Backgrounder

Welcome to this two-part webinar series on the strategic management of algal bloom impacts on local water sources, with a focus on drinking water. The first webinar in September 2019 will focus on reducing and minimizing algal bloom impacts in source water using watershed management approaches. The subsequent webinar in October 2019 will focus on managing the impacts of algal blooms in drinking water treatment plants. This backgrounder provides a Canadian context on algal blooms and the implications for municipalities and utilities across the country.

Terminology

Harmful and nuisance algal blooms (HNABs) occur when photosynthetic algae form high-biomass and/or toxic strains of cells that negatively impact humans and aquatic ecosystems.

Harmful algal blooms refer to algae which produce toxins that cause acute or chronic impacts to humans and aquatic and terrestrial fauna.

Nuisance algal blooms do not pose significant risk to humans and ecosystems. However, they negatively impact the functional and aesthetic uses of surface water bodies (e.g., posing challenges for drinking water treatment or limiting the recreational use of beaches).

In this webinar series, HNABs are assumed to include cyanobacteria and cyanotoxin strains such as 'blue-green algae'. These strains have similar traits to algae — i.e., they form blooms, absorb nutrients and photosynthesize — but are actually single-celled bacteria.

Source: Canadian Freshwater Alliance, 2018 and Alberta Water Portal, 2019

Algal Blooms in Canada

HNABs (i.e., nuisance and toxic algal blooms which impact human health and the environment) are a recurring issue for municipalities across Canada (Kudela et al., 2015). Algae are naturally occurring phenomena in almost all aquatic environments, but the severity, frequency and geographical distribution of HNABs are increasing globally. Some of the factors contributing to these increases are human activities such as agriculture and urban stormwater run-off that contribute nutrients such as phosphorus and nitrogen, as well as increasing temperatures, changing precipitation patterns and changes in the freeze-thaw cycle due to climate change (Canadian Water Network, 2017).

Across the country, HNABs are a recurring and ongoing concern in the Great Lakes, Lake Winnipeg, Lac St. Charles, Lake Simcoe and a range of other smaller water bodies (Canadian Water Network, 2017). Some water bodies in the Okanagan River Basin in British Columbia have encountered recurring algal blooms since the 1970s. In Alberta, approximately 75% of lakes and reservoirs experience HNABs at least once a year. HNABs, primarily in the form of blue-green algae, have also drastically increased in Lake Winnipeg since the early 1990s, impacting local fisheries, drinking water supplies, recreation and tourism. Nitrogen and phosphorus levels in Lake Winnipeg have increased due to increased agriculture, land clearing and rapid urban growth in the watershed (Federal Provincial and Territorial Governments of Canada, 2010). The issue is exacerbated by the City's challenges in upgrading its major wastewater treatment plant to remove phosphorus (Lake Winnipeg Foundation, 2019).

Algal blooms have been regularly reported in four of the Great Lakes (Ontario, Huron, Michigan and, most notably, Lake Erie) and are beginning to be reported in Lake Superior as well, posing challenges for urban and rural municipalities and drinking water utilities. In Quebec, the number of lakes and reservoirs experiencing HNABs increased from 21 to 150 between 2004 and 2009. HNABs are also of concern in Canada's marine systems. For example, both the Bay of Fundy in New Brunswick and the coast of British Columbia have a history of HNAB events, which have been increasing over the past two decades (Federal Provincial and Territorial Governments of Canada, 2010).

It is difficult to determine the specific number of occurrences of HNABs across Canada. This is partly due to the large number of water bodies involved, but also due to jurisdictional differences in the reporting of HNAB occurrences. In Ontario, Quebec and Nova Scotia, management and monitoring actions are triggered only when HNABs are reported. In British Columbia, Alberta, Manitoba, New Brunswick and Prince Edward Island, targeted blue-green algae monitoring programs have been established. Some jurisdictions do not track HNAB outbreaks (Our Living Waters, 2017). As a result, it is difficult to determine the extent and cost of HNAB impacts on a national scale.

The Impacts of Algal Blooms on Society and the Environment

- **Toxin-producing strains of HNABs can impact human health:**
  The impacts of toxin-producing strains (e.g. microcystins, anatoxins) to human health can be acute or chronic. If toxins are present in source water, they can cause illness or death if ingested directly or through exposure during activities like swimming. The toxins can also bioaccumulate in fish, shellfish and other aquatic organisms, which poses a health risk if ingested (Kudela et al., 2015).

- **HNABs impact drinking water treatment plants:**
  HNABs in source water can significantly impact drinking water treatment plant operations. Potential impacts include: clogged intake screens, fouled weirs, impeded settling processes, clogged filters, fluctuating pH levels, taste and odour issues (e.g. geosmin, methylisoborneol or MIB), increased formation of disinfection byproducts and increased demand for coagulant and chlorine (Odell, 2012). In the event of equipment failure or difficulty removing HNAB-produced toxins from drinking water (e.g. microcystins, anatoxins), health advisories are typically issued that require residents to avoid drinking local tap water (Kudela et al., 2015).

- **HNABs cause negative ecological impacts in watersheds:**
  High-biomass HNABs can shade aquatic plants and limit their growth. They may also create low-oxygen zones as they decay, which impacts aquatic fauna. Wildlife that consume shellfish or other aquatic organisms are also impacted (Kudela et al., 2015).

