Electronic Supplementary Material (ESI) for Environmental Science: Processes & Impacts
This journal is © The Royal Society of Chemistry 2014

Application of *in vivo* measurements for the management of cyanobacteria breakthrough into drinking water treatment plants

Arash Zamyadi[1*], *Sarah Dorner*[1], *Mouhamed Ndong*[1], *Donald Ellis*[2], *Anouka Bolduc*[2], *Christian Bastien*[3] *and Michèle Prévost*[1]

[1] École Polytechnique de Montreal, Civil, Mineral and Mining Engineering Department, P.O. Box 6079, Station Centre-ville, Montreal, Quebec, Canada, H3C 3A7

[2] Direction des politiques de l'eau, Ministère du Développement Durable, de l'Environnement, Faune et des Parcs (MDDEFP), 675, Rene-Levesque Est, 8[e] étage, Quebec City, Quebec, Canada, G1R 5V7

[3] Centre d'expertise en analyse environnementale du Québec (CEAEQ), 2700 Einstein, Quebec City, Quebec, Canada, G1P 3W8

* Corresponding author Phone: 647-227-1980; E-mail: arash.zamyadi@polymtl.ca

Supplementary data (SD)

Number of pages: 6

Number of table: 3

This journal is © The Royal Society of Chemistry 2014

Table SD-*I1*. Toxins produced by cyanobacteria and their documented human health effects (Chorus and Bartram 1999; Svrcek and Smith 2004; Cooperative Research Centre for Water Quality and Treatment 2007; Merel et al. 2010; Gutiérrez-Praena et al. 2012).

Cyanotoxin	Mechanism of toxicity
Microcystins (MCs) in general (~60 known analogues) MC-LR MC-LA MC-YR MC-RR	Hepatotoxic: Protein phosphatase blockers by covalent binding and cause haemorrhaging of the liver
Saxitoxins (STXs) also known as paralytic shellfish poisons in general (~30 known analogues) Saxitoxin (STX) C-toxin1 & 2(C1 & C2) Gonyautoxin2 & 3 (GTX2 & GTX3)	Neurotoxin: STXs are potent voltage-gated sodium channel antagonists, causing numbness, paralysis and death by respiratory arrest. STX disrupts the nervous system via binding to the sodium channel and inhibits the sodium ions transport
Cylindrospermopsin	Cytotoxic: blocks protein synthesis

*

This journal is © The Royal Society of Chemistry 2014

Table SD-*I2*. Guideline levels for managing drinking source waters containing cyanobacterial cells proposed by World Health Organisation (Chorus and Bartram 1999).

Alert level	Density of Cyanobacterial cells	Action
Vigilance	200 cyanobacterial cells/ml	• Non-bloom condition, weekly monitoring*
1	2,000 cyanobacterial cells/ml or 1 µg/l chlorophyll-a with a dominance of cyanobacteria	• Weekly cyanobacterial count • Weekly toxin testing to be initiated in drinking water supplies • Issue advisory notice to public
2	100,000 cyanobacterial cells/ml or 50 µg/l chlorophyll-a with a dominance of cyanobacteria	• Weekly cyanobacterial count • Weekly toxin testing in drinking water supplies • More extensive advice to public • Switching to alternative supply should be considered if available

* Monitoring methods: Microscopic enumeration methods, continuous flow cytometry, high-resolution digital photometry and real time quantitative polymerase chain reaction (qPCR) have been developed and proposed as cyanobacterial monitoring tools. However these methods cannot provide rapid cost-effective online results. These methods require highly qualified personnel and expensive instrumentation, and they remain tedious, as several steps must be taken to prepare the samples and the analytical methods (Daly et al. 2007; Gregor et al. 2007; Ziegmann et al. 2010). Furthermore, microscopic enumeration measurements may be subject to considerable systematic and operator error, particularly when filaments or colonies are present (Lawton and Robertson 1999; Ahn et al. 2007). Current monitoring and treatment adjustments strategies are not capable of detecting the rapid variation of cyanobacterial presence at the water intake and subsequent breakthrough events. This lack of real time treatment adjustment led to the breakthrough of cells and toxins into drinking water as documented by Zamyadi et al. (2012).

This journal is © The Royal Society of Chemistry 2014

Table SD-*I3*. Guideline levels and recommended interventions for management of cyanobacteria related issues at drinking water sources introduced by the "Ministère du Développement Durable, de l'Environnement, Faune et des Parcs (MDDEFP) / Ministry of Environment" of Province of Quebec (Canada) (Ellis 2009) in response to increasing presence of toxic cyanobacterial bloom in drinking water sources*.

