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Influence of non-point source pollution on water quality of Wetland Baiyangdian, China

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ABSTRACT

Nine sampling sites were evenly set up in Wetland Baiyangdian. A total of 478 grab samples were tested from March 2000 to December 2008. Analysis was conducted on the changes of pH, temperature and concentrations of dissolved oxygen (DO), chemical oxygen demand (COD), 5-day biochemical oxygen demand (BOD_5), ammonia nitrogen (NH_3-N), total phosphorus (TP) and total nitrogen (TN) along time. Results showed that average concentrations of DO, COD and BOD_5 in the rainy season were 28%, 7% and 6% lower than those in the dry season, respectively. Average concentrations of NH_3-N, TN and TP in the rainy season were 48%, 27% and 47% more than those in the dry season, respectively. DO concentration decreased by more than 1 mg/L in the rainy season due to non-point source pollution. These results demonstrated that non-point source pollution was a quite important pollution source to Wetland Baiyangdian. Nitrogen and phosphorus pollution in Wetland Baiyangdian mainly came from non-point sources. To reduce the TN and TP concentrations in the wetland, fertilizer utilization needs to be better controlled in the surrounding farmlands.

Keywords: Wetland Baiyangdian; Non-point source pollution; Rainy season; Total nitrogen; Total phosphorus; Dissolved oxygen

1. Introduction

Accelerated wetland degradation is a serious problem in many places around China due to the heavy nutrient input and deteriorated water quality, which is caused by the fast urbanization and industrialization [1,2]. Since wetlands are usually very important to keep the ecological balance of the surrounding areas, water quality improvement becomes very important for these wetlands [3,4]. Among various pollution sources, non-point source pollution has become a major pollution source for many wetlands with the progress of better control on point source pollution nowadays [5–10]. In the areas with obvious dry season and rainy season, seasonal or storm specific fluxes strongly deviate from their annual values [11].

Wetland Baiyangdian is located in the center of Hebei Province and is about 130 km south of Beijing, China. It is the largest natural freshwater body in Northern China Plain with a total water surface area of approximately 122 km^2 in recent years [12,13]. It serves as a very important water resource for agriculture, people living and breed aquatics for the surrounding area. In addition, it is a critical stop for bird migration in northern China. With the accelerated economic development since 1970th, much heavily polluted wastewater has entered the Wet-

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land and the water quality has been greatly degraded. Now Wetland Baiyangdian is in a eutrophic state [14]. With more and more control on point source pollution in recent years, non-point source pollution from agriculture, livestock feces, and people living wastes has become a primary pollution source to Wetland Baiyangdian.

The climate around Wetland Baiyangdian is the typical weather in northern China. The long term average annual precipitation is 560 mm. On average, more than 60% of the rainfall takes place between July and September, which is defined to be the rainy season in this paper. The rest of the year from October to June is defined to be the dry season. Usually, little runoff flows into the Wetland due to the limited amount of rainfall and the dry condition of the surrounding land in the dry season.

The objective of this study is to characterize the water quality of Wetland Baiyangdian and understand the impact of non-point source pollution.

2. Methods

As shown in Fig. 1, nine sampling sites were evenly set up in Wetland Baiyangdian. Each sampling site represents about 14 km^2 water surface area on average. The water in the Wetland was shallow with a water depth less than 2 m at most of the areas. One grab sample was taken at 0.5 m below the water surface in the vertical direction every one or two months at each sampling site. The concentrations of five water quality parameters including 5-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), ammonia nitrogen (NH_3-N), total phosphorus (TP) and total nitrogen (TN) were analyzed in the laboratory. Temperature (*T*), pH, and dissolved oxygen (DO) were measured on site.

3. Results and discussion

Names and locations of each site are described in Table 1. No sample was taken from S9 Gudingdian because the water was too shallow to let the sampling boat in for all of the sampling period. One grab sample was taken at each sampling site every one or two months from March to December every year and 478 grab samples were acquired in total. Table 2 shows the water quality summary of the 478 grab samples. Table 2 demonstrates that temperature, pH, BOD_5, COD and DO do not vary very much among samples with much lower standard deviations (Std-Dev) compared to the corresponding mean values. While for the nutrition indicators including NH_3-N, TN and TP, the Std-Dev are much more than the corresponding mean values. This is caused by the large seasonal variance of the pollutant concentrations.

