Management of Lakes & Beaches Plagued with Cyanotoxins

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The New York State Federation Of Lake Associations
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What are Algae?

- Most are microscopic, photosynthetic organisms
- More of an ecological term than taxonomic
- Base of the aquatic food web; many algae are necessary and good
- However, some algae, particularly the blue-green algae (cyanobacteria) are a nuisance (surface scums, taste and odor)
Diversity of Freshwater Algae
Cyanobacteria (blue-green algae)

- Photosynthetic bacteria
- Very old organisms so they are very well adapted to their environments
- The dominant nuisance group of algae in freshwater ecosystems
- Many can “fix” their own nitrogen
- Responsible for nuisance scums, impact on recreational usage, potable water supplies and ecological value
- Can produce taste and odor compounds (geosmin / MIB) and cyanotoxins.
- Many are not grazed by zooplankton
Blue-Green Algae

Heterocysts

Akinetes
Gas Vacuoles and Gas Vesicles
Conditions that Result in an Blue-Green Algal Bloom

- High seasonal temperatures
- Still water conditions / thermal stratification
- Total Phosphorus concentrations as low as 0.03 mg/L (30 ppb) can generate nuisance blooms / scums
Greenwood Lake, Passaic County, NJ and Orange County, NY

The graph shows a scatter plot with the logarithm of TP on the x-axis and the logarithm of chlorophyll a on the y-axis. The data points are plotted, indicating a trend or relationship between the two variables.
Harmful Algal Blooms (HABs)

Notice
An algae bloom has made this area potentially unsafe for water contact. Avoid direct contact with visible surface scum.
Cyanotoxins (toxins generated by blue-green algae)

- **Hepatotoxins** – microcystins, nodularins, cylindrospermopsins
- **Neurotoxins** – anatoxins, saxitoxins, BMAA
- **Dermatotoxins** – lyngbyatoxins and aplysiatoxins
Cyanotoxins are NOT Taste and Odor Compounds

- Cyanotoxins are colorless, tasteless and odorless compounds.
- Taste and odor compounds such as Geosmin and MIB can be produced by cyanobacteria (blue-green algae) and some actinobacteria.
- Blue-green algae can produce T&O compounds and not produce cyanotoxins and they can produce cyanotoxins but no T&O compounds.
Currently, US EPA does not have any regulatory requirements or restrictions for blue-green algae or cyanotoxins.

World Health Organization (WHO) has a drinking water guideline of 1 ug/L for microcystin-LR.

US EPA developed Health Advisories for two cyanotoxins in May 2015 in drinking water supplies.
10-DAY EXPOSURE LEVELS VIA ORAL EXPOSURE ONLY

<table>
<thead>
<tr>
<th>Microcystins</th>
<th>Cylindrospermopsin</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3 µg/L for bottle-fed infants</td>
<td>0.7 µg/L for bottle-fed infants</td>
</tr>
<tr>
<td>1.6 µg/L for adults</td>
<td>3 µg/L for adults</td>
</tr>
</tbody>
</table>
September / October 2016 (PA)
Recreational Waterbodies

Even if the water is not used as a potable source of water, cyanotoxins can impact users of recreational waterbodies.

Most impacts are associated with primary contact recreation (swimming, wading, water skiing, jet skiing, etc.)

Livestock and pets susceptible to the cyanotoxin poisoning.

From the late 1920’s to 2012 one study identified 368 cases of cyanotoxin poisoning in the U.S.
Cyanotoxins in Recreational Waterbodies

Draft Human Health Recreational Ambient Water Quality criteria and/or Swimming Advisories for freshwater recreational waterbodies were released in November 2016 by US EPA

- Draft criteria for microcystins is 4 ug/L
- Draft criteria for cylindrospermopsin is 8 ug/L
Princeton Hydro’s PARE™ Program – A Strategy For Dealing with HABs

**Predict** – Use long-term database, keystone parameter data relationships, and/or remote sensing techniques to forecast a bloom

**Analyze** – Measure/ quantify bloom’s severity:
- Chlorophyll *a*, nutrients
- Cyanobacteria ID and cell counts
- Monitor for Microcystin or other cyanotoxins

