Relationship between phytoplankton and environment factors in Lake Hongfeng

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Abstract
Phytoplankton and environmental factors were investigated quarterly from January 2011 to October 2011 in Lake Hongfeng. Results revealed that the abundance Pseudanabaena limnetica Lauterborn was 80% throughout the year. It was the key factor for water color change in 2011. The environmental factors such as water temperature, pH, DO were significantly related to phytoplankton abundance, but total abundance and community structure of phytoplankton were not influenced by environmental factors.

Key words
Phytoplankton, Environmental factors, Pseudanabaena limnetica, Hongfeng Lake

Introduction
Phytoplankton are free-floating microscopic plants that make up a significant proportion of the primary productions in aquatic systems (Dawes, 1998). They play an important role in maintaining the stability and integrity of the entire aquatic ecological system (Young et al., 2002) and occupy a central position in the circulation of nutrients, energy flow and the composition and structure of food chains (Long et al., 2009). The seasonal variation of phytoplankton’s community are strongly affected by several environmental factors like temperature and light intensity (Sussane et al., 2005; Farahani et al., 2006). The abundance and specie composition of algae can have significant implications with regard to both water clarity and quality of any water body (Adironack Ecologists, 2010). However, addition of various kinds of pollutants and nutrients through industrial effluents and agricultural run off etc. into the lakes can bring about series of changes in physico-chemical and biological characteristics of fresh water. In this regard, lake water eutrophication has become one of the most important factors impeding economic development in China. The frequent occurrences of algal blooms have disrupted the normal supply of drinking water in shore cities (Le et al., 2010). Water eutrophication can lead to rapid production of phytoplankton and other microorganisms and deterioration of water quality. Eutrophication can result in frequent outbreaks of algal blooms and threaten the reliable supply of drinking water.

The main object of the present research work was monitoring the variation of the phytoplankton structure of Lake Hongfeng. This research provides relevant data for the study of eutrophication and also offers a theoretical guidance for water resource management of artificial lakes.

Materials and Methods
Lake Hongfeng in located in Guiyang, the capital of Guizhou Province in southwestern China. It is one of the key drinking water sources for roughly 3 million people of Guiyang City. During 2011, water samples were collected quarterly from six sampling sites namely Dam of Lake Hongfeng (I), Yaodong(II), Huayudong (III), Houwui(IV), Piansanzai (V), Xijao water-works (VI) at depth of 0.5m, 6.0m, 12m respectively (Fig 1). Samples for quantitative analysis were added with Lugol's iodine, and samples for qualitative analysis were added with stationary liquid. The physico-chemical
parameters like total phosphorus (TP), total nitrogen (TN) and ammonical nitrogen (NH₃-N) of the water samples were estimated following the standard method of APHA (2005). Water temperature (WT), Secchi disk transparency (SD) was taken in-situ. Dissolved oxygen (DO) and pH were also recorded in-situ using a Dissolved Oxygen Meters.

The interrelationship between physico-chemical parameters and phytoplankton cell density were examined using Pearson correlation coefficient. The correlation coefficient, mean value and standard deviation were computed with SPSS 19.0.

**Results and Discussion**

A total of 170 species of phytoplankton were identified in Lake Hongfeng, belonging to 7 phyla, 10 classes, 20 orders, 30 families and 53 genera. There were 26 common species, with Chlorophyta exhibiting a large number of taxa, including *Microactinium pusillum* Frasenius, *Oocystis solitaria* Witt., *Dictyosphaerium*, *Pediastrum duplex* Mey., *Pediastrum simplex* Mey., *Pediastrum simplex var. duodenum* (Bail.) Rabenh., *Scenedesmus arcuatus* Lemm, *Scenedesmus quadricauda* (Turp.) Breb., *Scenedesmus disciformis* (Chod.) Fott. and Kom., *Scenedesmus abundans* (Kirem.) Chodat, *Coelastrum C. microporum* Nag, *Staurastrum tetracerum* (Kütz.) Ralfs. Bacillariophyta were represented by *Melosira granulata* (Ehr.) Ralfs, *Melosira granulata var. angustissima* O. Mull, *Cyclotella hubeiana* Chen and Zhu, *Cyclotella meneghiniana* Kutz., *Fragilaria capucina* Desm, *Synedra acus* Kutz.). The Cyanophyta were comprised of *Microcystis marginata* (Menegh.) Kutz., *Pseudanabaena limnetica* Lauterborn, *Aphanizomenon flos-aquae* (L.) Ralfs. Cryptophyta included *Cryptomonas erosa* Ehr. while Pyrrophyta included *Peridiniopsis penardiforme* Bourrelly, *Ceratium hirundinella* (Mull.) Schr. and *Cryptomonas erosa* Ehr. respectively.

