Water Crisis of Lake Taihu, China

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1. Cyanobacterial Blooms at Lake Taihu
Where is Lake Taihu?

太湖, Lake Taihu, 3rd largest Freshwater
Catchment of Taihu: floodplain, urbanization

Water surface: 2338 km$^2$
Average depth: 2 m
Maximal depth: 3 m
Catchment: 36500 km$^2$
Population density: >1200
Functions of Taihu

1. City water supply
2. Fishery
3. Recreation
4. Flood buffer
5. Water way
Water intakes in Taihu

Water intakes for water plants in Taihu.
Fishery

*Culter alburnus* Basilewsky

*Hemisalanx prognathus*

*Exopalaemon modestus*

*Aristichthys nobilis*

*Coilia nasus* Temminck et Schlegel

*Hyriopsis cumingii*

*Hypophthalmichthys molitrix*

*Pelteobagrus fulvidraco*

*Eriocheir sinensis* Milne-Edwards
Cyanobacterial blooms in Taihu
History of blooms in Taihu
Major player: *Microcystis* spp.

*Microcystis* spp. in Taihu

*Microcystis aeruginosa*  *Microcystis wesenbergii*  *Microcystis flos-aquae*

Photos by Gregory Boyer, at May 28 2012
Supporting actor: *Anabaena* spp.
Problem caused by blooms: Microcystin

**Figure 3.** Monthly variability of the concentrations of MCs and cyanobacteria cell density in Lake Taihu.

*Su et al., Toxins, 2015*
Problem caused by blooms: Black patch

Black patch at northwest bay of Taihu, June 22, 2015

Dimethyl trisulfide (DMTS); Geosmin; 2-MIB; β-cyclocitral, β-ionone; 2-isobutyl-3-methoxypyrazine (IBMP)
2. Drinking water crisis at May of 2007
Water crisis caused by black patch in Taihu

Water crisis happened at Wuxi during May 29 – 3 Jun 2007, for the block of intake at Gonghu blocked by black patch.
The major odor compounds

During the crisis

Dimethyl Trisulfide (DMTS):

A kind of volatile compound produced at anaerobic condition with plenty of corruptive organic matters, for example, the died algae.

The Next year, 2008

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<th>D (%)</th>
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<th>TC (ng/l)</th>
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</table>

Chen et al, 2010
The cause 1: Extreme serious bloom

Serious bloom start 8 April, a month earlier than normal.
The cause 2: Extreme warmer spring

Fig. 3 Changes in daily mean surface water temperature from March 1 to May 31 in Lake Taihu since 1995

Fig. 4 Changes in spring surface air temperature (March–May) since 1951 at Shanghai Meteorological Station, Meteorological Bureau of China

Qin et al, 2010
The cause 3: Suitable wind direction

Fig. 5  Simulated spatial distribution of chlorophyll concentration ($\mu$g L$^{-1}$) under the influence of different wind regimes.  a easterly wind;  b westerly wind;  c southerly wind;  d northerly wind. Bloom intensities are shown as chlorophyll $a$ concentrations.
3. Actions after water crisis of 2007
The total investigation is over 100 billions RMB

Catchment:  
- Fertilization control  
- Ecological restoration

In lake:  
- Bloom collection  
- Sediment dredging  
- Ecological engineering

Water hyacinth
A example: Monitor and forecast of bloom
Why we need monitoring and forecast

- Bloom and black patch are very patched in spatial.
- The density of bloom or black patch are depend on weather.
- To remove the toxin or odors from water need time and money.
Monitor 1: near shoreline check everyday

Checking area: 569 km²
Route length: 209 km
Stop and measure sites: 24
Dates: 194 days
   April 10 to Oct 20

Variables recording:
  Weather: wind speed; wind direction
  Water temp
  Air temp
  Algal: Cell density
         Chlorophyll a
  Water: DO; pH; Eh
         Secchi depth
         Odor
Special designed aeration boat
Monitor 2: Remote sensing image interpret bloom

Data sources:
- HJ – CCD
- MODIS
- MERIS
- GOCI

Interpret model:
- APPLE model
- 3 wavelengths model: 660-690 nm; 710-730nm; > 730nm

HJ-CCD: \[ \text{Chl. a} \propto R(b_4) - (R(b_1) - R(b_4)) \cdot R(b_4) + (R(b_3) - R(b_4)) \] \hspace{1cm} (16)

MODIS: \[ \text{Chl. a} \propto R(b_2) - (R(b_3) - R(b_2)) \cdot R(b_2) + (R(b_1) - R(b_2)) \] \hspace{1cm} (17)

MERIS: \[ \text{Chl. a} \propto R(b_9) - (R(b_2) - R(b_9)) \cdot R(b_9) + (R(b_7) - R(b_9)) \] \hspace{1cm} (18)

GOCI: \[ \text{Chl. a} \propto R(b_7) - (R(b_2) - R(b_7)) \cdot R(b_7) + (R(b_6) - R(b_7)) \] \hspace{1cm} (19)
Monitor report of Taihu bloom by remote senser

太湖蓝藻卫星遥感监测报告

2012年8月20日10时28分的MODIS卫星遥感影像显示太湖水面出现蓝藻水华，蓝藻水华集聚面积约633.2km²，其中高强度水华面积约174.2km²，低强度约459.0km²。MODIS卫星遥感反演结果分别见表1、图1~图3。

