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Original Research Paper

Study on the Changing Law of Dissolved Oxygen and Dissolved Oxygen Saturation in Baiyang Lake

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ABSTRACT

We studied the changing laws of dissolved oxygen (DO) and dissolved oxygen saturation of Baiyang Lake in the past few years. The analysis of dissolved oxygen was from two angles, they were monitoring value and saturability. The results showed that concentration of dissolved oxygen in Baiyang Lake was between 4.08 mg/L and 15.00mg/L, and concentration of dissolved oxygen in a day with the changes of light intensity showed a strong regularity, it was identical in changes of photosynthesis of aquatic plants. The volatility of changes of dissolved oxygen in summer and autumn were more than in spring and winter. The average values of dissolved oxygen were greater in winter than in spring and greater than in autumn and greater than in summer. This was related to water temperature, biomass and biological activities of lives. Dissolved oxygen saturabilities were close to 100% in spring and summer, so photosynthesis was stronger than oxidation in water. Dissolved oxygen saturabilities in autumn and winter nevertheless were less than 100%, and oxidation in water was in a dominate place. Following the comprehensive analysis, dissolved oxygen in Baiyang Lake was mainly affected by temperature, organic matter concentration and water-plants. The characteristics of photosynthesis were obvious in spring and summer and the oxidation in autumn and winter were obvious.

INTRODUCTION

Baiyang Lake is the key to maintain the species gene pool of the biodiversity of the region and the stability of regional climate as the largest lake wetland system in the north of China. Therefore, the environmental problems of the lake and its surrounding area were very important. In order to realize the harmonious development of economy and environment of Baiyang Lake area, and to improve the ecological environment that is polluted, more and more scholars investigate and study the ecological environment of the Baiyang Lake from different angles, and they also put forward a lot of treatment plans.

In recent years, the physical, chemical and biological changes were more active than before due to carrying out pollution control of the Lake area. Dissolved oxygen in water was not only an important infect factor in these processes, but also an important indicator of evaluation of surface water quality. Dissolved oxygen concentration could often reflect the self-purification ability and the status of water pollution and biological growth. The aquatic organisms would be harmed if dissolved oxygen concentration was too high or deficient, such as causing mass of fish to die (Chunfen 2011, Chengshan, 1999, Donglian 2002). Therefore, analysis had important significance from the angle of dissolved oxygen concentration in water about understanding the water quality condition and water self-purification ability.

At present, research on the changes of dissolved oxygen concentration in water at home and abroad, mainly carried out on dissolved oxygen concentration changes in time and space (Ealc, 2006, Engle 1999, Guodong 2007, Hongbo 2008, Manxin 2004). On time, they often chose one day or one year for dissolved oxygen concentration in the whole study. On space, they carried on the analysis from the horizontal (different places) and longitudinal (different depth) aspects. In addition to analysing dissolved oxygen concentration, analysing dissolved oxygen saturation could simplify the analysis (Manxin 2000, Ou 2008, Qinsheng 2010, Qinsheng 2007), and the result was more clear. Therefore, we analysed the changes and influence factors of dissolved oxygen concentration in Baiyang Lake from two aspects of monitoring values and saturation. These made the results more practical (Qun 2009) and also could provide more comprehensive scientific basis (Ranran 2010, Xiangbin 2011) to have an acquaintance with the water quality. Our study also had important significance for the water quality improvement.

MATERIALS AND METHODS

The determination of monitoring stations: There were seven monitoring stations chosen in our study, their names were Guangdian, Quantou, Duancun, Damaidian, Caiputai, Lianggoucun and Datianzhuangcun. The geographical locations of these monitoring stations are shown in Fig. 1.

Fig. 1: The distribution of the monitoring stations in Baiyang Lake.

The monitoring frequency and parameters: The monitoring was carried out in April, July, October and January each year, and the data of dissolved oxygen were recorded for 2 days and 24 hours a day. Dissolved oxygen concentration was determined by iodometric method of GB.