**React** – Implement measures to prevent, control or terminate bloom

**Educate** – Share information with public
Predict

- Develop algorithms from long-term data sets
  - **Weather**
  - Phosphorus : nitrogen ratio
  - Chlorophyll *a*
  - DO/Temperature profiles
  - Secchi disk values
  - Color / appearance
- Utilize remote sensing technology to track blooms
- Conduct *in-situ* mesocosm experiments
- CSLAP
Phytoplankton ID, enumeration and quantification

Measure precursors of impending bloom
- Declining Secchi disc clarity: < 1 meter
- Chlorophyll $a$: >20 µg/L
- Cyanobacteria cell counts: 5,000 cells/mL (single genus), 15,000 cells/mL (more than one)

Measure Microcystin
- Field kits
- Analytical lab testing
Focus the counts (cells / mLs) on the blue-green algae
While most blue-green algae appear to have the ability to generate cyanotoxins, not all can
Multiple cyanotoxins

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>ACTION LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Microcystis spp.</em></td>
<td>2,000 cells/mL</td>
</tr>
<tr>
<td>Combination of all potentially toxic cyanobacteria species present</td>
<td>15,000 cells/mL</td>
</tr>
</tbody>
</table>
Abraxis – measuring cyanotoxins
<table>
<thead>
<tr>
<th>Relative Probability of Acute Health Effects</th>
<th>Cyanobacteria (cells/mL)</th>
<th>Microcystin-LR (µg/L)</th>
<th>Chlorophyll-a (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>&lt; 20,000</td>
<td>&lt;10</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Moderate</td>
<td>20,000-100,000</td>
<td>10-20</td>
<td>10-50</td>
</tr>
<tr>
<td>High</td>
<td>100,000-10,000,000</td>
<td>20-2,000</td>
<td>50-5,000</td>
</tr>
<tr>
<td>Very High</td>
<td>&gt; 10,000,000</td>
<td>&gt;2,000</td>
<td>&gt;5,000</td>
</tr>
</tbody>
</table>

React - What We Need to Understand

- Biological links and interactions
  - Nitrogen fixers versus Non-Nitrogen fixers
  - Role of Iron and Silica
  - Do early bloom species set stage for more problematic later blooming species?
  - Zooplanktivory / Fishery relationships.
- Nitrogen/Phosphorus – type, availability, sources
- Applicability of pre-emptive controls -
  - Physical (mixing), Chemical (alum and alum surrogates), Biological (biomanipulation)
Near-Shore Management

Cyanotoxin management for recreational waterbodies will focus on the beaches and near-shore areas where there is direct contact with water.

A lake’s overall, long-term Management Plan should include a component that focuses on the beach/near-shore area; many of the preventative measures will contribute toward the control of cyanotoxins.

However, a “mini-plan” (PARE) should be in place for the beaches.
## Lake Hopatcong Algal Sampling 8/5/2014

<table>
<thead>
<tr>
<th>Site</th>
<th>Site Coordinates</th>
<th>Microcystin µg/l</th>
<th>Dominant Blue Green Algal Species</th>
<th>Cell Count cells/ml</th>
<th>Chl &quot;a&quot; µg/l</th>
<th>Sample Depth meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-74.6533460721</td>
<td>3.315</td>
<td><em>Anabaena sp</em></td>
<td>&lt;600</td>
<td>61.9</td>
<td>1</td>
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<tr>
<td></td>
<td>40.9489719098</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-74.6539569399</td>
<td>84.5</td>
<td><em>Anabaena sp</em></td>
<td>&gt; 10,000</td>
<td>275.9</td>
<td>0.05 (surface)</td>
</tr>
<tr>
<td></td>
<td>40.9489719098</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td>-74.6599679341</td>
<td>23.3</td>
<td><em>Anabaena sp</em></td>
<td>&gt; 10,000</td>
<td>181.5</td>
<td>0.05 (surface)</td>
</tr>
<tr>
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<td>40.9412379747</td>
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<tr>
<td>4</td>
<td>-74.657437886</td>
<td>3.1</td>
<td><em>Anabaena sp</em></td>
<td>&lt;600</td>
<td>73.1</td>
<td>1.02</td>
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<tr>
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<td>40.9432294947</td>
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<tr>
<td>5</td>
<td>-74.6520488191</td>
<td>0.907</td>
<td><em>Anabaena sp</em></td>
<td>&lt;600</td>
<td>27.2</td>
<td>0.05 (surface)</td>
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<tr>
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<td>40.940953995</td>
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<tr>
<td>6</td>
<td>-74.660213156</td>
<td>2.84</td>
<td><em>Anabaena sp</em></td>
<td>&lt;600</td>
<td>64.7</td>
<td>0.05 (surface)</td>
</tr>
<tr>
<td></td>
<td>40.9406403482</td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>
### Lake Hopatcong Microcystins Testing for 2015

