INSTITUT NATIONAL DE SANTÉ PUBLIQUE DU QUÉBEC

CLIMATE CHANGE IN SOUTHERN QUÉBEC

An analysis of the vulnerability of Québec drinking water facilities to toxic cyanobacteria

Summary

BACKGROUND

Conducted under the Ouranos Consortium's Health Program and coordinated by the Institut national de santé publique du Québec (INSPQ), this study is part of the "Water quality" component of the Program; it was funded by the Ouranos Consortium and the ministère de la Santé et des Services sociaux du Québec.

This fact sheet provides a summary of a report prepared at the École Polytechnique de Montréal, the full version (in French only) of which can be found on the Ouranos Website at:
http://www.ouranos.ca/en/publications/
in Scientific publications section (September 1, 2008)

Translated by the National Collaborating Centre for Environmental Health (NCCEH) in partnership with INSPQ through a financial contribution from the Public Health Agency of Canada through the NCCEH. The views expressed herein do not necessarily represent the views of the Agency or the Centre.

Québec

INTRODUCTION AND HISTORICAL OVERVIEW

Cyanobacteria are photosynthetic bacteria that are naturally present in the earth's fresh water and salt water ecosystems; they are not algae despite the fact that they are referred to as blue-green algae. For millions of years, these micro-organisms have been intimately associated with the development of life on the planet, since they helped enrich the earth's atmosphere with oxygen. Through biosynthesis, they also produce several groups of substances including cyanotoxins. From an evolutionary viewpoint, cyanotoxins are believed to increase the competitive advantage of cyanobacteria, allowing them to dominate the aquatic environment in which they grow. The particular environmental problem created by cyanobacteria since the 1990s is the result of excessive proliferation in surface waters (ponds, lakes and streams), caused primarily by surpluses of nutrients such as nitrogen and especially phosphorus. In this context, drinking water facilities that are supplied with surface water could be vulnerable to cyanobacterial blooms, allowing whole cyanobacteria cells or their toxins to pass into the water distribution system.

Climate change is one of the factors that need to be considered in connection with the proliferation of toxic cyanobacteria[1]. However, there is little data on changes in the abundance of cyanobacteria in Québec, and more importantly, there is no summary of the removal capacity of Québec's drinking water treatment plants. The purpose of this study was to review the state of knowledge regarding the elimination of cyanobacteria or their toxins during the production of drinking water in Québec.

METHODOLOGY

Four specific objectives were identified:

1. To compile historical data on the occurrence of cyanobacteria and cyanotoxins in Québec and elsewhere;
2. To identify cyanobacteria occurrence scenarios from a climate change perspective;
3. To produce a critical review of the scientific data on the elimination of cyanobacteria and the reduction of cyanotoxins through drinking water treatment processes;
4. To assess the vulnerability of existing municipal drinking water facilities (using surface water) to an increase in toxic cyanobacterial blooms.

The first three objectives have been achieved primarily through a review of the scientific literature; the choice of occurrence scenarios (objective 2) was made following meetings and discussions among the partners in the study. Assessing the vulnerability of municipal treatment facilities (objective 4) required special collaboration with the ministère du Développement durable, de l'Environnement et des Parcs du Québec (MDDEP) to secure the active participation of officials responsible for a sample of 29 municipal drinking water facilities supplied with surface water (lakes or rivers). The selection of facilities focused on areas particularly affected by cyanobacteria, including the southern part of the province, south of the Saint Lawrence River. These facilities were also chosen to include a range of the kinds of treatment commonly used in Québec that may be effective in managing cyanobacteria and their toxins (ozonation, powdered activated carbon, potassium permanganate and chlorine). The theoretical performance in the elimination of cyanotoxins was calculated using technical data obtained by sending a detailed questionnaire to the people in charge of the selected facilities, and using the treatment's performance as reported in the literature.

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[1] The information in this fact sheet has been taken from a report that examined only the potential impact of climate change. Aside from this important aspect of the subject, the development of cyanobacteria is primarily associated with the presence of nutrients, particularly phosphorus, without which no growth would take place. Moreover, particular climate events such as sudden intense precipitation may increase the input of nutrients into the aquatic environment and promote the proliferation of cyanobacteria. Although these issues are not addressed in this document, which is broader in scope, we must remember that they play a key role in the growth of cyanobacteria.

The assessment of the ability of treatment facilities to remove cyanotoxins was based on a maximum allowable concentration, established by Health Canada, of 1.5 µg/L of total microcystins in drinking water, while the Institut national de santé publique du Québec suggests a maximum anatoxin-a concentration of 3.7 µg/L in drinking water; however, this value is provisional.

RESULTS

Observed occurrences of cyanobacteria and their cyanotoxins

More than 2,000 species of cyanobacteria have been identified, but only sixty of them have been implicated as potentially capable of producing cyanotoxins. Those of greatest interest are the microcystins, anatoxin-a, cylindrospermopsin and saxitoxins.

Microcystins are among the most common cyanotoxins, and they are hepatotoxic. Associated with a single basic chemical structure, there are at least 60 structural analogues of varying toxicity. The most common and most studied is microcystin-LR (MC-LR). Anatoxins are neurotoxins that primarily affect the nervous system. Among the few known types, anatoxin-a is the most widespread in North America. The presence of cyanotoxins and their importance vary from region to region, depending on the occurrence and density of cyanobacteria populations. There are however significant gaps in our knowledge about the detection, occurrence and toxicity of many forms of these cyanotoxins. Although the acute toxicity of several of them is now established, their subchronic and chronic effects are still unclear.

