and ongoing studies of the Saint John River by the Canadian Rivers Institute*
11.00	**Steven Scott** (Government of New Brunswick, Fredericton, NB) *Anatoxin related dog deaths on the Saint John River, New Brunswick*
11.10	**Andrew Sinclair** (Government of Nova Scotia, Halifax, NS) *Cyanobacteria management and procedures in Nova Scotia*
11.30	**Heather Fraser** (City of Moncton, Moncton, NB) *Monitoring for blue – green algae in Moncton's reservoirs*
11.50	**Kyla Brake** (Department of Municipal Affairs and Environment, St. John's, NL) *Monitoring and occurrence of cyanobacteria in Newfoundland* (via WEBEX)

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National Research Council Canada, Halifax, NS

SCHEDULE

12.05	*Lunch - provided onsite*
13.00	**Daniel Beach** (National Research Council Canada, Halifax, NS) *Analytical methods for cyanobacterial toxins*
13.20	**Janice Lawrence** (University of New Brunswick, Fredericton, NB) *Genetic approaches for studying toxic cyanobacterial populations*
13.40	**Tri Nguyen-Quang** (Dalhousie University, Truro, NS) *Monitoring freshwater Harmful Algal Blooms in Nova Scotia and New Brunswick: current situation and future perspectives*
14.00	**Rob Jamieson** (Dalhousie University, Halifax, NS) *Development of watershed and lake assessment tools to identify and manage lakes at risk for Harmful Algae Blooms*
14.20	**Melissa Fraser, Mike Chaulk** (CBCL Limited, Halifax, NS) *Assessment of cyanobacteria treatment options: An Atlantic Canadian perspective*
14.40	*Coffee, Nutrition and Networking*
15.00	**Arash Zamyadi** (Polytechnique Montréal, Montreal, QC) *Management of harmful algal blooms: Lessons learned from water treatment plants at low and high risk of bloom events*
15:30	**Heather Raymond** (Ohio Environmental Protection Agency, Columbus, OH, USA) *Ohio EPA HAB response and lessons learned*
16.10	**Panel Discussion**
16.45	**Closing**
17.00	***Reception hosted by the Atlantic Canada Water & Wastewater Association (ACWWA)*** *Dalhousie University Club. Appetizers will be provided.*

ATLANTIC CANADIAN CYANOBACTERIAL WORKSHOP 2018

National Research Council Canada, Halifax, NS

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