RESULTS AND DISCUSSION

The diurnal variation of dissolved oxygen: The changing trend of dissolved oxygen in a day is shown in Fig. 2. The results were consistent with most of the researchers for dissolved oxygen of surface water.

It is shown that dissolved oxygen concentration varied regularly in 24h. Dissolved oxygen concentration increased in the daytime and decreased in night, and the minimum value of dissolved oxygen concentration appeared about one or two hours before sunrise and the highest value appeared about one or two hours before sunset. In the daytime, because light intensity was strong, photosynthesis was also strong, and the releasing of oxygen by aquatic plants for photosynthesis increased, and the oxygen partial pressure was higher in the daytime than in the night. Therefore, usually dissolved oxygen increasing rate was always greater than the decreasing rate in the daytime, dissolved oxygen concentration increased overall. Light intensity was almost zero at night, and it could not satisfy the requirement of aquatic plants to photosynthesize, so the photosynthesis almost stopped. And the oxygen partial pressure reduced at night. All these made dissolved oxygen increasing rate to decrease. At the same time, the respiration of aquatic organisms and the degradation of organic matter were still existent. All these resulted in dissolved oxygen increasing rate being less than decreasing rate and at last dissolved oxygen reduced at night.

Within a day, because the water temperature altered little, the ability of the water body of dissolving oxygen did not change much. Atmospheric oxygen partial pressure had little influence on the changes of dissolved oxygen in water.

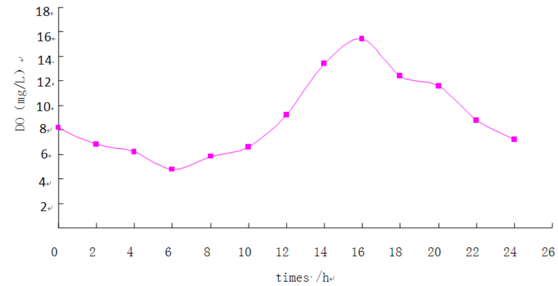

Fig. 2: The law of diurnal variation of dissolved oxygen.

Therefore, atmospheric oxygen reaeration rate would not change in a day. Aquatic biological respiration and organic degradation rates were mainly resolved by the activities of enzyme which participated in reaction. However, the activities of enzymes were related to the ambient temperature. Because of the temperature of this period was not much altered, dissolved oxygen decreasing rate was almost constant. Nevertheless, the photosynthesis of the aquatic plants changing with light intensity would not alter, so the photosynthesis of aquatic plants was the main factor to influence dissolved oxygen within 24 hours.

The changing laws of dissolved oxygen in monitoring stations: According to the monitoring data in recent years in Baiyang Lake, the changing laws of dissolved oxygen concentration with seasons at the seven monitoring stations are shown in Figs. 3, 4, 5 and 6. The maximum and the minimum values at every station are shown at the same time. Dissolved oxygen concentrations were in the range of 4.08-15.00 mg/L in different seasons in the Baiyang Lake. Furthermore, dissolved oxygen average concentration was above 7.5 mg/L in each quarter in every season. Analysing from dissolved oxygen concentration, the water qualities were accorded with the national surface water standard of the class one. It could be seen that the maximum value and the minimum value all appeared in summer, and waves of dissolved oxygen concentration in summer were the largest and the most unstable.