A study conducted in 45 North American cities showed that in 80% of the 677 samples analyzed, the growth of cyanobacteria has been associated with the production of microcystins. However, the positive samples in raw water revealed very low concentrations, almost always under 1 µg/L of microcystins. Another study showed that the majority of raw water samples from 33 facilities analyzed contained microcystins, but only 7% had more than 1 µg/L.

Cyanobacteria and their toxins have often been identified in Canada, particularly in drinking water. In Alberta, toxins were detected in 67% of samples of raw water from drinking water facilities, with a maximum total microcystin concentration of 14.8 µg/L. In the Great Lakes, microcystins at concentrations above 1 µg/L were observed in several locations on Lake Erie and Lake Huron. In other areas of the Great Lakes, concentrations of microcystins above 1 µg/L were observed in 14% of the 2,513 samples analyzed, but the concentration of anatoxin-a exceeded 1 µg/L in less than 1% of the samples.

In Québec, two MDDEP studies identified cyanobacteria and cyanotoxins in raw water and drinking water (six drinking water facilities were monitored for the period from 2001 to 2003, and seven facilities from 2004 to 2006). In total, 83% of raw water samples collected in 2006 contained one or more species of potentially toxic cyanobacteria, compared to 30% in 2004. In addition, from 0 to 83% of raw water samples containing cyanobacteria also contained cyanotoxins. The maximum concentration of microcystins (in all forms) measured in raw water was 5.35 µg/L (during the period 2004-2006) while that of anatoxin-a was 2.3 µg/L (during the period 2001-2003); for the period 2004-2006, the maximum measured concentration of anatoxin-a was 0.24 µg/L. However, the concentrations usually found in treated water were much lower – less than 1.0 µg/L for microcystins – while anatoxin-a was not detected. It should be noted that measured concentrations in treated water (drinking water) were 30 to 50 times lower than the maximum recommended values for drinking water (see above for allowable concentrations).

To date, concentrations of toxins detected in raw water have thus been relatively low, and very low in treated water (drinking water). In addition, most drinking water intakes in Québec are not located in places that are conducive to the development of cyanobacterial blooms (near the surface of the water or near the bank of a river or stream). Nonetheless, the concentrations of potentially toxic cyanobacteria and of microcystins increased from 2001 to 2006. There is therefore a possibility that these concentrations will continue to increase, to the point that they will pose a problem for some drinking water facilities, especially taking into account the variability (heat and precipitation) associated with climate change.

Scenarios for the occurrence and proliferation of cyanobacteria in the context of climate change

Climate change could alter the dynamics of cyanobacterial blooms by increasing:

1. the frequency of occurrence;
2. the quantities of cyanotoxins produced;
3. the duration of high-risk periods for such events (appearing earlier in the spring and late autumn).

It could also cause changes in the composition of cyanobacteria species, particularly favouring those that produce toxins.

The scientific literature generally supports the hypothesis that the expected changes in the climate could encourage the proliferation of toxic cyanobacteria in streams and bodies of water in temperate regions, but the scale of this increase is uncertain and imprecise. At the time of writing, no study has been conducted in Québec on the impact of climate change on the proliferation of cyanobacteria. In order to assess the vulnerability of drinking water facilities in Québec, three scenarios were identified:

- the first is based on the maximum cyanotoxin concentrations measured in Québec to date;
- the second is based on the recommendations of the "Guide for owners, operators and designers of municipal drinking water treatment plants dealing with a cyanobacterial bloom problem" prepared by the MDDEP;
- the third is based on the worst documented cases of occurrence in drinking water sources outside Québec.

These three scenarios are described in detail below.

One of the premises of this study was that all municipal drinking water intakes (from surface water) were likely to be affected by cyanobacterial blooms although, in fact, this is not the case. Consequently, this premise greatly overestimates the current situation, extrapolating the risk to areas or facilities where it will probably never exist, such as intakes in the Saint Lawrence River. Although it is reasonable to assume that some facilities will never be affected, it is useful to evaluate the worst-case scenario in order to judge potential responses for all facilities in Québec.

In addition, all occurrence scenarios assumed that 100% of the toxins were in dissolved form (or extracellular), i.e. not inside the cyanobacterial cells (or intracellular)[2].

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[2] An intracellular toxin may, in some cases, be easier to eliminate, since many water treatment plants have a filtration process (usually involving sand), which is capable of separating out cyanobacterial cells, along with the intracellular cyanotoxins they contain. On the other hand, toxins that are not inside the cells (extracellular toxins) are extremely fine and consequently escape filtration, with the exception of nanofiltration and reverse osmosis. Other processes must therefore be used to eliminate them.

The relationship between these two forms of toxin (intracellular and extracellular) is variable, depending on the time, the location and the type of cyanobacteria. Thus, actively growing cyanobacteria may contain more intracellular cyanotoxins while events leading to their death will cause a salting out effect, with the toxins becoming extracellular, expelled from the cell. The removal of extracellular toxins usually requires more advanced treatment.