<table>
<thead>
<tr>
<th>Near-Shore Sampling Station</th>
<th>6/16/2015*</th>
<th>21-Jul-15</th>
<th>22-Sep-15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beach in Northern Jefferson (B-1)</td>
<td>0 ppb / 0 ppb</td>
<td>0 ppb</td>
<td>0 ppb</td>
</tr>
<tr>
<td>CAPP Beach (B-2)</td>
<td>0 ppb / 0 ppb</td>
<td>0.5 ppb</td>
<td>0 ppb</td>
</tr>
<tr>
<td>Western shoreline of Crescent Cove (B-3)</td>
<td>0 ppb / 0 ppb</td>
<td>0 ppb</td>
<td>0 ppb</td>
</tr>
<tr>
<td>Borough of Hopatcong Beach (B-4)</td>
<td>0 ppb / 0 ppb</td>
<td>0 ppb</td>
<td>0 ppb</td>
</tr>
<tr>
<td>Barnes Bros Beach (B-5)</td>
<td>0 ppb / 0 ppb</td>
<td>0 ppb</td>
<td>0 ppb</td>
</tr>
<tr>
<td>Hopatcong State Park Beach (B-6)</td>
<td>0 ppb / 0 ppb</td>
<td>0 ppb</td>
<td>0 ppb</td>
</tr>
</tbody>
</table>

* two microcystin samples were run per collected water sample
ppb = ug/L
Watershed management programs targeting nutrient load reductions to reduce bloom frequency/intensity

Make use of nutrient sequesters
  - Alum
  - PhosLock
  - Iron
  - Nitrogen supplementation

Aeration / Destratification / Mixing

Biomanipulation

Ozone / Oxidizers

Very limited use of algicides
Use a variety of factors to determine when to respond to a bloom (Secchi depth, chlorophyll $a$, color of water / visual confirmation).

For drinking water systems, when microcystin samples should be collected is largely based on cyanobacterial algal counts (cells / mLs)

For recreational lakes, it tends to be the general appearance of water.

Once the total blue-green algae counts exceed 15,000 cells / mLs run the Abraxis test strip analysis to measure microcystins

Analogous to conducting fecal coliform / *E. coli* beach testing
Education and Outreach

- Inform/educate public about cyanobacteria and related health problems.
- Inform/educate public about measures to help prevent blooms.
  - Septic management
  - Fertilizer use
  - Shoreline buffer creation/maintenance
  - Waterfowl control
- Monitoring is part of solution, need to address bloom before it peaks.
- Know when not to go in the water; prevent pets from drinking the water
- Copper sulfate alone is not the answer.
Summarizing Management Options

Many in-lake management techniques can contribute toward reducing algal blooms (nutrient inactivation, Floating Wetland Islands, biomanipulation, etc.)

Watershed programs to reduce the **external pollutant loads** (e.g. TMDLs; BMPs)

- Aeration / Destratification / Circulation
- Nutrient Inactivation
- Ozone
- Oxidizers (e.g. GreenClean)

**CAREFUL** use of copper products (Earth-Tec)
Installation of a Destratification System
Conclusions

- Blue-green algal blooms are triggered by dry and hot conditions with elevated amounts of phosphorus.
- Many blue-green algae generate cyanotoxins, which are not taste and odor compounds.
- Develop a Plan to specifically address near-shore areas where this is primary contact with the water.
- Educate the community on what to look for relative to summer / fall algal blooms.