



# Region Distribution of Industrial Environmental Load and its Intensity in Baiyangdian Basin of China

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## Abstract

The industry is an important sources for the environmental pollution in Baiyangdian basin. A region distribution of the environmental loads can provide supporting information for effective environmental improvement. Based on an analysis of the key ecological environmental problems, we take the receiving water body of the industrial wastewater as the region unit, and select the industrial freshwater consumption, the industrial wastewater discharge and its contained pollutions as the main industrial environmental loads, the region distribution of the industrial environmental load and its intensity in Baiyangdian basin are estimated. The results show that freshwater consumption intensity of Caohe is the largest and is 3.21 times than the average level of the basin; the receiving quantity of the industrial wastewater of Baiyangdian is largest, is up to 6735 ton and accounts for 41.2% of the total. The COD receiving quantity of Caohe, Daqinghe and Baiyangdian are the three top highest. Meanwhile the ammonia-nitrogen receiving quantity of Zhulonghe is up to 202.04 ton/yr and accounts for 44.6% of the total; and the BOD receiving intensity of Zhongyishui and Caohe is about 6 times than the average level of the basin.

## Background

As the largest freshwater lake in the north China plain, with the area of 366 square kilometers, Baiyangdian is located at the central position among Beijing, Tianjin and Shijiazhuang, belongs to Baoding district on administration, and is affiliated to Daqinghe water system of Haihe basin, it has the important ecological functions of flood alleviation, drainage stagnation, water storage and so on, and enjoyed the reputation of 'the kidney of the north China'[1]. But in recent years, due to the combined action of natural factors (such as weather change) and artificial factors (such as development and utilization of water resources) [2], not only the frequency breaking of the river channels is caused and the wetlands are shrunk but also the serious water pollution problem is caused, and at present, most of the water quality of Baiyangdian is divided into IV type, V type, even bad V type. The rapid deterioration of the ecological environment has a serious influence on the ecological functions of Baiyangdian[3]. It has become the key points of the management of Baiyangdian basin and the affiliated haihe basin for saving Baiyangdian. The water quality deterioration is the important performance of the water environment problem in Baiyangdian basin, the pollutions of industrial wastewater, the domestic sewage, the agricultural recession, the fish culture in the net cages and so on are the main reason for the water quality deterioration in Baiyangdian [3]. Wherein, the treatment of the domestic sewage, the agricultural wastewater and the fish culture in the net cages and so on causing lake pollution has been deeply studied in the major project of national water body pollution control and treatment technology with the subject of the pollution load reduction technology of Baiyangdian basin and the safeguard mechanism for demonstrative operation of the engineering, and

the existing achievements can be used as reference, such as the relation between the urban domestic sewage discharge rule and the pollution load [4]; the relation between the discharge coefficient of COD, ammonia nitrogen, total nitrogen and total phosphorus in the country domestic sewage and the family income [5]. While the reports about the study in the aspects of the industrial pollution and the management in Baiyangdian basin are fewer. Especially, according to the statistic data of the industrial pollution census in Baiyangdian basin, there are 13759 enterprises with industrial wastewater flowing into Baiyangdian in Baiyangdian basin in 2008, 0.163 billion tons of industrial wastewater is discharged into the basin every year, wherein the industrial wastewater contains a great quantity of industrial pollutants such as BOD, COD, and heavy-metal substances and so on, which threatens the water environmental quality of Baiyangdian seriously. In addition, most counties and cities in Baiyangdian basin are in the process of industrialization and urbanization, if the industrial condition is not improved, larger pollution hidden trouble can be possibly formed, and the water quality deterioration of Baiyangdian basin is worse. Therefore, starting from the industry, important basis information can be provided for finding the measures for improving the environment of Baiyangdian basin by analyzing the water resource consumption and the classic pollutant discharge condition as well as the condition of the industrial operation technology level in the industrial operation, and at the same time, reference information also can be provided for industrial pollution management of other basins.