It is also essential to avoid making a direct link between target threshold concentrations of toxins in drinking water in Québec (1.5 µg/L of total microcystins – the equivalent in microcystin-LR – and 3.7 µg/L of anatoxin-a) and the density of cyanobacteria cells measured in raw water. A cyanobacterial population consists of a range of species that may or may not produce cyanotoxins, in which the proportion of those capable of producing toxins is highly variable. For example, in a region of Australia, the proportion of the species *Microcystis aeruginosa* producing microcystins was estimated at 56%, while in twenty-two lakes in southern Québec, researchers have found that the biomass of toxic cyanobacteria represented less than 1% of the total. The treatment capacity of facilities has therefore been assessed according to the concentrations of cyanotoxins rather than the density of cyanobacteria cells.

The following paragraphs provide detailed descriptions of the three cyanotoxin occurrence scenarios used to assess the current and future vulnerability of drinking water facilities

"Historic" scenario

The "historic" scenario is based on the maximum cyanotoxin concentrations measured to date in a raw water intake in Québec (data from MDDEP). The maximum concentration of microcystins (microcystin-LR equivalent) measured to date in Québec was 5.35 µg/L while that of anatoxin-a was 2.3 µg/L.

"MDDEP" scenario

The "MDDEP" scenario is based on a proposal by the MDDEP for design criteria for drinking water treatment works. These criteria are presented as a required percentage of removal for the two groups of cyanotoxins. Thus, for microcystins, 95% removal is proposed for intakes located near the surface of the water (< 5 meters from the surface); this translates into a maximum allowable concentration of 30 µg/L of microcystins in raw water (given the recommendation of 1.5 µg/L in treated water, i.e. 5% of 30 µg/L). This scenario was considered to be very conservative because historically, the maximum concentration has been about five times lower (5.35 µg/L). For anatoxin-a, the MDDEP proposes a maximum removal of 75%. Since the maximum value currently suggested for drinking water is 3.7 µg/L, the maximum allowable concentration to be treated in raw water is 15 µg/L (25% of 15 µg/L = 3.7 µg/L).

"Climate change" scenario

A number of studies from around the world have reported concentrations of cyanotoxins in various sources of raw water used for drinking water. The concentrations given are not necessarily those of extracellular cyanotoxins, but more often those of total toxins (extracellular + intracellular), and they have been measured using different methods.

The “climate change” scenario is based on a maximum concentration of 60 µg/L of microcystins to be treated in raw water, approximately the average maximum concentrations identified in the literature. For anatoxin-a, the concentration proposed in the “MDDEP” scenario (15 µg/L) was considered to be high enough since no higher concentrations are reported in the literature. As a result, the concentration of anatoxin-a was not increased for the “climate change” scenario and was maintained at 15 µg/L. It must therefore be conceded that the concentrations used in this scenario are somewhat arbitrary, as they are not the result of a mathematical analysis of the data collected, which is too heterogeneous and has not all been shown to be reliable.

General performance of drinking water treatment processes in removing cyanotoxins[3]

It is important to consider the form in which cyanotoxins are present in water (intracellular or extracellular). Some treatments are effective in removing only one of these forms, while some advanced technologies such as nanofiltration membranes or reverse osmosis are able to remove both. A drinking water treatment plant is usually comprised of a chain of processes which are selected based on the quality of the water to be treated. For readers who are not familiar with these main types of treatment, a summary of the processes is given in Appendix A of the full report, which can be found at: http://www.drinking-water.org/flash/en/water.html?_3_08_00.

The main types of water treatment can be divided into the following categories:

1. processes involving physical removal;
2. oxidation processes;
3. adsorption processes[4] and
4. biodegradation processes.

Only oxidation and biodegradation processes destroy cyanotoxins; the others allow cyanobacterial cells containing intracellular cyanotoxins to be physically separated out (by removing the cyanobacteria), or allow extracellular cyanotoxins to be “captured” (for example through the adsorption of the toxins onto a material with special properties, such as activated carbon).

While whole cyanobacterial cells (including intracellular cyanotoxins) can be removed by physical barrier techniques such decantation and filtration, it is preferable for extracellular toxins to be removed by oxidation or adsorption processes. Those processes that allow physical removal provide a significant protective barrier. However, it is possible for intracellular cyanotoxins to be released into the water because the physical barriers may facilitate their release by causing the cyanobacteria’s cell walls to rupture (a phenomenon called cell lysis). This is the source of one of the assumptions underlying this vulnerability analysis, which is based on the removal of extracellular toxins. As a result, treatments that are not effective in removing extracellular toxins have not been considered.

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[3] This section provides a summary of generic information regarding the effectiveness of the treatment technologies presented in the report. For specific information on each group of technologies, see the full version of the report.