Abundance of phytoplankton was lowest during winter (18.49×10⁶ cells l⁻¹), intermediate during spring and autumn and highest during summer (106.37×10⁶ cells l⁻¹). Chlorophyll a content of phytoplankton was least during winter (3.53 mg m⁻³), highest in summer (17.45 mg m⁻³) and intermediate during spring and autumn (Fig. 2).

There were distinct seasonal phases in algal total abundance and algal group composition. Cyanophyta were quantitatively dominant for most of the year (80%) followed by Bacillariophyta, Chlorophyta and Cryptophyta. The contributions of other groups were of least importance (Fig. 3).

*P. limnetica* was most dominant among Cyanophyta with 80% of total abundance. From bottom to surface, the abundance of *P. limnetica* was always above 10⁶ cells l⁻¹. *P. limnetica* was uppermost dominated in phytoplankton community of Lake Hongfeng, which is the most remarkable characteristic of phytoplankton community structure.
Cyclotella and Synedra acus were the dominant species among Bacillariophyta, both together accounting for 2.3-8.1% of total abundance. In addition to winter, the ratio of Synedra acus was higher than Cyclotella, and the gap between the ratios of Synedra acus and Cyclotella was high in summer. The periodic variation of water temperature may be responsible for the phenomenon. Among Chlorophyta, Pediastrum duplex, Pediastrum simplex Pediastrum simplex var. duodenium, contributing 2.0-8.1% of total abundance while Cryptomonas eosa, which contributed 1-6% of total abundance among Cryptophyta.

The result of physico-chemical analysis of water samples from all the sampling sites during the month of January-October, 2011 are given in Table 1. The values are mean of all sampling sites. The mean concentration of physico-chemical characteristics of Hongfeng Lake is shown in Table 1. The water temperature ranged between 6.75-25.65°C with maximum in July and minimum in April. The mean DO value was 6.30 mg l⁻¹ showing a high value in July (7.42 mg l⁻¹) and low in April (5.49 mg l⁻¹). Seasonal variation of Secchi Depth was not evident as the average SD was 1.18 m. The seasonal variation total phosphorus was also not obvious and the mean value was 0.033 mg l⁻¹. The ammonical nitrogen was lowest during July and highest during April with mean value of 0.121 mg l⁻¹. The mean total nitrogen value was found to be 1.33 mg l⁻¹, showing highest value in April and lowest in October.

Pseudanabaena is a filamentous Cyanophyte and a common phytoplankton species in tropical, subtropical reservoirs of eutrophication. It is widely distributed in Guangdong Province of China and rare in other places of the country (Havens et al., 1998). Qiuhua et al. (2011) and Lili et al. (2011) reported Pseudanabaena in Hongfeng and Baihua Lake. In most water bodies, water temperature is the main environment impact factor in growth and community structure of phytoplankton. Water temperature has important influence on algal activities, through controlling enzymatic reaction of photosynthesis or respiration intensity, directly affecting algae proliferation. And it can control water solubility, dissociation degrees or decomposition, then indirectly impacting growth of algae (Liu, 2000). Studies have shown that variation of water temperature have periodical influence on algal growth, mainly affecting algal physiological activity, especially impacting necessary enzymes of physiological activities of algae. At an appropriate temperature range, activity of algae increased with rise of temperature, which cause metabolic rates of algae to speed up (Zhao et al., 2008; Qifei et al., 2009). Abundance of phytoplankton and chlorophyll a was found to be least during winter (18.49 x 10⁶ cells l⁻¹), high during summer (106.37 x 10⁶ cells l⁻¹) and intermediate during spring and autumn. The low water temperature during winter lead to reduced reproduction ability, abundance of phytoplankton than other seasons. Due to rise in water temperature during spring season the abundance of phytoplankton also began to increase. High temperature is also known to affect the metabolic activity of phytoplanktons and accelerate reproduction of phytoplankton, so abundance of phytoplankton was highest during summer. When the water temperature began to decrease in autumn, the growth of phytoplanktons was also affected and abundance of phytoplankton declined. The correlation analysis showed a significant positive correlation (n=24, p<0.01, r = 0.587) between phytoplankton density and water temperature and between chlorophyll a and water temperature (n=24, p<0.01, r=0.809), revealing that water temperature was an important factor in phytoplankton growth. Zhang et al. (2003) reported that water temperature was a main factor in temporal and spatial distribution of phytoplankton community. But nowadays in different water temperature during different seasons, P. limnetica always dominated the phytoplankton community and community structure variation was litter. This indicated that water temperature affected less the structure of phytoplankton community.