From Fig. 3, we knew that dissolved oxygen concentration of Baiyang Lake was in a high level and the changing range was not big in winter. In winter, continentally controlled by the cold air mass, climate was dry and cold with little snow, and at the same time north-west monsoon prevailed. Because, the winter monsoon appeared frequently in the beginning of winter, communication between water and air increased and a large amount of oxygen dissolved into water. Influenced by the low temperature in winter, the oxygen concentration increased in saturated state. The aquatic organisms were all in dormant state or blasted state, so biomass decreased. The low temperature kept activities of

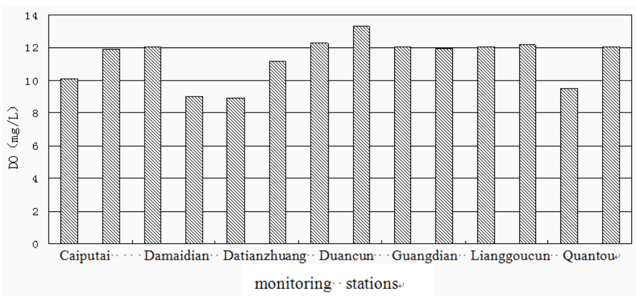

Fig. 3: Dissolved oxygen concentration in winter.

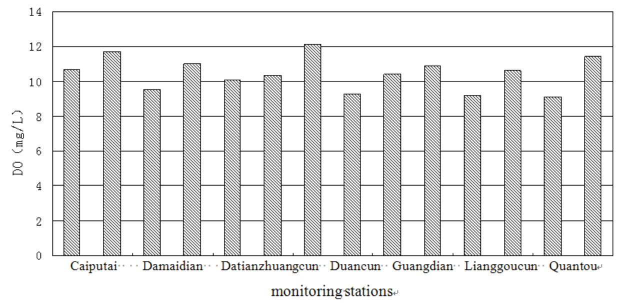

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Fig. 4: Dissolved oxygen concentration in spring.

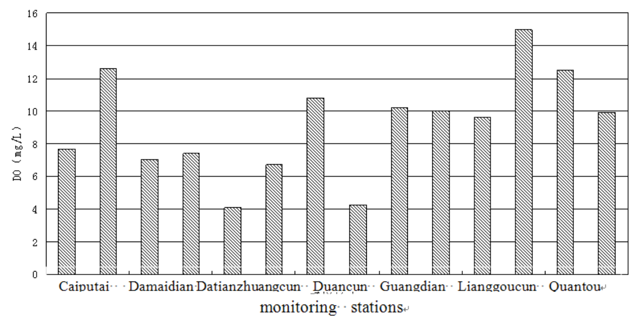

Fig. 5: dissolved oxygen concentration in summer.

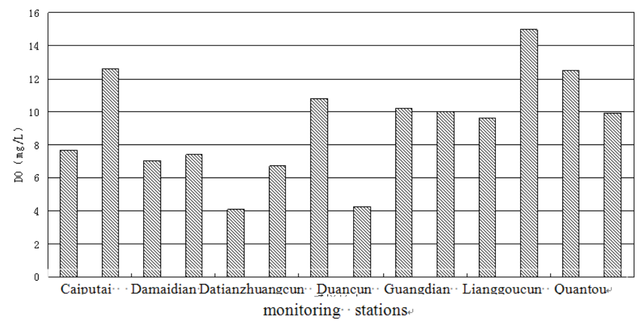

Fig. 6: Dissolved oxygen concentration in autumn.

biological enzymes decreasing and biological photosynthesis, respiration, oxidation and degradation also decreased. Therefore, dissolved oxygen concentration increased to a high level under the influence of reaeration effect strengthening and oxygen consumption decreasing. In addition, icing phenomenon in a certain extent avoided the interference of environment to water body, which would make dissolved oxygen concentration to change little.

From Fig. 4, it can be seen that the average value of dissolved oxygen in spring was slightly lower than that in winter. Because the water temperature was rising, it made dissolved oxygen concentration under the saturated level, and the biological activities increased due to enzyme activities increasing. Therefore, the oxygen restoration process in the water reduced, but the oxygen consumption process improved. Comparing Figs. 3 and 4, we knew that the changing ranges of dissolved oxygen concentration at the seven ports were smaller in spring than that in winter. Nevertheless, dissolved oxygen concentration changed more frequently than that in winter, because the cold air acted frequently, climate was dry and windy, furthermore, rainfall was low. The sudden drop of temperature would reduce atmospheric oxygen partial pressure, which will result in the oxygen restoration process weakened in water, therefore, dissolved oxygen concentration in water got reduced.