## Methods

### Factor analysis on ecological environment bottleneck factor

Baiyangdian is located in the north China plain, the rainfall has obvious seasonality, while in recent years, due to dry weather, the quantity of water flowing into Baiyangdian is reduced, the dry frequency of Baiyangdian is higher and higher, and the lack of water quantity

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becomes one of the important factors for influencing the ecological environment condition of Baiyangdian [6]. On the other hands, quantity of wastewater was discharged into Baiyangdian in another important factor for the worse water quality in Baiyangdian basin. Although the influence factors of the water environmental quality in Baiyangdian basin are complex, the combined action of various natural and social factors has the influence on the water quality of the basin [7]. But since 1970s, the change formed by the main pollutants of Baiyangdian shows that the industrial wastewater discharge is the important reason for the water quality deterioration in Baiyangdian basin, especially the BOD pollutants which are closely relevant to the paper making and textile and the like of the key industries in the basin, the COD pollutants which are closely relevant to the paper making industry, and the ammonia nitrogen pollutants which are closely relevant to the leather product industry become the main pollutants of the water body in the Baiyangdian basin, therefore, the excessive discharge of the industrial pollutants becomes the important bottleneck factor for restraining the ecological environment condition of the Baiyangdian basin.

#### **Selection of representation index**

**Environmental loads:** It is considered that the main factors for influencing the ecological environment of Baiyangdian basin are water resource consumption and the excessive discharge of the pollutants, the availability of the relevant environmental loads data of the basin is also considered, and on the basis of the industrial pollution census data in 2008, the water resource consumption and the industrial wastewater discharge are selected as the main industrial environmental loads of the basin. Wherein, the water resource consumption is shown by industrial water taking quantity, namely the water resource quantity consumed by industrial operation, and calculated by the fresh water taking quantity, the unit is ton/yr. In the aspect of industrial wastewater discharge, according to the characteristics of the key industries in Baiyangdian district, by combination of the main superstandard projects in the bulletin on water resources of Haihe basin [8], the industrial wastewater discharge quantity in the year and the pollutant quantity of COD, BOD and ammonia nitrogen contained in the industrial wastewater discharged in the year are respectively selected as the environmental load of the industrial wastewater discharge, and the units are respectively ton/yr.

**Environmental load intensity:** The environmental load of the unit industrial output value is defined as the corresponding environmental load intensity, and it is the ratio between certain specific environmental load and the industrial economic output in the same region and can reflect the technical level of the industrial development of the region. This index had been applied in the study on the pollution production intensity of the key industries of Liaohe basin and the study on the unit difference of the pollutant discharge intensity of the industrial wastewater [9,10]. In addition, this index and the conception of the ecological efficiency proposed by OECD have the similar physical meaning [11], while the ecological efficiency has been widely used as the important index for measuring the technical

level of the industry [12,13], and the environmental load intensity and the ecological efficiency are in reciprocal relationship on value. In present study, because the environmental load is divided into two main categories such as water resource consumption and industrial wastewater discharge, correspondingly, the environmental load intensity is also divided into two main categories such as water consumption intensity and wastewater (and pollutants thereof) discharge intensity, wherein the water consumption intensity is the ratio between the industrial water taking quantity (i.e., the fresh water intake quantity) and the industrial economic output in the same region, and the unit is ton/wanyuan output value; the wastewater (and the pollutants thereof) discharge intensity is the ratio between the industrial wastewater discharge quantity and the industrial economic output in the same region, and the unit is ton (wastewater (and the pollutants thereof) discharge)/ ton/wanyuan output value. The pollutants of the industrial wastewater are still the three main pollutants such as COD, BOD and ammonia nitrogen. In the aspect of industrial economic output, according to the availability of the pollution census data, the total industrial output value is adopted as the reference index for estimating the environmental load intensity.