Water transparency, a crucial parameter of lake optics, and one of important indexes of eutrophication evaluation of lake, directly reflected the lake limpid and muddy degree, and affected by suspended solids and phytoplankton in water (Dokulil et al., 2001). The transparency of the lake was quite low revealing

Table 1 : Physico-chemical properties of water of Lake Hongfeng during the period January-October, 2011

<table>
<thead>
<tr>
<th>Parameters</th>
<th>January</th>
<th></th>
<th>April</th>
<th></th>
<th>July</th>
<th></th>
<th>October</th>
<th></th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Range</td>
<td>Mean</td>
<td>Range</td>
<td>Mean</td>
<td>Range</td>
<td>Mean</td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td>WT (°C)</td>
<td>8.7-10.8</td>
<td>9.76±0.57</td>
<td>4.10</td>
<td>6.75±2.06</td>
<td>25.2-26.4</td>
<td>25.65±0.31</td>
<td>18.7-21.4</td>
<td>20.44±0.68</td>
</tr>
<tr>
<td>SD (m)</td>
<td>1.1-3</td>
<td>1.14±0.10</td>
<td>1.2-1</td>
<td>1.5±0.16</td>
<td>1.13</td>
<td>1.24±0.10</td>
<td>0.6-1.4</td>
<td>1.03±0.22</td>
</tr>
<tr>
<td>pH</td>
<td>7.9-8.2</td>
<td>8.09±0.09</td>
<td>8.2-8.5</td>
<td>8.39±0.07</td>
<td>8.2-8.6</td>
<td>8.37±0.12</td>
<td>7.9-8.3</td>
<td>8.2±0.11</td>
</tr>
<tr>
<td>DO (mg l⁻¹)</td>
<td>6.3-8.2</td>
<td>7.06±0.50</td>
<td>5.6-4</td>
<td>5.49±0.36</td>
<td>5.5-10</td>
<td>7.42±1.29</td>
<td>3.5-6.82</td>
<td>5.44±0.72</td>
</tr>
<tr>
<td>TP (mg l⁻¹)</td>
<td>0.02-0.04</td>
<td>0.029±0.005</td>
<td>0.02-0.05</td>
<td>0.03±0.006</td>
<td>0.02-0.05</td>
<td>0.03±0.01</td>
<td>0.02-0.05</td>
<td>0.03±0.01</td>
</tr>
<tr>
<td>TN (mg l⁻¹)</td>
<td>1.2—1.7</td>
<td>1.54±0.15</td>
<td>1.4-3</td>
<td>1.77±0.40</td>
<td>0.88-1.5</td>
<td>1.12±0.16</td>
<td>0.44-1.2</td>
<td>0.92±0.17</td>
</tr>
<tr>
<td>NH₄-N (mg l⁻¹)</td>
<td>0.08-0.1</td>
<td>0.089±0.005</td>
<td>0.11-0.36</td>
<td>0.203±0.089</td>
<td>0.07-0.1</td>
<td>0.083±0.01</td>
<td>0.09-0.13</td>
<td>0.11±0.01</td>
</tr>
</tbody>
</table>

Journal of Environmental Biology, April 2013
Table 2 : Pearson correlation coefficient matrix between physical, chemical and biological parameters attributes