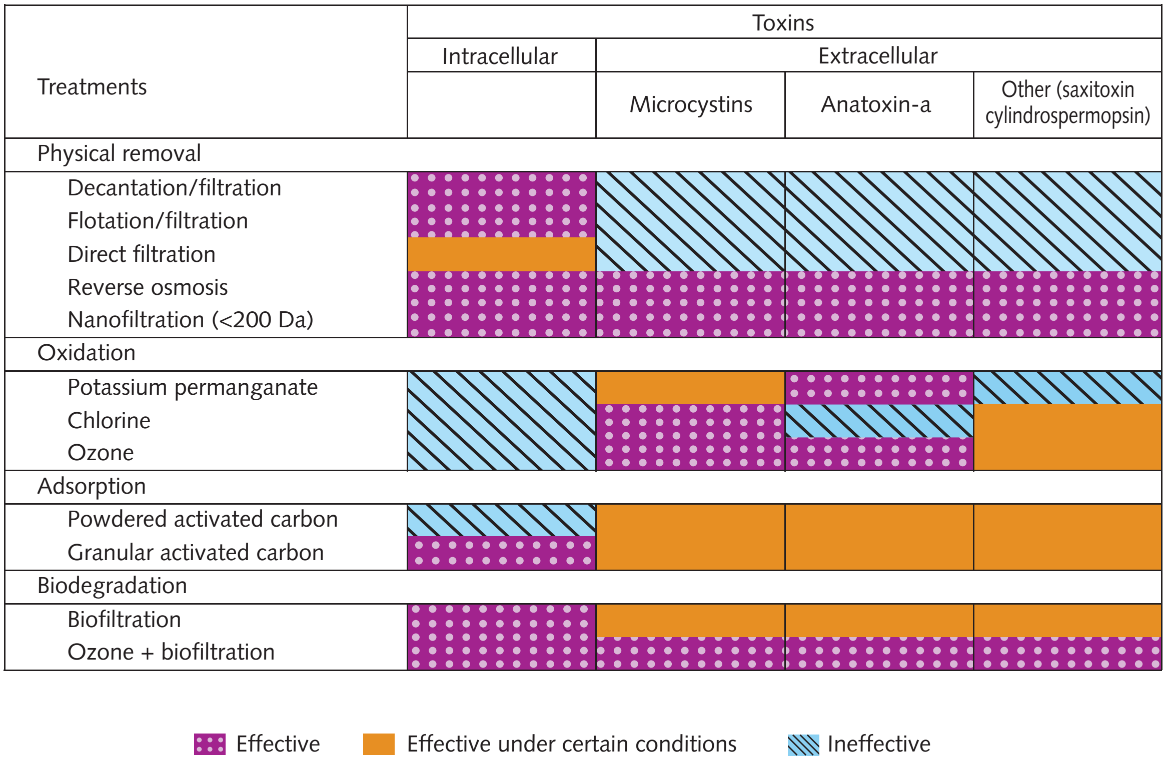
[4] Adsorption should not be confused with absorption. Absorption refers, for example, to the penetration of a liquid into a substance or material (e.g. water absorbed by a sponge), while adsorption refers to retention on a surface (cyanotoxins may adhere to the surface of a grain of activated carbon without penetrating it).

Figure 1 shows the effectiveness of the main categories of treatment to eliminate of cyanobacteria and their toxins. As illustrated, treatments involving physical separation (clarification, filtration, etc.) are effective in removing cyanobacteria (including intracellular cyanotoxins), but ineffective in separating out extracellular cyanotoxins, except where membrane technologies (reverse osmosis and nanofiltration) capable of separating out small molecules are used. Among oxidation treatments, ozone is the most effective method, followed by potassium permanganate. Chlorine, widely used for disinfection, is effective for one of the two families of toxins studied, microcystins.

Adsorption treatments involve the use of powdered activated carbon (PAC) or granular activated carbon (GAC). The use of PAC provides an extremely variable removal performance, from 15% to 100% depending on the type of carbon used, its concentration, the concentration of cyanotoxins, the organic matter dissolved in the water and a number of other parameters. In general a high concentration in the order of 20 to 30 mg of PAC per litre of water to be treated is required to achieve a removal rate of over 90%. Although filtration using granular activated carbon (GAC) may be very effective, its very short service life in drinking water plants (less than 6 months) greatly limits its use. Biofiltration may be an effective process provided that a bacterial biomass capable of degrading cyanotoxins has first been established in the biofilter, which seems generally to be the case[5].

FIGURE 1

Summary of the efficacy of treatments to remove intracellular and extracellular cyanotoxins



Treatments	Toxins			
	Intracellular	Extracellular		
		Microcystins	Anatoxin-a	Other (saxitoxin cylindrospermopsin)
Physical removal				
Decantation/filtration	▦	▨	▨	▨
Flotation/filtration	▦	▨	▨	▨
Direct filtration	🟧	▨	▨	▨
Reverse osmosis	▦	▦	▦	▦
Nanofiltration (<200 Da)	▦	▦	▦	▦
Oxidation				
Potassium permanganate	▨	🟧	▦	▨
Chlorine	▨	▦	▨	🟧
Ozone	▨	▦	▦	🟧
Adsorption				
Powdered activated carbon	▨	🟧	🟧	🟧
Granular activated carbon	▦	🟧	🟧	🟧
Biodegradation				
Biofiltration	▦	🟧	🟧	🟧
Ozone + biofiltration	▦	▦	▦	▦

▦ Effective 🟧 Effective under certain conditions ▨ Ineffective

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[5] When cyanotoxins are present in water for an extended period, bacteria capable of destroying them (or more precisely, metabolizing them) develop naturally. Biofiltration involves concentrating these bacteria, growing them on an inert medium, and circulating them in the water to be treated.

Comparison of the capacity of Québec municipal drinking water facilities to remove cyanotoxins

The vulnerability of a drinking water facility depends primarily on two variables: the quality of the water supplying it and the overall performance of the treatments in place. With regard to the quality of the water supply, the assumption is that all plants are affected by cyanobacterial blooms; this is a deliberate overestimation of the current situation.

