Challenges to Treat Cyanotoxins from Drinking Water on a Large, Small and Household Scale

OWWA/OMWA Joint Annual Conference

Tory Hewlett, Souleymane Ndiongue, Larry Moore
May 5, 2013
## Introduction

- Increasing events of cyanobacteria blooms
- Health Implications:

<table>
<thead>
<tr>
<th>Cyanotoxins</th>
<th>Health effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anatoxin (AnTX)</td>
<td>Nervous system</td>
</tr>
<tr>
<td>Saxitoxin (STX)</td>
<td>Nervous system</td>
</tr>
<tr>
<td>Microcystins (MC)</td>
<td>Liver</td>
</tr>
<tr>
<td></td>
<td>Tumor promoting effects</td>
</tr>
<tr>
<td>Nodularins (Nod)</td>
<td>Liver</td>
</tr>
<tr>
<td>Cylindrospermopsin (CYN)</td>
<td>Liver and kidney</td>
</tr>
<tr>
<td></td>
<td>Tumor promoting effects</td>
</tr>
</tbody>
</table>

WHO provisional guideline 1.0 µg/L MC-LR
Canadian maximum acceptable concentration 1.5 µg/L MC-LR
Challenges:

1. Aging cyanobacteria cells

2. Some treatment cause cell rupture

3. Treatment effectiveness varies with intracellular and released cyanotoxins

4. Treatment effectiveness varies with specific cyanotoxins
Water Treatment

- Conventional Treatment Processes
- Dissolved Air Flotation
- Slow Sand Filtration
- Ultrafiltration
- Nanofiltration
- Activated Carbon
- Oxidation
Intracellular

Conventional

- 70-99.9% removal
- Trapped cells could rupture and release toxins
- May be influenced by NOM
Dissolved Air Flotation

- 93-99% removal
- Sludge must be removed frequently
- Not as influenced by NOM, than conventional
Slow Sand Filtration

- 80-99% removal
- Trapped cells could rupture and release toxins
- Vulnerable between maintenance and at low temperatures
Intracellular

Ultrafiltration
- 90-98% removal
- Studies varied whether process ruptures cells
- May increase fouling

Effective
Moderately Effective
Ineffective

Conventional  DAF  SSF  UF
Effective

Moderately Effective

Ineffective

**Nanofiltration**
- Similar to UF
Activated Carbon

- Cells will foul and clog filters quickly
Effective

Moderately Effective

Ineffective

Ozone

- Ruptures cells
- Suggested to filter before ozone
Intracellular

Chlorine
- Ruptures cells
- Avoid pre-chlorination during a bloom
Extracellular

Effective

Moderately Effective

Ineffective

Conventional

- Inconsistent results
- MC-LR removal > AnTX-a removal
- Iron chloride > aluminum sulphate
Effective

Moderately Effective

Ineffective

Conventional

Dissolved Air Flotation
- Inconclusive
Extracellular

### Slow Sand Filtration
- 80-95% MCs removed
- 70% AnTX-a removed
- Vulnerable between maintenance and at low temperatures
<table>
<thead>
<tr>
<th>Extracellar</th>
<th>Effective</th>
<th>Moderately Effective</th>
<th>Ineffective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>DAF</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSF</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UF</td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

**Ultrafiltration**
- Ineffective due to pore size exclusion
<table>
<thead>
<tr>
<th>Effective</th>
<th>Moderately Effective</th>
<th>Ineffective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>DAF</td>
<td>UF</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**Nanofiltration**
- 90-100% MCs, AnTX-a & CYN removed
- Depends on hydrophobicity and net charge
**Activated Carbon**

- 70-85% MC-LR removed
- 70% SXT & AnTX-a removed
- 50-60% Nod & CYN removed (chemically activated wood PAC)
- Ineffective for MC-LA
- wood > coal > coconut > peat
### Extracellular

#### Effective

**Ozone**
- 36-100% of MCs degraded
- 92% of AnTX-a & CYNs degraded
- Ineffective for SXT
- Must have ozone residual
- MC-LR removal > MC-RR

#### Moderately Effective

-...

#### Ineffective

-...

---

**Others**
- Conventional
- DAF
- SSF
- UF
- NF
- Activated Carbon
Extracellular

Effective

Chlorine
- 72-100% MC-LR degraded
- 100% Nod & CYN degraded
- 60-100% SXT degraded
- 15-18% AnTX-a degraded
- Depends on pH (<8), temp., dose and contact time

Moderately Effective

Ineffective

Conventional, DAF, SSF, UF, NF, Activated Carbon, Ozone
Household Treatment

- Cartridge Filters
- Reverse Osmosis
- Ultraviolet Treatment
Household Treatment: Microcystins only

- **Effective**
  - Carbon-based filters
    - 99% MC-LR removed
    - Did not assess cell removal

- **Ineffective**
- **Moderately Effective**

- **Extracellular**
- **Intracellular**
### Household Treatment: Microcystins only

<table>
<thead>
<tr>
<th></th>
<th>Intracellular</th>
<th>Extracellular</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Moderately</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effective</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Ineffective</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Fiber wound & pleated paper
- **5.84%** MC-LR removed (Fiber-wound)
- **4.65%** MC-LR removed (Pleated paper)
- Did not assess cell removal

#### Carbon-based filters

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber wound &amp; pleated paper</td>
</tr>
</tbody>
</table>
Household Treatment: Microcystins only

**Intracellular**
- 60% filament cells removed
- 10% single cells removed
- Trapped cells could rupture

**Extracellular**
- 40-57% MCs removed
- Pre-rinse, flush and filter repeatedly
- Impractical

**Effective**
- Carbon-based filters
- Fiber wound & pleated paper
- Ion exchange resin & GAC

**Moderately Effective**
- Carbon-based filters
- Fiber wound & pleated paper

**Ineffective**
- Pre-rinse, flush and filter repeatedly
- Impractical
Household Treatment: Microcystins only

**Reverse Osmosis**
- 96.7-99.9% MC-LR and MC-RR removed
- Toxins accumulate in waste
- Did not assess cell removal

**Ineffective**
- Carbon-based filters
- Fiber wound & pleated paper
- Ion exchange resin & GAC

**Effective**
- RO
Ultraviolet Light

- 20-50% MC-LR & MC-RR degraded at 88.2-300 mJ/cm²
- 13.3% CYN degraded at 36 mJ/cm²
- 50-88% AnTX-a degraded at 1285 mJ/cm²

- Dose is impractically high
Household Treatment: Microcystins only

- Intracellular
- Extracellular

**Effective**

- Carbon-based filters
- Fiber wound & pleated paper
- Ion exchange resin & GAC
- RO
- UV

**Moderately Effective**

-

**Ineffective**

-
Research gaps

• Study other variants, particularly for household units
• Long-term pilot-scale tests and full-scale tests
• Periodic exposures of cyanotoxins to treatment studies
• Further research & development for household treatment removal efficiencies
Conclusion

• Knowledge gap in household treatment units for cyanotoxin removal
• Technologies for large and small water plants
  – Intracellular toxins: Conventional, DAF, SSF
  – Extracellular toxins: SSF, NF, AC, Ozone, Chlorine
• Multi-barrier approach add resilience
References


References


Thank you for your attention!

Questions?

Tory Hewlett
thewlett@wcwc.ca