#### **Region distribution**

Affiliated to Daqinghe water system of haihe Basin, Baiyangdian basin involves the regions such as Hebei province, Beijing and Shanxi and so on, but it is mainly located in Hebei province with 81.04% occupied area, and Baoding district also occupies about 70.8% area of the basin of Hebei province, and is the key region of Baiyangdian basin. The rivers in Baoding district are mainly Daqinghe water system of Haihe basin. Daqinghe is divided into two branches in the south and north, in the south branch, Zhulonghe, Menglianghe, Xiaoyihe, Tanghe, Qingshuihe, Jinqianhe, Jiehe, Fuhe, Caohe, Pinghe, Puhe and so on flow into the Baiyangdian. In the north branch, Jumahe is divided into the south Jumahe and the north Jumahe from the iron lock cliff. The north Jumahe flows into Baigouhe from Dongci country of the Zhuozhou city. The south Jumahe meets the Baigouhe at the Baigou village, hereinafter referred to as Daqinghe. Daqinghe is connected with the Baiyangdian through the Baigouyinhe. The Hebei divided region mainly involves the branches such as Cihe, Dashaha, Zhulonghe, Hutuohe, Yanchuanhe and so on. The Shanxi divided region is mainly penetrated by Tanghe, and a part of the region flows into Shahe. For the Beijing divided region, there are the north Jumahe and Xiaoqinghe penetrating through Fangshan district. The study selects the Baoding district as the key region of the basin study, and carries out region distribution analysis on the industrial environmental load and the environmental load intensity in the region.

In the study, by taking the receiving water bodies of the industrial wastewater as region units, the values of the industrial environmental loads and the environmental load intensity in all the region units of Baiyangdian basin are respectively estimated, and are marked on all the region units of Baiyangdian basin by columnar sizes so as to form the spatial distribution map of the industrial environmental load and the environmental load intensity in Baiyangdian basin.

**Data source**

In this study, the data category mainly relates to the total industrial output value, the industrial water taking quantity, the wastewater the discharge quantity of the three kinds of pollutants, *i.e.*, COD, BOD and ammonia nitrogen in wastewater. The statistical data is from the pollution census data of Baiyangdian basin.

**Results and Discussion**

**Region distribution of water resource consumption**

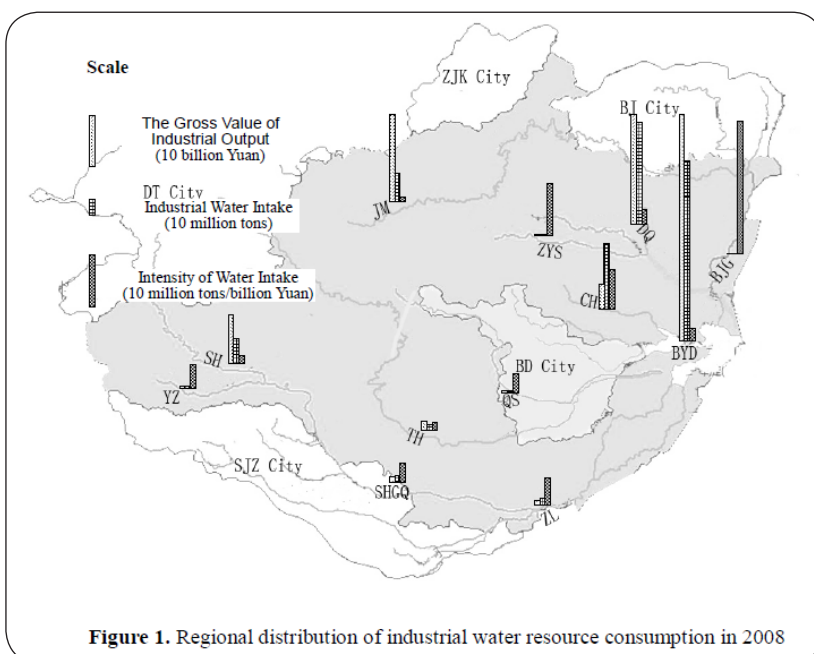
In 2008, there are 13.4 thousand industrial enterprises in total in the key regions of Baiyangdian basin, the total industrial output value finished in this year is 103.9 billion yuan, the total water consumption quantity is 1.56 billion ton, wherein the fresh water taking quantity is 0.257 billion ton and accounts for 16% of the total industrial water consumption quantity, the industrial water consumption circulation rate is 83.4%, and the water resource consumption intensity is 24.74 ton/ten-thousand yuan (industrial output value).