Fig. 5 shows the volatility of dissolved oxygen concentration in summer, which was significantly stronger than that in spring and winter. In summer, the temperature rose and the sunshine time lengthened, photosynthesis of the aquatic plants became more and more and the gap between night and day became large. Therefore, aquatic photosynthesis became the main factor affecting the changes in dissolved oxygen concentration in the day and night. The DO concentration in water was high during the day and low at night, and the diurnal variations were huge. Because the water temperature was in optimum range for enzyme activities, biological respiration and organic matter degradation reached the best, and the consumption of oxygen in water increased sharply. Furthermore, the oxygen saturation decreased for the high temperature, and the dissolved oxygen concentration in summer in the lake area would maintain at a relatively lower level than in other seasons.

Fig. 6 shows that the dissolved oxygen concentration in Baiyang Lake still kept in a higher level in autumn, and volatility of concentration was stronger than in winter. This was because air temperature began to decline and precipitation was significantly reduced, all these made the environment of Baiyang Lake forming the crisp autumn climate. At this time, plants and animals began to wither or enter into a dormant state, life activities due to the lower enzyme activities (caused by lower temperature) weakened gradually, photosynthesis, respiration and oxidation of organic matter also decreased. Under the double influence of the enzyme and light intensity, photosynthesis rate reduced more than other life activities, but the death of algae and other aquatic plants made organic matter concentration

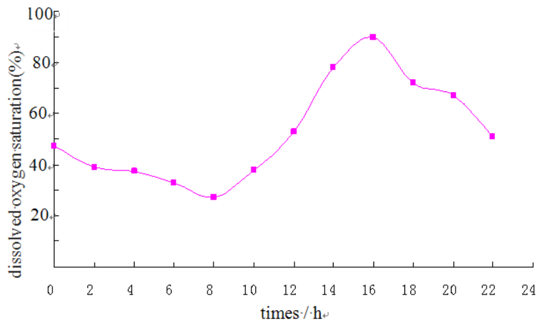

Fig. 7: The diurnal changing laws of dissolved oxygen saturation.

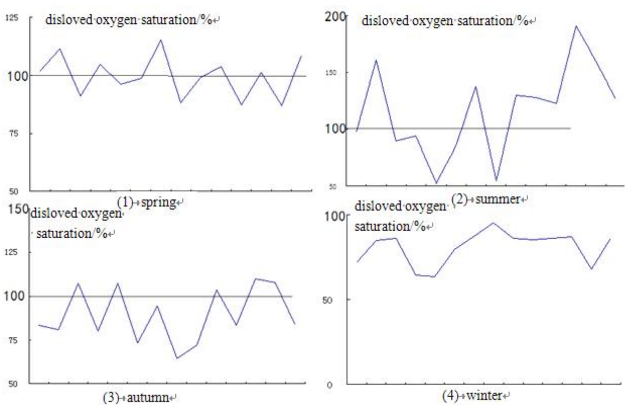

Fig. 8; The seasonal laws of dissolved oxygen saturation.

increased and the oxygen consumption of organic oxidation increased also in water. Dissolved oxygen saturation and reaeration ability increased because the water temptation decreased. Therefore, the oxygen consumption by respiration and decomposition of organic matter in autumn increased more than that in summer. Aquatic plant photosynthesis and atmospheric reaeration made the total dissolved oxygen concentration increased in autumn. So, dissolved oxygen concentration was much lower in summer than in autumn. The crisp autumn climate did not make the water temperature to show large fluctuation, so dissolved oxygen concentration could still keep in a higher level, and the variation was small.

