Analysis of cyanobacteria outbreak effects in southern offshore area of Taihu lake

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Abstract. The eutrophication of lake water bodies has been emphasized for decades in our country due to its severe environmental effects. Indeed, 85.4% of lakes have met the eutrophication standard, and 40.1% of the lakes have met the severe eutrophication standard in China nowadays. Taihu lake, as the most important freshwater lake in eastern China, has been embarrassed because of the serious cyanobacteria outbreak problem every year. In this study, a statistic analysis of cyanobacteria outbreak in the offshore area of Taihu lake is conducted. Both the satellite image and field monitoring data are cited and analyzed. As a result, it is confirmed that the cyanobacteria outbreak effects are serious in spring and summer due to the high temperature and the high ratio of TN/TP. Additionally, the variations of TN/TP and cyanobacteria density are both computed and compared to show the environmental issues close to the Taihu lake.

1. Introduction

Eutrophic lakes usually have higher TN (Total Nitrogen) and TP (Total Phosphorus) concentration, previous studies show that the ratio of TN/TP will affect cyanobacteria in the eutrophic lakes [1-4]. Taihu lake has been embarrassed by the cyanobacteria outbreak problem for decades although its water area reaches 2338.1 km² [3,5,6]. The offshore line of Taihu lake is almost 393.2km, numerous sources of pollutant lead to serious water environmental issues in Taihu lake. In this study, Taihu lake and its southern offshore area is focused, the TN/TP is computed and the cyanobacteria density is analyzed in order to clarify the environmental issues due to the outbreak of cyanobacteria. A detailed comparison between satellite image and field monitoring data is also represented to show the local environmental issues close to the southern offshore area of Taihu lake as shown in Figure 1 [7-9].

Figure 1. Cyanobacteria disaster in southern offshore area of Taihu lake.
2. Distribution of Cyanobacteria in Taihu lake

According to the Taihu Lake Health Status Report (2018) issued by the Taihu Lake Basin Administration [5], the average density of cyanobacteria in Taihu Lake in 2018 was 86.24 million/L, which decreases of 26.7% from 2017. Among the lake areas which are shown in Figure 2, the number of cyanobacteria in the western coastal area and Zhushan Lake is on a relatively high level. Satellite remote sensing images show that the frequency and intensity of water blooms in Taihu Lake in 2018 have decreased compared with 2017. The largest water bloom area in 2019 was 775.37km², which appeared on May 23rd. [10-12]

![Figure 2. Taihu lake and its offshore areas.](image)

The problem of cyanobacteria in Taihu Lake in 2020 has an descend trend compared with previous years. The density of cyanobacteria and the concentration of chlorophyll a decreased compared with 2019. According to the statistical data of cyanobacteria in each lake area of Taihu Lake, the average density of cyanobacteria in the eastern and southern parts of Taihu Lake is classified as medium and low-severe (the density in most areas is less than 100 million per liter), while the cyanobacteria in the western and Zhushan Lake areas are classified as moderate and severe, which means that the cyanobacteria density is greater than 100 million cells/liter in most areas, and is greater than 150 million cells/liter especially in west and southern areas [4, 6, 13-15].

As shown in Figure 3, combined with the time of the cyanobacteria outbreak period in Lake Taihu over the years, it can be seen that the cyanobacteria outbreaks of Taihu Lake are mostly concentrated in May to July (Summer season) and October to November (Autumn season) each year, and the cyanobacteria outbreaks are mostly close to western and southern regions of Taihu Lake, which occupies almost 3/4 parts of the lake. There are relatively few cyanobacteria outbreaks in the western and northern regions. It is also confirmed that most of the lake areas except the east bank of Taihu Lake are affected by the outbreak of cyanobacteria over years. When considering the southern offshore area of Taihu lake, the river network in Changxing city is affected by Taihu Lake water inversion, and cyanobacteria blooms have a greater impact on the water quality of the river network. According to statistics data, it is found that the river network in Changxing city affected by the cyanobacteria intrusion of Lake Taihu has an impact range up to 15km above the inflow sections, where the cyanobacteria density is usually greater than 20 million cells/liter. Additionally, during the cyanobacteria outbreak period, the rivers in Changxing city were particularly severely affected by the influx of cyanobacteria.
Figure 3. Satellite remote sensing images of cyanobacteria distribution in Taihu lake\(^1\).

