MIB-producing cyanobacteria (*Planktothrix* sp.) in a drinking water reservoir: distribution and odor producing potential

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Outline

- Introduction
- Methods
- Results & Discussion
- Conclusion
T&O problems in reservoirs caused by HAB

Reservoir ➔ Algal growth ➔ Water quality

- Artificial
- River >>> Reservoir
- HRT (hydrology resistant time)

Dam
Turbidity ↓ Light ↑
river < reservoir < lake

Odor

- *Anabaena* bloom with extremely high concentration of geosmin (7100 ng/L) in 2007.

Li, Z. et al., 2009
CASE 2. MIB problem in Miyun Res.

- Good water quality;
- But with high conc. of MIB

Water Intake

- MIB con. (>100 ng/L)

Large deep reservoir
Questions

- Why different algal species grow in different reservoirs and cause odorous problems?
  - The diver of Planktothrix sp. in Miyun Reservoir, and its distribution characters.
Uncover the sources and divers of odorous problems in source water

Providing scientific support to source water management
**Methods**

- **Online Monitor**
  - Online monitoring station
  - Meteorological, hydrological, physico-chemical data

- **LAB analysis**
  - Surface mapping system
  - Water sampling
  - Algae, nutrients, odorous compound

**Data analysis, modeling**

**Harmful algal dynamics, impacts on WQ**
Field investigation

Methods

- Online monitoring station
- Meteorological data
- Physic-chemical data
- Surface mapping system
- No extra power
- Benthic algae sampler

Quantification of algal biomass and odorous compounds based on real time qPCR

Anabaena sp. & geosmin
Planktothrix sp. is the main producer of MIB.

Sep – Oct (max conc.)
Introduction

Methods

Result & discussion

Conclusion

MIB problem in Miyun Res.

2009

2010
Miyun Res.: main surface water source;
Capacity: 1.0-1.2/4.375 billion m³;
Surface area: 188 km²
Introduction

Methods

Result & discussion

Physi-chemical characteristics

Good water quality

- Low nutrients
- High water transparency

Why odor problem even occurs in a reservoir with good water quality?

Long term investigation
Long term investigation

- Algal dynamics
  - *Planktothrix* sp.

- Environmental factors
  - General physi-chemical parameters
  - Nutrients
  - Meteorological data
  - Hydrological data

- MIB monitoring
**Algae species investigation (2009-2012)**

<table>
<thead>
<tr>
<th>Phylum</th>
<th>SPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacilla.</td>
<td>39</td>
</tr>
<tr>
<td>Green</td>
<td>63</td>
</tr>
<tr>
<td>Cyano.</td>
<td>37</td>
</tr>
</tbody>
</table>

* Lake Tai: SPs-64 种*

*: 李军 生态环境, 2006*
Algae dynamics (2009)

Microcystis sp.

Planktothrix sp.
Investigation - *Planktothrix sp.* (MIB)

- MIB distribution ***Planktothrix distri.***
- Main distribution area
  - North shallow area
Investigation - *Planktothrix* sp. distribution

Sampled in the north shallow area

Conc. of *Planktothrix*: $10^6$ cells/L

Diameter represents concentrations

Colors stand for different water depth
Introduction

Methods

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Seasonal distribution of *Planktothrix* (2009-12)

Annually repeated during Sep. and Oct.

Detection rate of *Planktothrix* (2009-2012)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Mar–Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
</tr>
</thead>
<tbody>
<tr>
<td>NESR</td>
<td>11.1%</td>
<td>5.9%</td>
<td>63.6%</td>
<td>65.7%</td>
<td>67.7%</td>
<td>40.0%</td>
</tr>
<tr>
<td>NSR</td>
<td>8.3%</td>
<td>15.6%</td>
<td>81.8%</td>
<td>84.4%</td>
<td>64.3%</td>
<td>44.4%</td>
</tr>
<tr>
<td>SDR</td>
<td>8.8%</td>
<td>7.4%</td>
<td>60.9%</td>
<td>73.9%</td>
<td>71.4%</td>
<td>37.5%</td>
</tr>
<tr>
<td>WDR</td>
<td>12.5%</td>
<td>0.0%</td>
<td>25.0%</td>
<td>21.9%</td>
<td>38.3%</td>
<td>33.3%</td>
</tr>
<tr>
<td>Total</td>
<td>10.7%</td>
<td>7.6%</td>
<td>47.1%</td>
<td>65.9%</td>
<td>58.7%</td>
<td>41.2%</td>
</tr>
</tbody>
</table>
Spatial distribution (Sep.)