To characterize the performance of the different treatments, the theoretical performance was calculated based on a sample of 29 selected municipal treatment facilities in Québec that are supplied with surface water (of a total of 284 municipal facilities, thus providing a sample of 10%). This detailed, technical approach was justified by the fact that the performance of certain processes depends on the specific conditions of treatment (e.g. concentration of chlorine or activated carbon, or contact time between the water and these treatments). As already mentioned, only the treatments believed to be effective in eliminating extracellular cyanotoxins were considered, i.e. oxidation treatments (ozone, chlorine and permanganate) and adsorption treatments (powdered activated carbon). High pressure membranes were not considered as they are not commonly encountered in Québec.

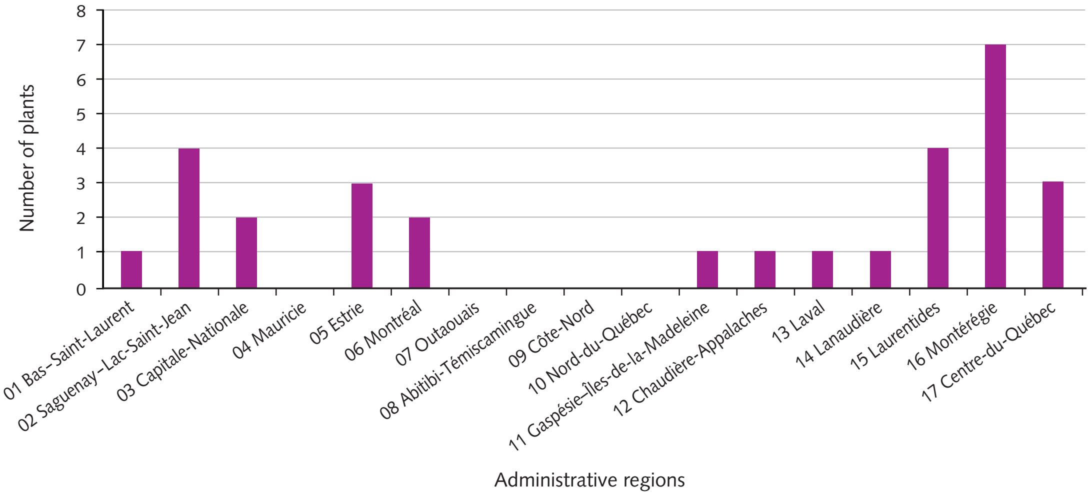
For this project, the subset of the 284 municipal drinking water plants was selected in such a way that it would be representative of:

- the main areas affected by cyanobacteria, i.e. the following administrative regions: Laurentides, Lanaudière, Montérégie, Estrie, Centre-du-Québec, Capitale-Nationale (Québec), Saguenay-Lac-Saint-Jean and Chaudière-Appalaches;
- all treatments that are effective against cyanotoxins (ozone, PAC, etc.);
- sources of raw water (rivers and lakes).

Figure 2 shows the distribution of the 29 municipal facilities among the administrative regions of Québec. Some regions were not represented, either because the people contacted did not respond or because they were regions that have had few or no cyanobacterial blooms (e.g. the North Shore or Northern Québec). Among the 29 facilities selected, 15 were supplied from lakes and 14 from rivers.

FIGURE 2

Geographic distribution of the 29 municipal drinking water facilities selected (the sample) to assess vulnerability to cyanobacterial blooms



The types of treatment used in these facilities are shown in table 1. All 29 facilities have chlorination; filtration is used in 26 (including 3 with biofiltration), 7 have ozonation, 5 use potassium permanganate ($KMnO_4$) and 11 use powdered activated carbon (PAC). This sample was not quite proportionally representative of the treatments used in all municipal facilities in Québec, since the most effective treatments (less prevalent throughout Québec) were used as a selection criterion.

TABLE 1

Treatments used in the 29 facilities selected for assessing vulnerability to cyanobacterial blooms and in all municipal surface water facilities in Québec

	Sample used in this study (n = 29)		Plants in Québec (n = 284)	
Treatment	N	%	N	%
Total	29	100%	284	100%
Chlorine	29	100%	276	97%
Ozone	8	28%	42	15%
PAC	11	38%	32	11%
$KMnO_4$	5	17%	5	2%
Filtration	26	90%	136	48%
Biofiltration	3	10%	9	3%

Capacity to remove cyanotoxins at the 29 drinking water plants selected

The performance of the treatments used at the 29 facilities was evaluated based on the three occurrence scenarios described above. The actual conditions under which the treatments are used have been incorporated into the assessment. However, with regard to PAC, the potential maximum concentrations were used in the assessment since the concentrations actually used in the facilities (often very low) would not have allowed us to estimate the potential treatment capacity[6].
The percentage of compliance with the three occurrence scenarios for each treatment is shown in table 2. For example, PAC alone allows 5 of the 11 plants using this treatment (45%) among the 29 studied, to eliminate microcystins in the context of the historical scenario.

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[6] Activated carbon can be used in various concentrations in the water to be treated. In many treatment facilities, a PAC concentration that is below maximum capacity is used because in order to eliminate tastes and odours, a lower concentration than would be necessary to manage cyanotoxins is required. However, if there were a major problem, such as the presence of cyanotoxins, it would be necessary to use the maximum concentration. It was this theoretical maximum concentration that was used in this study.