3. Analysis of TN/TP and eutrophic index
According to the 2019 annual water quality monitoring data (25 indicators, excluding chlorophyll A) of Xintang Section in Changxing city. A variation curve of TN/TP (Total Nitrogen and Total Phosphorus ratio) of Xintang Section from January to December 2019 is drawn. While the eutrophic index are also calculated on the basis of the water quality monitoring data. The comparison between TN/TP and eutrophic index are shown in Figure 4.

Figure 4. Comparison of TN/TP and eutrophic index.

\(^1\) Cited by Taihu Lake Health Status Report, issued by the Taihu Lake Basin Administration
From the above figure, in 2019, the monthly monitoring data of the TN/TP and the nutritional status index of the Xintang section showed a clear synchronization trend, and the peak and valley value of the change were basically the same, both of them appears in July. The relative peak value occurs in January, March, and September, and the relative valley value occurs in February, August, and October.

When considering the comparison data in Figure 4, firstly, when TN/TP is between 7 and 10, the phytoplankton in the water body is in a nitrogen-restricted state, and biological nitrogen fixation may occur in order to adjust TN/TP to absorb relatively more phosphorus in the water body. Secondly, when the TN/TP is between 23 and 30, the phytoplankton in the water body is limited by phosphorus, and the lower phosphorus concentration will inhibit the organic synthesis of nitrogen. Thirdly, when TN/TP is greater than 29, cyanobacteria outbreaks are widely existed, the release of phosphorus in sediments is easily activated during the cyanobacteria outbreak, while leads to an environmental disaster.

**Figure 5.** Analysis of TN concentration, TP concentration, TN/TP ratio and eutrophic index.

From Figure 5, according to the quarterly statistical analysis of TN concentration, TP concentration, TN/TP ratio, and eutrophic index at Xintang Section in 2019, it is confirmed that,

① In spring and summer (February to July), the average concentration of TN and TP in Xintang section is higher than autumn and winter (January, August to December). The concentration changes in spring and summer are relatively small, while the concentration varies greatly in autumn and winter.

② The TN/TP ration and the eutrophic index of Xintang section in spring and summer are maintained at high values and the fluctuation is small, the median nutritional status index is 60.90, which belongs to the moderate eutrophication status.
When considering autumn and winter seasons, lower concentration values are obtained, and the ratio of TN/TP and eutrophic index are also lower than spring and summer season. However, the fluctuation of the above indices are greater. The median eutrophic index is 59.60, which belongs to a mild eutrophication state.

It can be seen that the nutrient status of water bodies in spring and summer is more conducive to the growth of cyanobacteria than in autumn and winter. The outbreak period of cyanobacteria from 2016 to 2020 is usually from May to June each year. Therefore, the southern offshore area of Taihu lake should focus on spring and summer season to reduce the deteriorating effect of the water environment caused by the outbreak of cyanobacteria.

As can be seen from the above Figure 6, the main source of TN pollution load into the river in southern offshore area is the urban citizen pollution which accounts for 79.3% of the total pollution load. While the second main source of pollution load is rural citizen pollution, which accounts for 19.0%. When considering COD (Chemical Oxygen Demand), similar component is obtained, the urban the rural pollution sources attribute almost 95% of the COD pollution, while the livestock and non-point sources are less than 5%. Indeed, livestock and poultry breeding becomes the third pollution source, and the agricultural non-point sources ranked as fourth. Hence, in the southern offshore area of Taihu lake has embarrassed by the urban and rural citizen pollution, which also lead to a serious cyanobacteria outbreak problem. A systematic control plan of pollution sources in these areas is preferred in the future.

4. Conclusion
Eutrophication is a severe problem in lots of lakes in China. In this study, the relationship between TN/TP and cyanobacteria density has been focused and studied. In addition, the seasonal analysis of Eutrophication in southern offshore area of Taihu lake is conducted. The comparisons between satellite image and monitoring data show that a medium TN/TP with appropriate TP concentration will lead to a serious cyanobacteria outbreak problem.

As the most developed zone in China, the Taihu basin is embarrassed wastewater pollution problems for decades. For the southern offshore area of Taihu lake, the main pollution source lead to the cyanobacteria outbreak problem is urban and rural pollution. It is also found that the cyanobacteria outbreak problem usually occurs in spring and summer season. Therefore, the pollution control plan as well as the water diversion project in the southern offshore area becomes important in the future to minimize the eutrophication effects in the local zones.

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