By taking all the receiving water bodies in the key regions of Baiyangdian basin, and taking the pollution census data of Baiyangdian basin in 2008 as the basis, the total industrial output value, the industrial water taking quantity (namely fresh water consumption quantity and water consumption intensity (namely fresh water taking quantity of unit industrial output value) of the industrial enterprises received by all the units in the basin are respectively calculated. The obtained values are marked in the basin distribution graph, and the region distribution of industrial economic output and water resource consumption in Baiyangdian basin is obtained, which is showed in Figure 1. the code of each river is listed in Table 1. Seen from the Figure 1, for the total industrial output value, the value of Baiyangdian subbasin is far ahead of those of other subbasins, reaches about 45 billion yuan and accounts for the 43.17% of the

total industrial output value of the whole basin; next, for Daqinghe, Jumahe and Shahe trunk canal, their total industrial output values are more than 10 billion yuan or close to 10 billion yuan, the sum of the industrial output values of the four subbasins accounts for 90.06% of the output value of the whole basin. The industrial output values of the other subbasins are obviously low. It is clear that the industrial enterprises of Baiyangdian basin have obvious concentrated distribution phenomenon of the subbasins, are more densely distributed in some basins, but are fewer in other basins.

In the aspect of water resource consumption, the industrial freshwater taking quantity of Baiyangdian subbasin is largest and reaches 0.1 billion ton/yr, the second place is Daqinghe and Caohe, and their freshwater taking quantities are respectively 60 million ton/year and 40 million ton/yr; the freshwater taking quantities of the industrial enterprises of all the other subbasins are respectively below 20 million ton/yr, the industrial freshwater taking quantities of the three subbasins respectively account for 41.45%, 23.65% and 15.21% of the total freshwater taking quantity of the whole basin, the sum of the three parts accounts for 80.36% of the whole basin; and the three subbasins are respectively distributed in the regions into Baiyangdian of the northeast of Baiyangdian basin, take on the obvious concentration phenomenon of industrial water consumption, and are key regions for industrial freshwater taking.

In the aspect of industrial freshwater taking intensity, the industrial freshwater taking intensity of Baijiangouhe is largest and is over 300 ton(freshwater)/wanyuan (output value), the second place is Zhongyishui, Caohe and Zhulonghe and so on, it shows that the industrial freshwater consumption level of these subbasins is poorer and should be managed as a key point, more attentions should be paid especially for Caohe and Daqinghe which have larger freshwater taking quantity and larger freshwater consumption intensity, wherein



**Table 1.** The name of river and its code

Code	Name of River
JM	Jumahe
ZYS	Zhongyishui
DQ	Daqinghe
CH	Caohe
BJG	Baijiangou
SH	Shahe
YZ	Yanzhihe
TR	Tanghe
SHGQ	Shaheganqu
QS	Qingshuihe
ZL	Zhulonghe
BYD	Baiyangdian subbasin

the water taking intensities of Caohe and Daqinghe are respectively 3.21 times and 1.14 times more than the average level. In addition, the industrial water taking quantities of Shahe trunk canal and Jumahe are also over 15 million ton, but their water taking quantities are lowest in the whole basin and are respectively 0.39 time and 0.64 time of the average intensity of the basin, the two subbasins are distributed in the upstream region of the south line and the north line of Daqinghe, and the effective utilization of the water resources has good action on keeping water quantity balance of the whole basin. The industrial water resource consumption of other subbasins is lower, the sum of their water taking quantities is less than 7% of the total water taking quantity of the basin, no stronger character exists for the geographical distribution, and more study is not made here.