The changing law of dissolved oxygen saturation: Many factors affected the dissolved oxygen, they were physical factors (such as temperature, pH, water sports, water and atmospheric air exchange and other physical factors), chemical factors (such as organic matter concentration) and biochemical factors (such as degradation of organic matter and photosynthesis). Dissolved oxygen saturation is percentage of dissolved oxygen concentration with respect to its saturation level under particular temperature and pressure. It can highlight the association of chemical and biochemical processes with dissolved oxygen in surface water. Therefore, our studies discuss the angle of dissolved oxygen saturation in relation to influence of some factors and make dissolved oxygen (DO) more intuitively and accurately.

The determination method of dissolved oxygen saturation: According to the national standards, the determination method for dissolved oxygen used iodometry. Dissolved oxygen saturation was the theoretical value obtained by calculation on the basis of dissolved oxygen concentration. The calculation formula was as follows (Ximin 2010).

$$R(O)\% = C(O) / C'(O) \times 100 \qquad ...(1)$$

In the formula:

R(O): Dissolved oxygen saturation, unit: %

C(O): Dissolved oxygen concentration, actually measured, unit: mg/L

C'(O): The saturated concentration of dissolved oxygen under certain temperature, unit: mg/L

The formula above is based on the condition that atmospheric total pressure was 1013.25Pa, oxygen proportion was 20.95% and relative humidity was 100%. Because changing values of atmospheric pressure, oxygen ratio, salinity and humidity in Baiyang Lake were small, and the influence of them on dissolved oxygen saturation was also small. The calculation formula of dissolved oxygen saturation concentration was from "Technical Guidelines for Environmental Impact Assessment" (HJ/T211 ~ 213-93).

$$C'(O) = 468/(31.6 + T) \qquad ...(2)$$

In the formula:

T: the temperature of measurement, unit: °C

We also could see in formula above that dissolved oxygen saturation would increase if the water temperature decreased. Thus, if we only considered the influence of temperature to dissolved oxygen concentration in a year, dissolved oxygen concentration in winter would be much more than that in summer.

The diurnal changing laws of dissolved oxygen saturation: There were 3 kinds of representation states to dissolved oxygen saturation (Xiangzhong 2011, Yan 2006, Yong 2011). The first was that dissolved oxygen saturation exceeded 100%, the oxygen released by photosynthesis was more than that consumed by respiration and degradation of organic matter. At this time dissolved oxygen was mainly influenced by photosynthesis of aquatic plants. In water the processes of inorganics synthesizing organics played a leading role following with the absorption of carbon dioxide. The second was that dissolved oxygen saturation was equal to 100%, the concentration of dissolved oxygen was equal to the saturation concentration at the same temperature, and exchanges of oxygen in water and in air were in a state of equilibrium. The rate of oxygen consumption and the rate of

Table 1: Dissolved oxygen saturation of Baiyang Lake.

	Winter			Spring			Summer			Autumm		
Winter temperature, °C	1.8			13.0			28.2			12.8		
	C(O)	C'(O)	R(O)	C(O)	C'(O)	R(O)	C(O)	C'(O)	R(O)	C(O)	C'(O)	R(O)
Average value	11.10		79.22	10.39		99.02	8.82		112.70	9.78		92.78
Maximum value	13.32	14.01	95.06	12.10	10.49	115.31	15.00	7.83	191.67	11.60	10.54	110.05
Minimum value	8.31		59.31	9.12		86.91	4.08		52.13	7.55		71.63

oxygen releasing were in equal or slightly variant state, the characteristics of dissolved oxygen in water did not change or change slightly. The third was that dissolved oxygen saturation was under 100%, the oxygen consumed by respiration and degradation of organic matter was more than that released by photosynthesis and atmospheric reaeration. At this time, dissolved oxygen was mainly influenced by oxygen consumption of respiration and degradation of organic matter.