- Mainly in north shallow region (NSR)
- Biomass in bottom layer > surface (70%)
- It present in South deep region (SDR)

---Question: Why?

R: Bottom > Surface
B: Bottom < Surface
Spatial distribution - topography

Topography of Miyun Res.
**Spatial distribution - Water stability**

## Water stability

<table>
<thead>
<tr>
<th></th>
<th>WDR</th>
<th>SDR</th>
<th>NSR</th>
<th>NESR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>Low water flow velocity</td>
<td>Low</td>
<td>Estuary, high</td>
<td></td>
</tr>
<tr>
<td>Vertical</td>
<td>WDR/SDR deep, strong stratification (Jun-Oct)</td>
<td>NSR/NESR shallow, weak stratification (Jun-Aug)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Diagram:**

- **Deep**
  - Temperature [°C] (MY08)
  - Depth [m]
  - Jun <--- stratification ---+--- Oct

- **Shallow**
  - Temperature [°C] (MY05)
  - Depth [m]
  - Jun <--- stratification ---+--- Aug
Spatial distribution - nutrients

- Shallow regions (NSR/NESR)
  - Significant seasonal variations
  - Minimum conc. observed in August.
  - Nutrients increase from mid-Aug, (stratification weaken, vertical mixing enhancement)
  - Nutrient hot spot: bottom layer in NSR.

- Deep regions (WDR/SDR)
  - Less seasonal variations (low algal biomass)
- *Planktothrix* is affected by nutrients (phosphate, surface/middle layer).
- In bottom layer, *Planktothrix* is not highly related to nutrients.
- **Microcystis** biomass decrease: due to nutrients exhaust, water temperature decrease
- **Planktothrix** biomass increase: due to higher water transparency, relative high nutrient conc. in bottom layer
- M. sp. is affected by temperature (temp. decreases in late Aug is harm to M. sp.)
- Low temp.: high MIB yield.
Planktothrix growth affects water transparency.

Microcystis growth is sensitive to water transparency.
Sketch map of niche competition (*M.* sp & *P.* sp)
Similar to *Planktothrix*, concentrates during Sep. and Oct.
Spatial distribution of MIB (2009-2012)

WDR

12.2 ± 8.7

SDR

36.6 ± 25.0

NSR

67.0 ± 36.6

NESR

48.1 ± 26.1
**Spatial distribution of MIB (Jul)**

**Jul and before:**
- MIB conc. is low
- No significant spatial variations
- No sig. vertical variations
Result & discussion

**Sep:**
- MIB conc. increases significantly in NSR
- Conc. in WDR < threshold (15 ng/L)
- Conc. SDR increasing — Why?
- Conc. in bottom layer > surface water (70%)
**Spatial distribution of MIB (Oct)**

**Oct:**
- MIB conc. Decrease
- SDR conc. remains high—why?
Nov: MIB conc. less than threshold
### MIB & *Planktothrix* sp.

<table>
<thead>
<tr>
<th>MIB conc. [ng/L]</th>
<th>log(Pla) [cells/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>4.2</td>
</tr>
<tr>
<td>50%</td>
<td>4.7</td>
</tr>
<tr>
<td>90%</td>
<td>5.7</td>
</tr>
</tbody>
</table>

Threshold: 15 ng/L
**Possible strategy for MIB problems**

- **Depth < 5.13 m**: risk of MIB > threshold is about 90%.
- **Depth < 7.73 m**: risk of MIB > threshold decreased to 50%.

**Possible strategy for MIB problems**

- Reservoir construction
- Reservoir water level management

**Introduction**

**Methods**

**Result & discussion**

**Conclusion**
Conclusion

- *Planktothrix* biomass increase during Sep. - Oct.: Decreasing of *Microcystis* enhanced underwater light availability; weaken stratification enhanced nutrients transportation;

- The risk of MIB concentration higher than its threshold can be reduced from 90% to 10% by controlling the *Planktothrix* cell density from $10^{5.7}$ to $10^{4.2}$ cells/L.

- The water level affect the *Planktothrix* biomass, which suggesting that the *Planktothrix* biomass can be controlled by adjusting the water level if possible.


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Thanks for your attention!