Within the nine sampling sites, the water quality of S8 Nanliuzhuang is the worst since it is close to the inflow of Fu River, which is mainly composed of municipal and industrial wastewater from upstream. Boxplots of pollutant concentrations for different sites are shown in Fig. 2. Fig. 2 shows that the water quality of different areas of

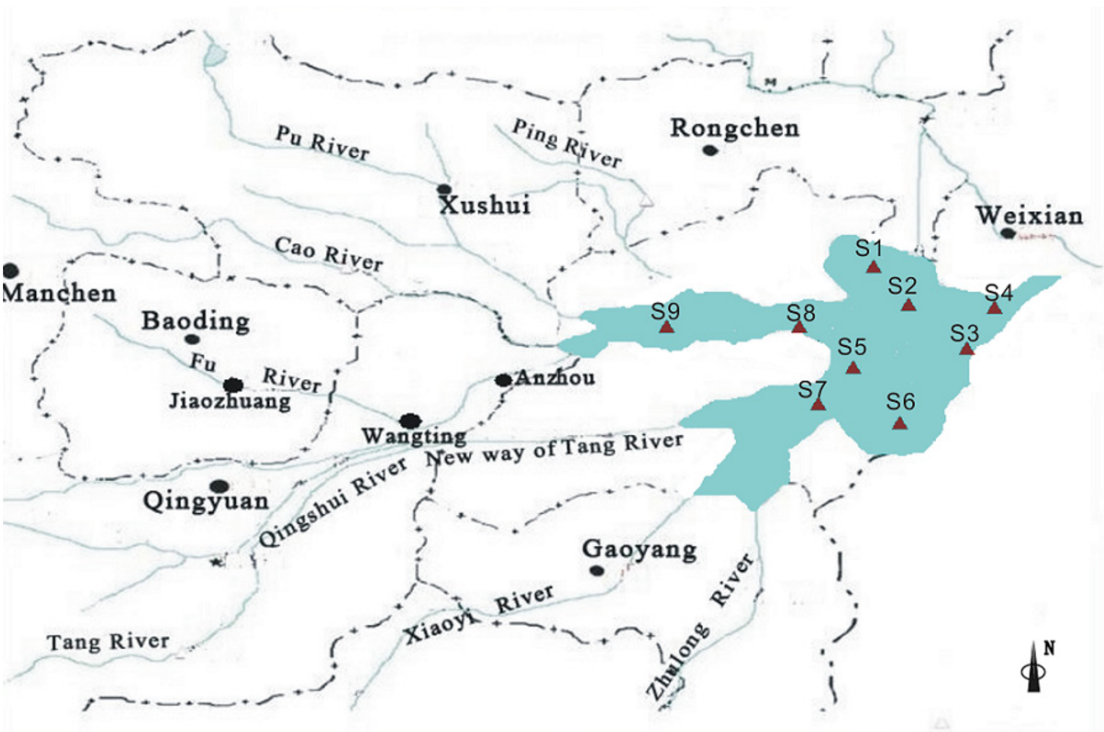

Fig. 1. Sampling sites location in Wetland Baiyangdian (the shade area).

Table 1
Site description

Site ID	Name	Location
S1	Shaochedian	At 1.8 km west and 1.8 km north of Guolikou village
S2	Wangjiazhai	At 0.35 km east and 0.35 km north of Wangjiazhai village
S3	Guangdian-zhangzhuang	At 0.7 km east and 0.7 km south of Guangdianzhangzhuang village
S4	Zaolinzhuang	At 1 km west of Zaolinzhuang village
S5	Quantou	At 0.8 km east and 0.8 km north of Quantou village
S6	Caiputai	At 0.7 km east and 0.7 km north of Caiputai village
S7	Duancun	At 1 km south of Duancun village
S8	Nanliuzhuang	At north west of Nanliuzhuang and 50 m east of Baiyangdian bridge
S9	Gudingdian	At 1 km north of Beihezhuang

Table 2
Statistical summary of the water quality parameters for the 478 grab samples

