A framework for cyanobacteria harmful algal bloom (cHAB) monitoring: A case study of China’s Lake Taihu

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The Lake Taihu Story

- Most populated province
- Pop. Centers to N & E and about 100 km W of Shanghai
- 3rd largest lake (2,338 km²)
  - Shallow (1.9 m)
  - Polymictic
  - HRT ~300 days
  - 200+ water inputs
- Eutrophying since 1980’s
2007 Drinking Water Crisis

Wang and Shi, 2008
2007 Drinking Water Crisis
1. Microscopic identification of genera/morphospecies present
2. Are there toxin producers present in *this system*?

Direct measurements of toxins will indicate if toxin producers are present, but not necessarily which one(s).

Conventional PCR can indicate the presence of potential toxin-producers; false negatives are a concern.
Hazard Identification/Characterization

3. Which morphospecies are capable of toxin production?

Otten and Paerl, 2011
1. How prevalent is the hazard (e.g., toxigenic *Microcystis*)?

![Map of Lake Taihu showing water intake points and exposure assessment/risk characterization areas.](image)

<table>
<thead>
<tr>
<th>Sample Site</th>
<th>Temperature (°C)</th>
<th>Ratio TN:TP</th>
<th>Ratio DTN:DTP</th>
<th>Avg. DTN (mg l⁻¹)</th>
<th>Avg. DTP (mg l⁻¹)</th>
<th>Chl a (µg l⁻¹)</th>
<th>Avg. MCs (µg l⁻¹)</th>
<th>% Toxic (mcyE)</th>
<th>Turbidity (NTUs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Northwest</td>
<td>26.4 ± 3.1</td>
<td>17:1</td>
<td>29:1</td>
<td>3.62 ± 0.91</td>
<td>0.12 ± 0.10</td>
<td>192.1 ± 359.5</td>
<td>28.7 ± 6.6</td>
<td>42.6</td>
<td>26.4 ± 9.6</td>
</tr>
<tr>
<td>(2) West</td>
<td>26.8 ± 3.0</td>
<td>18:1</td>
<td>40:1</td>
<td>3.62 ± 0.86</td>
<td>0.09 ± 0.03</td>
<td>97.1 ± 92.3</td>
<td>8.2 ± 0.8</td>
<td>44.6</td>
<td>47.6 ± 23.3</td>
</tr>
<tr>
<td>(3) Southwest</td>
<td>25.7 ± 3.0</td>
<td>50:1</td>
<td>144:1</td>
<td>2.56 ± 1.00</td>
<td>0.02 ± 0.01</td>
<td>8.6 ± 8.9</td>
<td>1.1 ± 0.1</td>
<td>11.1</td>
<td>34.8 ± 18.0</td>
</tr>
<tr>
<td>(4) Lake Center</td>
<td>25.1 ± 3.1</td>
<td>58:1</td>
<td>132:1</td>
<td>2.64 ± 0.79</td>
<td>0.02 ± 0.01</td>
<td>7.1 ± 3.9</td>
<td>0.4 ± 0.1</td>
<td>15.5</td>
<td>23.9 ± 12.6</td>
</tr>
<tr>
<td>All Sites (n = 96)</td>
<td>26.3 ± 3.0</td>
<td>23:1</td>
<td>49:1</td>
<td>3.09 ± 1.06</td>
<td>0.06 ± 0.06</td>
<td>56.1 ± 147.9</td>
<td>6.4 ± 1.2</td>
<td>36.2</td>
<td>32.7 ± 20.3</td>
</tr>
</tbody>
</table>

*Sites (1) and (2) = high *Microcystis* biomass and toxigenicity (mcyE possessing). Sites (3) and (4) = low *Microcystis* biomass and toxigenicity (mcyE possessing).*
2. Can exposure risk be quantified (e.g., MCs in drinking water)?

\[
MCs = 0.07965(chl \ a) + 0.01021
\]

* Taihu only disinfects with HOCl

Key variables in calculation of water treatment system’s specific removal

Effect of treatment
- Concentration
- Time
- Temperature
- pH (lower = greater removal)

Otten et al., 2012
1. Do you treat the symptoms or the causes?
   - Chlorination often assumed ineffective – key lies in removing organic reactants prior to addition

Table 2. Chlorine CT values for reducing microcystin concentration to 1 μgL⁻¹ for a batch reactor.

<table>
<thead>
<tr>
<th>pH</th>
<th>MCYLR (μg/L)</th>
<th>10°C</th>
<th>15°C</th>
<th>20°C</th>
<th>25°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>50</td>
<td>46.6</td>
<td>40.2</td>
<td>34.8</td>
<td>30.8</td>
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<td>10</td>
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<td>67.7</td>
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<td>39.8</td>
<td>34.4</td>
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<td>25.9</td>
</tr>
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<td>8</td>
<td>50</td>
<td>187.1</td>
<td>161.3</td>
<td>139.8</td>
<td>121.8</td>
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<tr>
<td></td>
<td>10</td>
<td>110.3</td>
<td>94.9</td>
<td>82.8</td>
<td>71.7</td>
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<tr>
<td>9</td>
<td>50</td>
<td>617.2</td>
<td>526.0</td>
<td>458.6</td>
<td>399.1</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>363.3</td>
<td>309.6</td>
<td>269.8</td>
<td>234.9</td>
</tr>
</tbody>
</table>
1. Do you treat the symptoms or the causes?

Remediation of drinking waters

1. Avoid pre-oxidation and cell lysal – toxins are primarily intracellular
2. Most problematic CHABs are positively buoyant – DAF is superior to sedimentation of intact cells but will not remove extracellular toxins
3. Disinfection: $O_3$ or $\text{MnO}_4^- > \text{HOCl} > \text{NH}_2\text{Cl}$ or $\text{ClO}_2$
4. Physical disinfection such as UV can also be effective
5. Auxiliary removal by adsorption ($\text{GAC} > \text{PAC}$)
Remediation of source waters

1. Identify major N & P inputs
   • Sewage = 31% TN and 47% TP
   • Industrial point source = 30% TN and 16% TP
   • Ag fertilizer/livestock = 25% TN and 25% TP

2. Effect of hydraulic residence time
   • Can impacted area be flushed out?

3. Stratified systems
   • Will artificial destratification control cyanos?

Xu et al., 2010
Policy Development

2. Do you treat the symptoms or the causes?

Remediation of source waters

1. Nutrient bioassays
Remediation of source waters

1. Nutrient addition bioassays indicate that N & P are both limiting at different times of the year

Paerl et al., 2011
Policy Implementation

1. Results are ongoing, but a greater than 50% reduction in N & P will likely be needed to mitigate Microcystis blooms
2. Potential for community shift to toxin-producing diazotrophs under reduced N scenario currently being investigated
3. Due to highly toxic Microcystis populations in the lake, drinking water treatment should account for this
4. Public needs to be educated on cyanotoxin risks
References

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