<table>
<tr><th rowspan="2">Characteristics of the water body**</th><th rowspan="2">Characteristics of the water intake***</th><th colspan="2">Intervention</th></tr>
<tr><th>Necessary</th><th>Suggested</th></tr>
<tr><td>– Absence of historical records or sporadic presence of cyanobacterial blooms</td><td>– Absence of historical records of cyanobacterial blooms</td><td>-</td><td>Water quality monitoring in the water body</td></tr>
<tr><td>– Historical presence of cyanobacterial blooms within 200m of the drinking water intake</td><td>– Absence of historical records of cyanobacterial blooms</td><td rowspan="2">Water quality monitoring at the water intake prior to any treatment</td><td rowspan="2">Protective measures</td></tr>
<tr><td rowspan="3">– Historical presence of cyanobacterial blooms within 200m of the drinking water intake</td><td>– Absence of historical records of cyanobacterial blooms and
– Water intake situated over 3m deep at any time from July to October</td></tr>
<tr><td>– Absence of historical records of cyanobacterial blooms and
– Water intake situated less than 3m deep at any time from July to October</td><td>Water quality monitoring at the water intake prior to any treatment and protective measures</td><td>Considering alternative treatment options ****</td></tr>
<tr><td>– Historical presence of cyanobacterial blooms</td><td>Water quality monitoring at the water intake prior to any treatment, protective measures, and implementation of efficient treatment barriers</td><td>-</td></tr>
</table>

This journal is © The Royal Society of Chemistry 2014

* Direct and indirect effects of climate change including combination of anthropogenic nutrient loading, rising water temperatures, enhanced vertical stratification, and increased atmospheric CO_2 supplies, could enhance the timing and proportional dominance of the cyanobacteria in different water bodies (Elliott 2012; Paerl and Paul 2012).

** For a given water body, a test result showing an abundance of over 20,000 cells/mL in the water column over a year in the last 5 years indicates a historical presence of cyanobacterial blooms.

*** For a water intake supplying a drinking water treatment plant (DWTP), a test result showing an abundance of over 10,000 cells/mL in raw water prior to any treatment (including the presence of potentially toxic genera) at least one occasion during the last 5 years indicates a historical presence of cyanobacterial blooms.

**** The assessment of potential alternative treatment options is recommended if upgrade of the DWTP is planned/ongoing, in order to provide immediate design elements needed to insure the new treatment efficiency in removal of cyanobacteria and their associated toxin.

This journal is © The Royal Society of Chemistry 2014

References

C. Y. Ahn, S. H. Joung, S. K. Yoon and H. M. Oh, Alternative alert system for cyanobacterial bloom, using phycocyanin as a level determinant, *J. of Microbiol.*, 2007, 45, 98-104.

Toxic cyanobacteria in water: a guide to their public health consequences, monitoring and management, ed. I. Chorus and J. Bartram, World Organization Health (WHO), E&FN Spon, London, UK, 1999.

Cyanobacteria: management and implications for water quality: 36. Cooperative Research Centre for Water Quality and Treatment, Australia, 2007.

R. I. Daly, L. Ho and J. D. Brookes, J. D., Effect of chlorination on Microcystis aeruginosa cell integrity and subsequent microcystin release and degradation. *Environ. Sci. and Tech.*, 2007, 41, 4447-4453.

J. A. Elliott, Is the future blue-green? A review of the current model predictions of how climate change could affect pelagic freshwater cyanobacteria. *Water Res.*, 2012, 46, 1364-1371.

D. Ellis, *Guide d'intervention pour les propirétaires, les exploitants ou les conceptieurs de stations de production d'eau potable municipales prises avec une prblématique de fleurs d'eau de cyanobactéries*. Ministère du développement durable, de l'environnement et parcs Québec, Québec City, 2009.

J. Gregor, B. Marsalek and H. Sipkova, Detection and estimation of potentially toxic cyanobacteria in raw water at the drinking water treatment plant by *in vivo* fluorescence method, *Water Res.*, 2007, 41, 228-234.

D. Gutiérrez-Praena, S. Pichardo, A. Jos, F. J. Moreno and A. M. Camean, Biochemical and pathological toxic effects induced by the cyanotoxin Cylindrospermopsin on the human cell line Caco-2. *Water Res.*, 2012, 46, 1566-1575.

L. A. Lawton and P. K. J. Robertson, Physico-chemical treatment methods for the removal of microcystins (cyanobacterial hepatotoxins) from potable waters. *Chemical Society Reviews*, 1999, 28, 217-224.

S. Merel, M. Clément and O. Thomas, Review State of the art on cyanotoxins in water and their behaviour towards chlorine. *Toxicon*, 2010, 55, 677–691.

H. W. Paerl and V. J. Paul, Climate change: Links to global expansion of harmful cyanobacteria. *Water Res.*, 2012, 46, 1349-1363.

C. Svrcek and D. W. Smith, Cyanobacteria toxins and the current state of knowledge on water treatment options: a review, *Environ. Eng. and Sci.*, 2004, 3, 155-185.

A. Zamyadi, S. MacLeod, Y. Fan, N. McQuaid, S. Dorner, S. Sauvé and M. Prévost, Toxic cyanobacterial breakthrough and accumulation in a drinking water plant: a monitoring and treatment challenge. *Water Res.*, 2012, 46, 1511-1523.

M. Ziegmann, M. Abert, M. B. Muller and F. H. Frimmel, Use of fluorescence fingerprints for the estimation of bloom formation and toxin production of *Microcystis aeruginosa*. *Water Res.*, 2010, 44, 195-204.