Parameter	T (°C)	pH	DO (mg/L)	BOD_5 (mg/L)	COD (mg/L)	NH_3-N (mg/L)	TN (mg/L)	TP (mg/L)
Mean	18.30	8.18	9.35	5.58	33.90	1.70	2.94	0.17
Median	18.35	8.18	9.21	4.30	29.45	0.44	1.41	0.09
Minimum	0.00	0.83	0.46	1.00	4.54	0.04	0.01	0.01
Maximum	32.00	9.56	20.00	49.50	188.00	27.80	28.40	2.89
Std-Dev	8.36	0.48	3.81	4.86	18.67	4.39	4.74	0.27

Wetland Baiyangdian is similar except around S8, which is close to the Fu river inflow. Since the pollutant concentrations of S8 are much higher than those of other sites and don't represent the condition of the overall wetland, S8 is removed from the later discussion on the overall water quality trend of Wetland Baiyangdian.

The average pollutant concentrations for individual year are plotted in Fig. 3. Fig. 3 shows that the pollutant concentrations vary for different years, which might be caused by different amount of precipitation and pollutant input. No obvious trend along years can be found from 2000 to 2008. This implies that although the government has invested lots of money on point source control over the past years, the water quality of Baiyangdian did not improve very much. This might be caused by non-point source pollution and the breed aquatics inside.

Fig. 4 is the monthly water quality change with time from March 2000 to December 2008. The monthly average pollutant concentrations were obtained using the water quality data from S1 to S7. The x axis is time at monthly basis. The y axis represents pollutant concentrations. Fig. 4 shows that when the rainy season approaches, pH decreases very much due to large amount of storm water runoff into the wetland. After the rainy season, pH increases. DO concentration drops very much when the rainy season comes. This is caused by the high temperature in the summer and the large amount of pollutants brought by runoff, which consume lots of DO by nature degradation. Concentration of BOD_5 does not change very much with dry and wet seasons. Concentrations of NH_3-N, TN and TP increase very much when the rainy season approaches and decrease after the rainy season. The reason for these phenomena is that large amount of nitrogen and phosphorus are flushed into the wetland by storm water runoff from the surrounding farmlands.

To better understand the seasonal change of DO concentration and the cause for the change, monthly average temperature, monitored DO concentration, and calculated DO concentration are plotted in Fig. 5. The monthly average monitored DO concentration and temperature are calculated from the water quality data of 478 grab samples taken from 2000 to 2008. Calculated DO concentration is the saturated DO content in water calculated with the monthly average temperature, a pressure of 760 mm Hg and a salinity of 0 parts per thousand [15]. Fig. 5 shows that the monthly average temperature increases from 9.9°C in March to about 28.1°C in July and then decreases to 3.5°C in December. The monthly average monitored DO concentration is highest in March which is about 14.2 mg/L. After March, it decreases to 7.3 mg/L in July and then keeps low values of 6.4, 7.5, 8.7 mg/L in August, September and October. After October, the monitored DO concentration increases. There are two main reasons for the change of monitored DO concentration.