- **There are economic and social impacts associated with HNABs:**
  HNABs impact the aesthetic value of beaches and coastal zones, which impacts the recreational use of these areas and tourism. They can also harm the health and habitat of fish species, impacting commercial fisheries. HNABs can also result in higher operational costs for municipal drinking water treatment plants (Kudela et al., 2015) and drinking water advisories can harm customer confidence.

Factors that Influence the Formation of Algal Blooms

The growth rate and biomass produced by HNABs are influenced by a combination of physical, chemical and biological factors, including (Kudela et al., 2015):

- Nutrients (mainly phosphorus and nitrogen)
- Light
- Temperature
- Water circulation
- Salinity
- Competition with, and predation by other species in the food web

Human activities and climate change can significantly impact the balance of these factors and become key drivers for the increased frequency and severity of HNABs.

Human Activities

Human activities such as agricultural practices and urban densification exacerbate HNAB events by increasing nutrient contributions to water bodies, typically leading to eutrophication, which is the excessive enrichment of water bodies with nutrients. The key nutrients contributing to eutrophication are phosphorus and nitrogen, with phosphorus being the main limiting agent in freshwater environments and nitrogen serving a more limiting role in marine and coastal environments. It is important to note that although particle-associated phosphorus comprises most of the total phosphorus loads delivered to surface water bodies, recent research is finding that smaller fluxes of soluble reactive phosphorus can be a key contributor to algal blooms (Canadian Water Network, 2017).

Managing nutrient discharges from municipal wastewater is an ongoing challenge and concern for Canadian experts (Canadian Water Network, 2018). Nutrient removal processes in wastewater treatment plants are well-established and can be incorporated into primary, secondary or tertiary treatment processes. Some, but not all, provinces regulate nutrient levels in discharges. The lack of national regulations or targets for Canadian wastewater treatment plants on nutrient discharge levels poses ongoing challenges for managing these point sources of nutrient pollution (Canadian Water Network, 2018).

Non-point sources of nutrients from urban and agricultural land uses also fuel the growth of HNABs in receiving waters. Urban non-point sources are often carried by stormwater runoff to surface waters and include pet wastes and atmospheric particulates as well as combined sewer overflows or bypasses (Canadian Water Network, 2018). Management practices such as lot-level retention measures and green infrastructure can be useful in managing nutrients from these sources (Marsalek & Schreier, 2009). Nutrients from agricultural fertilizers and manure from farm fields can also be delivered to surface waters through stormwater runoff. Particulate-associated phosphorus comprises most of the total phosphorus load transported in surface runoff to water bodies. However, there is a growing body of work examining the role of soluble reactive phosphorus in promoting algal blooms due to its being more bioavailable (i.e. more readily available for direct uptake by algae species), thus contributing to accelerated impacts to ecosystem functions (Canadian Water Network, 2017). Best management practices (BMPs) to improve nutrient retention on the landscape and nutrient uptake by crops can be useful in managing these sources, but due to nutrient legacies in the landscape and aquatic ecosystems there can be significant lag times between management actions and ecosystem responses (Canadian Water Network, 2017).

HNAB events can also be exacerbated through the alternation and intensive use of coastal zones and the spread of species through ship ballast waters (Kudela et al., 2015). These activities can significantly impact two HNAB growth factors: water circulation, and competition with and predation by other species in the food web.

Climate Change

The role that climate change plays in HNAB occurrence is complex; the science is evolving, but can be better understood by assessing how factors like temperature may be altered by climate change. Some examples of how climate change can exacerbate HNAB events include:

- Warmer water temperatures in some regions favour the development and proliferation of many HNAB species. Warmer temperatures also lead to less mixing in water bodies, which allows HNABs to grow faster and thicker.
- Changes in rainfall patterns, such as less frequent but more intense rainfall events, can lead to increased nutrient runoff to water bodies, thus promoting HNAB growth. Changing rainfall patterns pose ongoing challenges in both forested and agriculture-dominated watersheds. In both types of watersheds, intense rainfall events can mobilize nutrients and other materials (e.g. fine sediments) that alter the balance of factors impacting HNAB growth (e.g. nutrient availability, water circulation).
- Higher levels of atmospheric carbon dioxide can lead to increased growth and severity of HNAB events since they are photosynthetic in nature and require carbon dioxide to grow. (United States Environmental Protection Agency, 2017)
- More severe and frequent wildfires can lead to the delivery of ash, sediment, nutrients and contaminants to surface water bodies after rainfall events. These contributions can promote HNAB growth (United States Environmental Protection Agency, 2019).

Factors impacting the frequency and severity of HNABs vary regionally and locally, but will ultimately be determined by the complex interaction of the aforementioned factors given the influence of current and past human activities and climate change.

The Need for Holistic Solutions

Due to the complex interaction of factors which determine whether HNABs will occur, as well as their severity and frequency, a holistic management approach is needed to minimize impacts. Often HNABs cannot be completely prevented or eliminated, so management approaches should strive to:

1. Improve the prediction of HNABs through **monitoring** to better target mitigation measures.
2. Limit negative impacts through active **mitigation**, such as promoting agricultural BMPs and upgrading wastewater treatment plants to limit nutrient runoff into receiving waters, and optimizing drinking water treatment plant operations to better respond to HNABs when they do occur.

Additionally, the scale at which management measures are implemented must be considered. Both treatment plant scale and sub-watershed/watershed scale approaches may be effective, but typically require coordination among different sets of stakeholders and decision-makers. This webinar series will examine potential mitigation and monitoring approaches at both scales, including considerations for implementation.

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