Fig. 7 shows that the diurnal changing laws of dissolved oxygen saturation were consistent with the diurnal changing law of dissolved oxygen (as shown in Fig. 2). Because of specific heat capacity of water, the water temperature in a day changed little and the dissolved oxygen saturation fluctuated in the same level.

The seasonal laws of dissolved oxygen saturation: Dissolved oxygen saturation in different seasons is given in Table 1. It could be seen that the average values of dissolved oxygen saturation were 90% and according with the national class one of surface water standard in addition to that in winter. Changes of dissolved oxygen saturation in all the seasons are shown in Fig. 8. It can be seen that more than half of dissolved oxygen saturation was greater than 100% in spring and in summer, only a part of dissolved oxygen saturation was greater than 100% in spring and autumn and none of dissolved oxygen saturation reached 100% in winter.

Combining with dissolved oxygen saturation of 3 kinds of representation states and their characteristics, we knew that in summer dissolved oxygen was mainly influenced by photosynthesis of aquatic plants. In autumn, the dropping temperature made some aquatic plants enter into dormant state or even withered and photosynthesis weakened. The withering of plants provided conditions for the degradation of organic matter by microorganisms. Therefore, the influence of photosynthesis on dissolved oxygen was weakened, and the influence of respiration and organic matter degradation on dissolved oxygen strengthened. In early winter, because of the frequent winter wind, reaeration effect would blend a lot of oxygen into the lake, and this made the dissolved oxygen concentration almost reach saturation. But as the water temperature decreased, all kinds of life activities were weaken due to the decrease in enzyme activities, and they had not enough impact on dissolved oxygen, and the icing of water made the atmosphere a relatively independent and reaeration effect reduced, while the saturation concentration of dissolved oxygen in water increased because of decreasing temperature. So atmospheric reaeration could not satisfy the oxygen demand and dissolved oxygen saturation reduced. Therefore, water temperature was the main factor to affect dissolved oxygen in winter (Zhen & Jing 2005). In spring, as water temperature increased, biological life activities began to strengthen under the influence of the enhancement (caused by rising temperature) of enzymatic activities. But, because of the aquatic plants were mostly in the growth state, the oxygen release from the photosynthesis was less than that in summer and was mostly used for the life activities, and the dissolved oxygen was mainly from atmospheric reaeration in spring.

CONCLUSIONS

From our studies, we knew that the changing laws of dissolved oxygen in Baiyang Lake were as follows:

1. Dissolved oxygen in Baiyang Lake changed with light intensity in the day time, and it was mainly affected by influence of photosynthesis by aquatic plants. Dissolved oxygen concentration reached the minimum value one or two hours before sunrise, and reached the maximum value one or two hours before sunset.
2. Dissolved oxygen in Baiyang Lake was between 4.08 and 15.00mg/L, and the average value of dissolved oxygen concentration was above 7.5 mg/L. The average value of dissolved oxygen in winter was higher than that in spring, autumn and summer. This was mainly caused by the difference of water temperature, biomass and biological activities of life in different seasons.
3. The average value of dissolved oxygen saturation was greater than 100% in summer, was close to 100% in spring and was less than 100% in autumn and in winter. In spring, photosynthesis had great influence on dissolved oxygen, inorganic matters in water would be consumed

because of photosynthesis and water self-purification ability was stronger. In autumn and winter, water oxidation was dominant, and large amounts of organic matters in water were decomposed, and water self-purification ability was weak. This phenomenon was more serious in winter than that in autumn.

4. From the perspective of dissolved oxygen concentration, water quality in Baiyang Lake conformed to the class one of the national standard of surface water, but the average value of dissolved oxygen saturation was 79.22% in winter, it did not meet the class one of dissolved oxygen requirements. This was relational to low water temperature and weakening of absorption of inorganic compounds by plants.

Overall, dissolved oxygen concentration of Baiyang Lake was mainly affected by temperature, concentration of organic matter and photosynthesis of plants. The self-purification capacity of water in spring and in summer was better than that in autumn and winter.

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