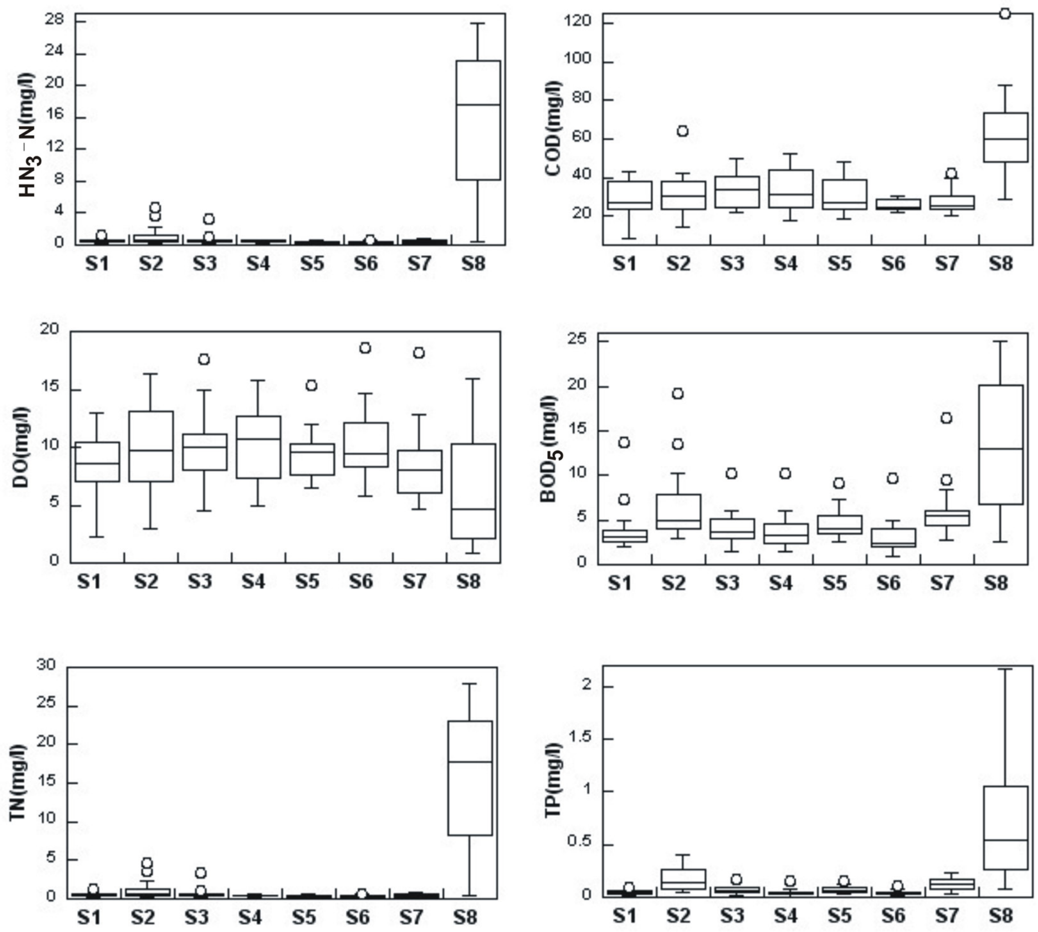

Fig. 2. Boxplots of pollutant concentrations for different sampling sites.

One is the change of temperature and the other is pollutant degradation. Calculated DO concentration represents the variation of DO with the change of temperature. Compared to the calculated DO concentration, the monitored DO concentration is more than 1 mg/L lower from July to October, which is caused by the pollutant consumption from non-point sources carried by runoff.

Fig. 6 compares average pollutant concentrations of rainy season and those of dry season. Since the water samples were usually taken at the beginning of each month, we use the water quality data of August, September and October to demonstrate the water quality change in the rainy season of July, August, and September. Concentrations of DO, COD and BOD_5 in the rainy season are 28%, 7% and 6% lower than those in the dry season respectively. Concentrations of NH_3-N, TN and TP in the rainy season are 48%, 27% and 47% more than those in the dry season respectively. These results show that nitrogen and phosphorus pollution in Wetland Baiyangdian mainly comes from non-point sources. To reduce the NH_3-N, TN and TP concentrations in the wetland, fertilizer utilization needs to be better controlled in the surrounding farmlands.

4. Conclusions

Overall, non-point source pollution is a quite important pollution source to Wetland Baiyangdian. When the rainy season approaches, pH and DO concentration decrease very much. The monitored monthly average DO concentration is highest in March which is about 14.2 mg/L. After March, it decreases to 7.3 mg/L in July and then keeps low values in August, September and October. After October, the DO concentration increases. The degradation of pollutants from non-point sources in the rainy season leads to a DO concentration decrease of more than 1 mg/L. The average concentrations of NH_3-N, TN and TP in the rainy season are 48%, 27% and 47% more than those in the dry season respectively.