表1 太湖水体卫星遥感反演结果

<table>
<thead>
<tr>
<th>含藻量平均</th>
<th>浮藻量平均</th>
<th>表层水温平均</th>
<th>水华面积</th>
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<tr>
<td>(μg/1)</td>
<td>(μg/1)</td>
<td>(°)</td>
<td>(km²)</td>
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<tr>
<td>10时28分</td>
<td>异常</td>
<td>异常</td>
<td>低: 459.0</td>
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太湖温度分布较为均一，沿岸温度略高于湖中心温度。

图3 2012年8月20日10时28分太湖遥感影像
Monitor 3: High-frequency “buoy” monitor

- Weather station
- YSI sonde: Chl-a, DO, PC, Turb, pH, Cond, Temperature, et al.
- Bottom DO sensor
- Wave and current sensors
- Energy: wind and solar radiation panel
Buoy distribution
Buoy types

EMB01  EMB02  EMB03  EMB04  EMB05  EMB06  EMB07

EMB08  EMB10  EMB11  EMB12  EMB13  EMB14
Forecast the bloom

Model development and calibration

Stereo-monitoring system in Lake Taihu

Chlorophyll a and DO model

Model calculation

Model result

Model calibration

Chl-a

DO

Field data
Possibility of bloom and black patch calculation

\[ P_{\text{bloom, black patch}} = f_{1, \text{DO}}(O) \times f_{2, \text{Wind}}(V) \times f_{3, \text{Rain}}(R) \times f_{4, \text{Chl-a}}(B) \]

<table>
<thead>
<tr>
<th>DO mg/L</th>
<th>f(O)</th>
<th>Wind speed m/s</th>
<th>f(V)</th>
<th>Rain</th>
<th>f(R)</th>
<th>Chl-a µg/L</th>
<th>F(B)</th>
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<td>&lt;2</td>
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<td>0.3-3.3</td>
<td>1</td>
<td>Sunny</td>
<td>1</td>
<td>&gt;60</td>
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<td>3.4-5.4</td>
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<td>Cloudy</td>
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<td>4--6</td>
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<td>5.5-7.9</td>
<td>0.8</td>
<td>Light rain</td>
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<td>30-50</td>
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<td>&gt;8</td>
<td>0.4</td>
<td>&gt;10.8</td>
<td>0.5</td>
<td>Heavy rain</td>
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太湖蓝藻及湖面监测预警周报

中国科学院南京地理与湖泊研究所太湖蓝藻及湖面监测预警周报

3-days forecast report

6月28日至6月30日三天内
梅梁湾、水磨头、香山、大顺等区域水体已出现蓝藻，超标标准。

三日温度（℃） 三日风向 三日气象
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<td>5.7</td>
<td>4.8</td>
<td>3.4</td>
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<tr>
<td>DO(mg/L)</td>
<td>7.8</td>
<td>6.0</td>
<td>4.8</td>
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<td>7.8</td>
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今日太湖蓝藻水华及藻类现状描述：监测点所在的湖区东南风，风力和，全湖区监测范围内水域均出现颗粒状蓝藻，未见水华。其中湖西新港和清湖东水域藻类生长量较高，其余水域藻类生长量不高。

全湖溶解氧浓度的水域为梅梁湾、渣港，浓度低于1.2mg/L，水色偏黑，气味微臭，面积约为0.3km²；清湖湾北部油港至杨干港沿岸带，浓度低于2.0mg/L，水色深沉，气味微臭，面积约为0.3km²；其次为湖面南部水域。

未来三天内蓝藻水华及藻类发展预测：未来三天以阴雨天气为主，气温下降，气象条件不利于藻类的扩散和聚集。在持续风的影响下，处于下风口的清湖湾沿岸带至梅梁湾藻类生长量将维持较高，部分水域在风力减弱时可能出现较多藻类水华。梅梁湾各区域、清湖湾北部沿岸带及湾口水域在风力减弱时可能出现较多藻类水华。

全湖中溶解氧浓度最高的水域出现在湖西新港至香山区域，梅梁湾、渣港、清湖湾北部沿岸带及湾口水域，未来三天的阴雨天气可能造成藻类水华的生长，需加强监管。
Possible reaction of local managers

- Water plants: Change the intake site, or use Yangtze river as source.
- Tourism agency: Change the travel lines.
- Monitoring agency: Pay more attention to High possible zone.
- Bloom emergency team: adjust the collection power.
4. Challenge remained
Nutrient reduction still far from bloom control

\[ y = -0.44\ln(x) + 4.98 \quad R^2 = 0.79 \]

\[ y = 0.14x^{0.17} \quad R^2 = 0.35 \]

\[ y = -0.14\ln(x) + 0.74 \quad R^2 = 0.86 \]

\[ y = -0.69\ln(x) + 3.6 \quad R^2 = 0.83 \]
The bloom is still heavy
Taihu, similar to Lake Chaohu and Lake Dianchi in China, suffered from cyanobacterial bloom for more than 30 years. The major trouble maker is Microcystis spps. In Chaohu and Dianchi, Anabeanana spps also are one of the major players.

The biggest challenge in these lakes is the safety of city water supply. Being the spatial drift or movement behaviors of Microcystis bloom, to monitor and forecast the risk of bloom and black patch events for short time in these lakes are very possible.

The ability of technology to solve bloom is limited. The pollution is a social and economic issue, too. To solve the problem, more social and economic solution should be introduced.
Thank you for your attention!