TABLE 2

Percentage of compliant municipal drinking water facilities, based on the use of the individual treatments[7]

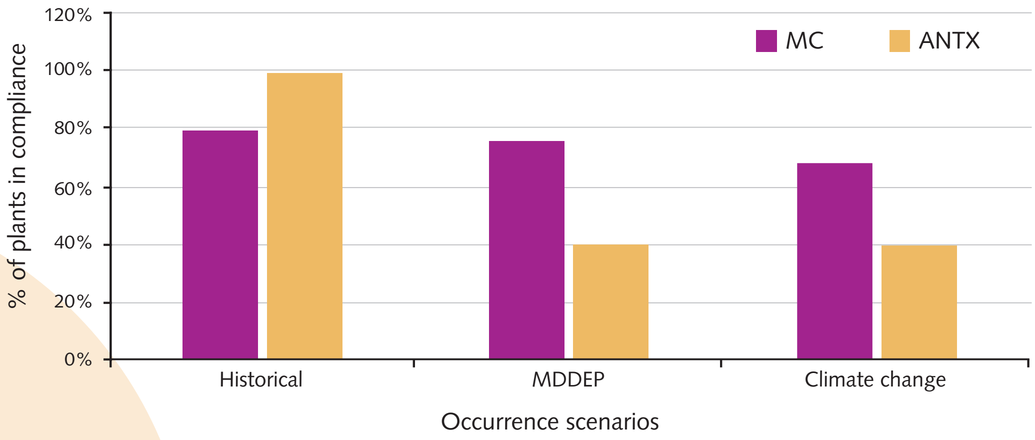
Toxins	Scenarios	Types of treatment		
		Ozone	Chlorine	PAC
Microcystin-LR	Historical	100	75	45
	MDDEP	100	62	18
	Climate change	100	55	9
Anatoxin-a	Historical	100	100	100
	MDDEP	100	0	45
	Climate change	100	0	45

The overall percentage of compliance at the 29 facilities studied is shown in figure 3. Thus, for the historical scenario, approximately 80% of the facilities surveyed should be capable of reducing the concentration of microcystin-LR to below the maximum recommended concentration in drinking water, i.e. 1.5 µg/L. In addition, facilities capable of treating concentrations in the historical scenario (75%) could, to a large extent, also manage the much higher concentrations in the climate change scenario.

FIGURE 3

Compliance of the 29 municipal facilities selected for assessing vulnerability to cyanotoxins, for the three occurrence scenarios identified

MC: microcystin ANTX: anatoxin-a



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[7] Potassium permanganate ($KMnO_4$) was not evaluated since only 2% of the 284 facilities use this treatment.

With regard to anatoxin-a, given that the maximum concentration measured in Québec to date (2.3 µg/L) is lower than the provisional guideline value suggested for drinking water (3.7 µg/L), 100% of the 29 facilities are compliant for the historical scenario. However, for higher concentrations (MDDEP or climate change scenarios), it is expected that only facilities with effective treatment against this cyanotoxin (either ozone or PAC) would reduce the concentration to below the provisional value suggested for treated water.

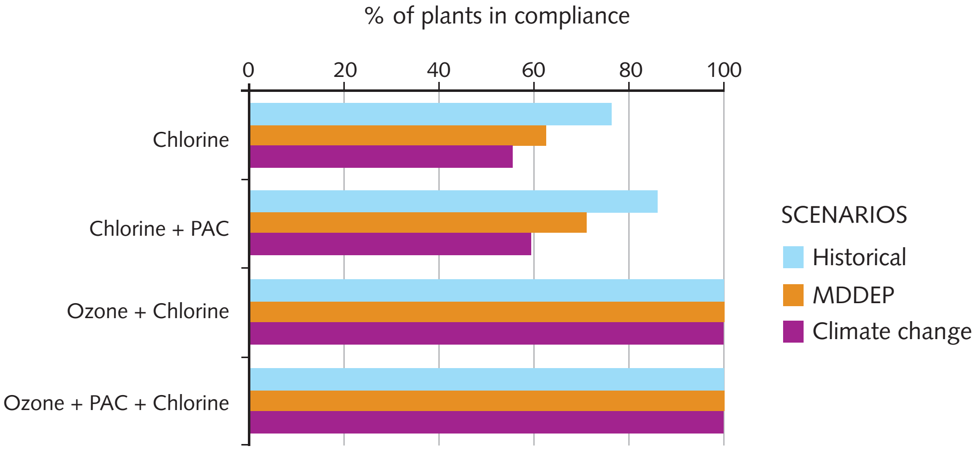
Estimated treatment capacity of all municipal drinking water plants in Québec (supplied with surface water)

In order to extrapolate the results from the 29 facilities selected to all municipal plants supplied with surface water in Québec, a summary of the treatments used at these 284 facilities was made. Based on the treatment efficiencies calculated for the 29 selected facilities, the treatment capacity of all the plants was estimated for three occurrence scenarios.

Figure 4 shows that every treatment facility using ozonation (ozone + chlorine or ozone + chlorine + PAC) is guaranteed to be compliant for permitted residual concentrations of microcystins because this oxidation process is sufficiently efficient to destroy cyanotoxins. In addition, chlorination alone is sufficient to ensure compliance for 55% of the facilities under the “climate change” scenario (bottom bar of the first group at the top of figure 4). However, this percentage could be increased by bringing up to standard (e.g. increasing chlorination performance) several municipal treatment facilities that are required to comply with the regulations within a few years. The use of PAC in conjunction with chlorination would increase the performance achieved by chlorine alone by a few percentage points (from 4 to 11% – the second group of bars compared to the first group in figure 4).