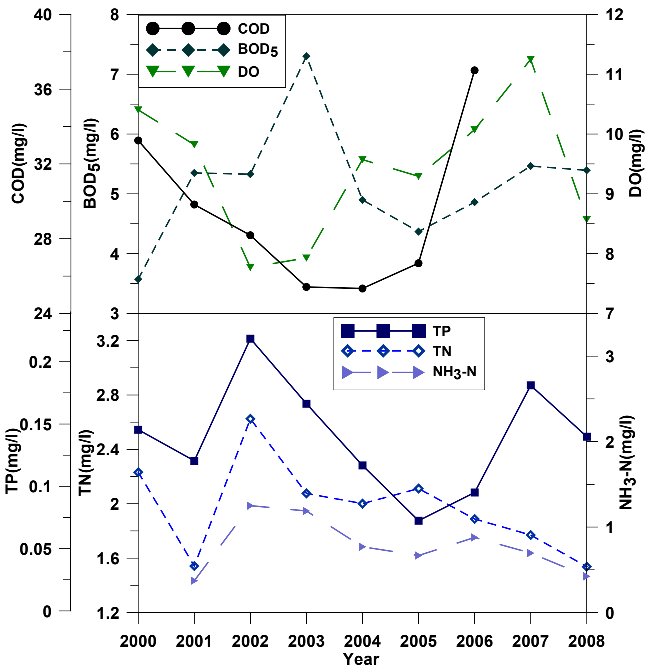

Fig. 3 Average pollutant concentrations for individual year from 2000 to 2008.

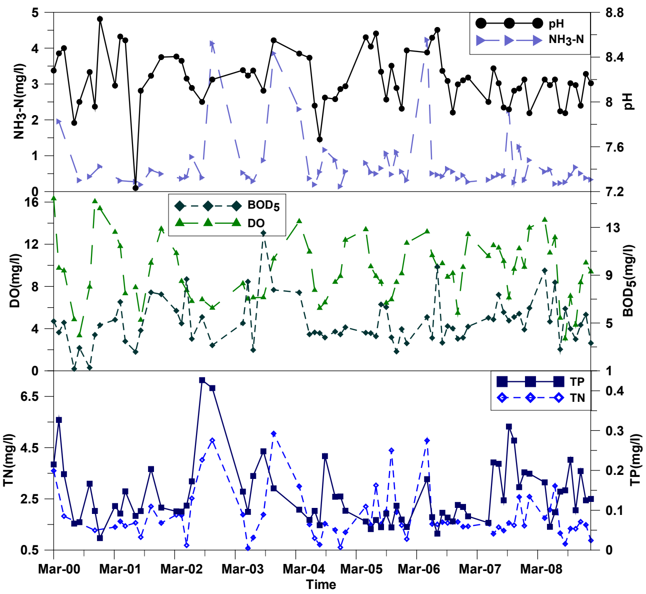

Fig. 4. Monthly water quality change from March 2000 to December 2008.

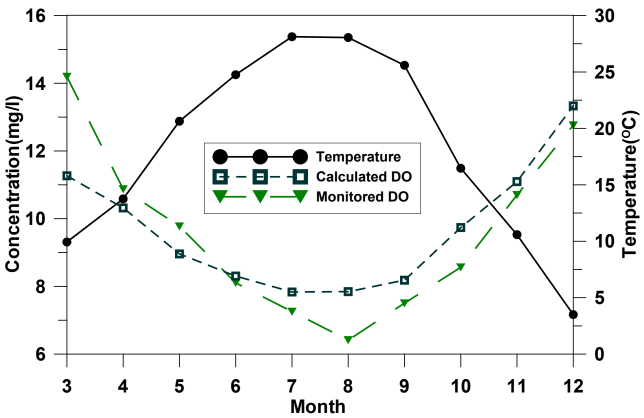

Fig. 5. Comparison between calculated DO and monitored DO for different months.

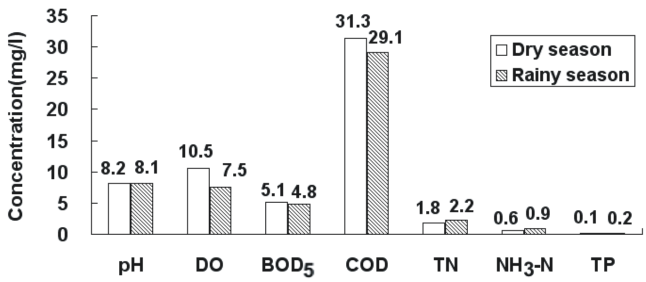

Fig. 6. Comparison between average pollutant concentrations of rainy season and those of dry season.

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