<table>
<thead>
<tr>
<th></th>
<th>Density</th>
<th>Chl-a</th>
<th>WT</th>
<th>SD</th>
<th>pH</th>
<th>DO</th>
<th>NH₃N</th>
<th>TP</th>
<th>TN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chl-a</td>
<td>0.585**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>WT</td>
<td>0.597**</td>
<td>0.809**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>-0.229</td>
<td>-0.321</td>
<td>-0.548*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>0.625**</td>
<td>0.620**</td>
<td>0.815**</td>
<td>-0.317</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DO</td>
<td>0.435*</td>
<td>0.520**</td>
<td>0.623**</td>
<td>0.004</td>
<td>0.670**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NH₃N</td>
<td>0.016</td>
<td>0.013</td>
<td>0.269</td>
<td>-0.729**</td>
<td>0.170</td>
<td>-0.291</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TP</td>
<td>0.284</td>
<td>0.142</td>
<td>0.486'</td>
<td>-0.542**</td>
<td>0.364</td>
<td>0.061</td>
<td>0.238</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>TN</td>
<td>-0.374</td>
<td>-0.624''</td>
<td>-0.886''</td>
<td>0.660''</td>
<td>-0.563''</td>
<td>-0.419''</td>
<td>-0.473''</td>
<td>-0.423''</td>
<td>1</td>
</tr>
</tbody>
</table>

* significant at the 0.05 level (2-tailed); ** significant at the 0.01 level (2-tailed).

Eutrophication. The cells of *P. limnetica* could well tolerate the limit of light, easily leading to being forming advantage in low transparency and eutrophication water (Reynolds et al., 2002; Xie, 2007). Although the correlation analysis showed phytoplankton density and chlorophyll concentration was not significantly correlated to transparency, there was a significant (n=24, p<0.01, r=0.548) negative correlation between temperature and transparency, otherwise water temperature was an important factor in phytoplankton growth. Though this explained that transparency did not directly affect phytoplankton growth, they also had important indirect relations. One hand, the low transparency of water made *P. limnetica* easy to compete, on the other hand massive reproduction of *P. limnetica* reduced the transparency of water.

Massive reproduction and photosynthesis of phytoplankton in water would result in CO₂ and O₂ release. On one hand this would increase oxygen in water and promote dissolved oxygen concentration, on the other hand would consume CO₂ in water, making carbonate disintegrate and increasing the value of water pH (Zhang et al., 2004; Zao Wen, 2000). There was a positive correlation between Chl-a content and dissolved oxygen (Cui, 2000; Feng et al., 2011). In the reservoir, phytoplankton density was very correlated to pH (n=24, p<0.01, r=0.625) and DO (n=24, p=0.05, r=0.453); chlorophyll a was significantly correlated to pH (n=24, p<0.01, r=0.620) and DO (n=24, p<0.01, r=0.520). It illustrated that phytoplankton growth caused variation of DO and pH. But the variation of phytoplankton density was obvious while the variation of DO and pH was not. It may account for that the impact of pH and DO caused by massive reproduction was weakened for the reservoir being large capacity.

Nitrogen and phosphorus are essential nutrients and also crucial factors affecting phytoplankton growth. According to the correlation analysis, there was a very significant negative correlation (n = 24, p < 0.01, r = 0.624) between chlorophyll a density and total nitrogen. With increase in phytoplankton and chlorophyll a content, total nitrogen reduced, showing total nitrogen was not a limiting factor. Zhang et al. (2002) reported that the maximum value of total phosphorus concentration in the reservoir in 2010 was 0.239mg l⁻¹ and phosphorus was the limiting factor to phytoplankton growth. Though correlation analysis showed total phosphorus was not related to phytoplankton density and chlorophyll a, N : P ratio illustrated that phosphorus was still a limiting factor to phytoplankton growth.

Structure of phytoplankton community having altered in 2011, *P. limnetica* dominated the community all the year round was a remarkable characteristic. The environmental factors such as water temperature, pH and DO were significantly related to phytoplankton abundance, but total abundance and community structure of phytoplankton were not influenced by environmental factors.

**Acknowledgments**

We would like to thank Professor Henri, University of Ghent, Belgium who helped in reviewing the manuscript. This work was supported by the Research Project of Social Development of Guiyang City (2011 No. 59).

**References**


Journal of Environmental Biology, April 2013
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