FIGURE 4

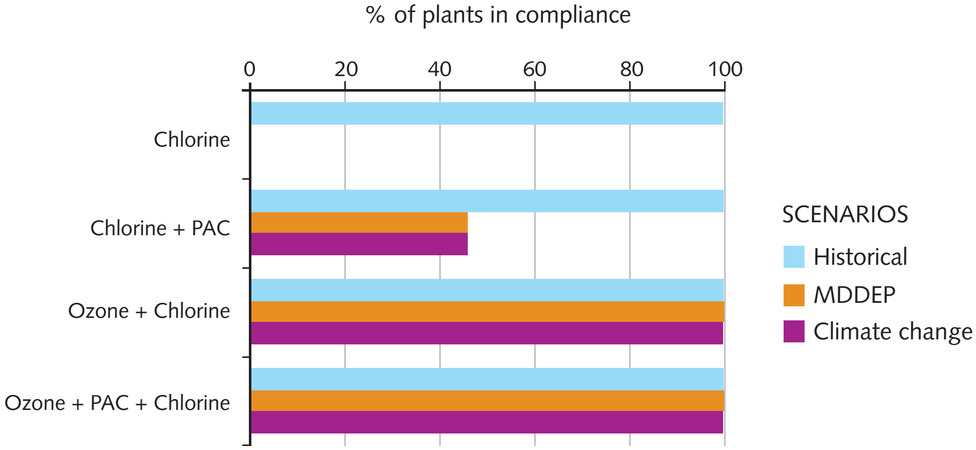
Theoretical treatment capacity of the 284 municipal drinking water facilities (supplied with surface water) by microcystin occurrence scenarios



With regard to the effectiveness of treatment in eliminating anatoxin-a (figure 5), the use of chlorination alone is not sufficient to destroy it in the context of the "MDDEP" and "climate change" scenarios (0% of plants in compliance). As for the use of PAC in addition to chlorine (the second group of bars), it allows 45% of facilities to comply under these two scenarios, but only if the theoretical maximum capacity of carbon is applied. Finally, ozonation (alone or in addition to other treatments, as shown by the third and fourth groups of bars) allows anatoxin-a to be totally eliminated.

FIGURE 5

Theoretical treatment capacity of the 284 municipal drinking water facilities (supplied with surface water), based on the anatoxin-a occurrence scenarios

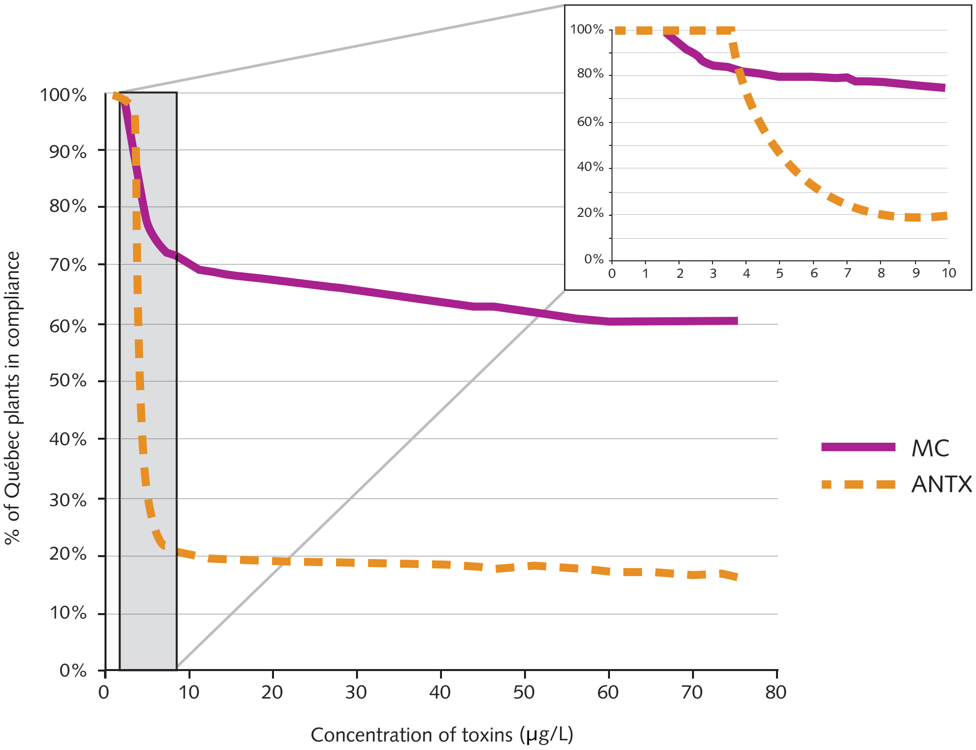


Based on the treatments used in all 284 Québec facilities (table 1) and the toxin removal capacity of each treatment (table 2, figures 4 and 5), figure 6 shows the overall potential performance for various concentrations of cyanotoxins in raw water. It was found that after a significant decrease in the number of compliant facilities as the concentration of cyanotoxins is increased from 0 to 10 µg/L, treatment capacity remains relatively stable thereafter as cyanotoxin concentrations continue to increase. This is because in the absence of adequate treatment, a drinking water facility will be ineffective as soon as cyanotoxins go above 5-10 µg/L. However, where appropriate treatment is in place (e.g. ozonation) treatment capacity is maintained, even with higher concentrations of toxins. This chart also shows that the treatments currently used would in most cases be capable of handling relatively high concentrations of microcystins in raw water.