**Region distribution of discharge of industrial pollutants**

In the aspect of the discharge scale of the industrial wastewater, the total discharge quantity of the key regions of Baiyangdian basin is 0.164 billion ton, the total industrial output value is 104 billion yuan, the average wastewater discharge intensity in the basin is 15.72 ton/wanyuan of output value. In the aspect of pollutant discharge, the total COD discharge quantity of the basin is 38.7 thousand ton, the total ammonia-nitrogen discharge quantity is 452.75 ton, the total BOD discharge quantity is 6836.21 ton, and the average pollution producing intensities of the three pollutants such as COD, ammonia nitrogen and BOD in the basin are respectively 3.724 kg/wanyuan output value, 0.044 kg/wanyuan output value and 0.658 kg/ten-thousand output value. According to the distribution graph of the receiving water bodies of the key region, the annual discharge quantities of the wastewater and all the three types pollutants of all the subbasins in the basin are shown in Figure 2, and the discharge intensity of the wastewater and the three types pollution producing intensity of all the pollutants is shown in Figure 3.

The discharge quantity of the industrial wastewater of Baiyangdian is highest in Baiyangdian subbasins, and is 67.35 million ton;

the discharge quantities of Daqinghe and Caohe are respectively 49.62 million ton and 28.82 million ton, the discharge quantities of the three subbasins account for 89.2% of the total discharge quantity of the basin, and the three subbasins are distributed in the east of Baoding region, and belongs to the downstream stage of Baiyangdian basin. The discharge quantities of the industrial wastewater of all the other subbasins are respectively below 10 million ton. The subbasins with higher discharge intensities of wastewater are also mainly distributed in the east of Baoding region, namely the downstream part of the basin, wherein the intensities of the three subbasins such as Baiyangdian, Daqinghe, Caohe, Baijiangouhe and Zhongyishui are highest and are respectively 115.3 ton/wanyuan, 66.57 ton/wanyuan and 58.44 ton/wanyuan, while the discharge intensities of Baiyangdian and Daqinghe with larger discharge quantities of wastewater are respectively 15.01 ton/wanyuan and 22.90 ton/ten-thousand yuan and are close or higher than the average sewage discharge intensity of the basin, therefore, the key management is needed for the five subbasins such as Baiyangdian, Daqinghe, Caohe, Baijiangouhe and Zhongyishui, and the treatment of the industrial wastewater needs to be enhanced. The discharge conditions of the industrial wastewater in the middle and the west are better, the annual discharge quantity and the annual discharge intensity are lower, therefore, it is clear that the wastewater discharge management in the upstream region of the basin has certain effect.

The discharge conditions of the pollutants such as COD, ammonia and BOD in all the subbasins have obvious differences, and the discharge intensities of the pollutants take on the characteristic of being high in the east and low in the west still.

Shown in Figure 2, almost the main subbasins have obvious COD discharge phenomenon, wherein the discharge quantities of three subbasins such as Baiyangdian, Caohe and Daqinghe are highest, are respectively 17.7 thousand ton, 5.2 thousand ton and 10.6 thousand ton and account for 86.6% of the total discharge quantity of the basin in total. While Zhulonghe and Jumahe rack the fourth and the fifth respectively by the discharge quantities of 2.6 thousand