For anatoxin-a, the high percentage of compliance for the historical scenario (100%) is due only to the fact that the maximum concentration reported so far in raw water (2.3 µg/L) is lower than the suggested provisional guideline value (3.7 µg/L). All facilities are compliant without any treatment at the time of the study. A high percentage of drinking water plants (> 60%) would be unable to eliminate anatoxin-a beyond this guideline value (3.7 µg/L) because of the inefficiency of chlorination, which is currently the most widespread treatment. This explains the shape of the curve, with a sharp drop after 3.7 µg/L. Ozone, PAC or potassium permanganate would be treatment options to be considered in the event of a potential increase in anatoxin-a. It should be remembered, however, that the guideline value is liable to be re-evaluated over the coming years, as more specific information regarding the toxicity of anatoxin-a comes to light. Moreover, upgrades in Québec water treatment plants (resulting in increased performance) would be required only for plants located in areas where the presence of this cyanotoxin is detected in raw water on a recurring basis.

FIGURE 6

Diagram of cyanotoxin theoretical treatment potential extrapolated to 284 municipal drinking water facilities (supplied with surface water) in Québec, by toxin concentration in the raw water (accounting for acceptable concentrations of microcystin (MC) and anatoxin-a (ANTX) in the treated water)



CONCLUSION

In a context of projected climate change, preliminary scientific assessments point to a possible increase in cyanobacterial blooms. Its precise impact on Québec is currently impossible to assess, but reports of cyanobacterial blooms in surface water have increased in recent years.

It is possible to control the risk associated with the presence of cyanotoxins in drinking water using existing processes. Ozone is the most effective treatment for both microcystins and anatoxin-a. Chlorine, the most common treatment used in Québec facilities, is effective against microcystins but does not eliminate anatoxin-a above a certain concentration. The use of powdered activated carbon (PAC) may be effective to some extent, but its capacity depends on a number of parameters.

The assessment of the cyanotoxin removal capacity of 29 specific municipal drinking water facilities was extrapolated to all facilities using surface water in Québec (284 facilities). This generalization assumes that all plants supplied with surface water in Québec could be affected by cyanobacterial blooms, which is not the case, and far exceeds what has been observed to date. This approach was justified by the absence of data to evaluate a specific percentage of plants that could potentially be affected. A better knowledge of water quality would make a more realistic assessment possible.

Although this study is based on a theoretical analysis of the anticipated performance of the facilities, the approach chosen is similar to that used in North America for designing disinfection water treatment processes. The assumption that the toxins are 100% present in extracellular form – the form that is more difficult to treat – served as a basic premise. In practice, the proportion of extracellular toxins would be about 30%, according to some studies. It is also important to note that the analysis of the performance of plants was based on a summer ambient temperature of 20 °C, because there is little information in the scientific literature about the influence of temperature; this is also because cyanobacterial blooms usually occur in warm water. However, in Québec, blooms have been observed as late as November. Note also that this study was limited to a detailed analysis of 29 municipal facilities (or 10% of the Québec municipal facilities supplied with surface water), with the results extrapolated to all 284 municipal facilities supplied with surface water, and this obviously imposes a degree of uncertainty.

Another limitation of the study concerns the way in which the scenarios used were developed, given that the concentration of cyanotoxins in raw water supplying treatment plants is not well-known and will inevitably vary. Cyanobacterial blooms are not stable events, and their distribution over space and time is highly variable. As a result, with the many variables present, the scenarios will need to be reviewed or revised as the science becomes clearer.

The key points are that at the time of the study:

1. the vast majority of drinking water facilities in Québec do not take raw water from areas where there are cyanobacterial blooms;
2. known blooms are highly localized and affect only a few facilities;
3. cyanotoxin concentrations in raw water are usually quite low;
4. facilities using raw water contaminated by cyanobacteria are able to reduce concentrations of cyanotoxins to values of 30 to 50 times lower than limit values for drinking water;
5. there is no data suggesting that cyanobacterial blooms will be a problem affecting all of Québec in the foreseeable future.

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TRANSLATION

National Collaborating Centre for Environmental Health (NCCEH)

We acknowledge the active participation of Mr. Donald Ellis and Mrs. Caroline Robert, ministère de l'Environnement, du Développement durable et des Parcs (MDDEP, Québec) in producing the report, and the participation of Mrs. Hélène Tremblay in the revision of this fact sheet. In addition, the final scientific review was conducted by Dr. Pierre Gosselin of the Institut national de santé publique du Québec.

This summary is available in electronic form (PDF) on the Institut national de santé publique du Québec Website: *http://www.inspq.qc.ca*.

Publication number: 900

Legal Deposit - 2nd quarter 2009
Bibliothèque et Archives nationales du Québec
Library and Archives Canada
ISBN: 978-2-550-55319-9 (PDF)

Institut national de santé publique Québec

CHAIRE INDUSTRIELLE CRSNG EN EAU POTABLE

ÉCOLE POLYTECHNIQUE MONTRÉAL

Funding by:

Ministère de la Santé et des Services sociaux Québec

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