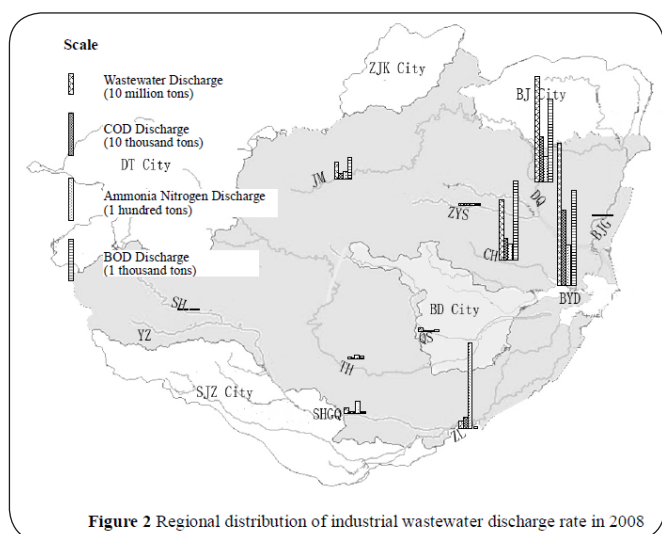


Figure 2 Regional distribution of industrial wastewater discharge rate in 2008

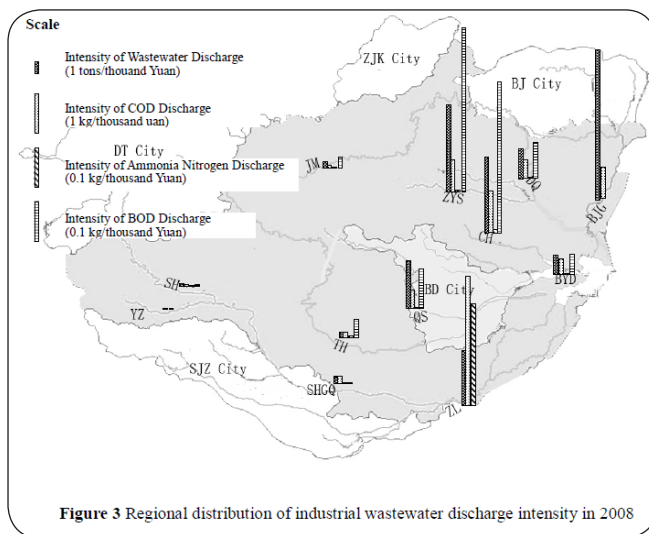


Figure 3 Regional distribution of industrial wastewater discharge intensity in 2008



ton and 1.4 thousand ton, and are also the key branches for COD discharge. Seen from the discharge intensity of COD, the intensity of Zhulonghe is largest, is 33.2 kg/wanyuan, and is 10 times of the average level of the basin; the discharge intensities of COD in Caohe and Zhongyishui are also 2 times more than the average intensity; and for Jumahe, although the annual discharge quantity is larger, the discharge intensity is 1/5 of the average level, the wastewater treatment condition is better. By analysis of the region distribution, the COD discharge conditions of the branches in the middle and the east of Baiyangdian basin are more serious, therefore, these branches need to enhance the management.

The ammonia-nitrogen discharge in Zhulonghe of the south and the region into Baiyangdian of the east is stronger, and the discharge in other regions is less; the annual discharge quantity of the ammonia nitrogen in Zhulonghe is 202.04 ton and accounts for 44.6% of the total discharge quantity; Baiyangdian and Daqinghe follow closely, the annual discharge quantities are respectively 96.05 ton and 57.09 ton and respectively account for 21.2% and 12.6%. Seen from the ammonia-nitrogen discharge intensity, only the discharge intensity of Zhulonghe is highest, reaches 2.6 kg/ten-thousand yuan and is 60 times of the average level of the basin, while the ammonia-nitrogen discharge quantities of other subbasins are respectively and slightly higher or lower than the average level of the basin, therefore, it is very necessary to control the wastewater discharge of the relevant ammonia-nitrogen industries in Zhulonghe basin.

The BOD discharge is mainly concentrated in the subbasins in the middle and the east. The subbasin with largest annual discharge quantity of BOD is Baiyangdian, and the BOD discharge quantity is 2265.01 ton and accounts for 33.1%; the annual BOD discharge quantities in Daqinghe and Caohe are respectively 1963.42 ton and 1899.10 ton and respectively accounts for 28.7% and 17.8%. Seen from the BOD pollution discharge intensity, the pollution discharge intensities of Zhongyishui and Caohe are respectively 4.17 kg/wanyuan and 3.85 kg/wanyuan, and is about 6 times of the average level of the basin; and the BOD discharge intensities of other basins are respectively and slightly higher or lower than the average level of the basin, therefore, in the aspect of BOD, the control on the pollution discharge intensity of the middle branch and the BOD discharge quantity in the east region into Baiyangdian is the key point for reducing BOD discharge.

#### **Discussion on distribution difference of environmental load**

Seen from the region distribution result of the environmental loads, different environmental loads have large difference in their distribution, while the main environmental loads of different subbasins in Baiyangdian basin also have large differences, therefore, the difference analysis on the environmental loads in different subbasins has important significance in better understanding of the water ecological environment of Baiyangdian and industrial upgrading of the industries.

The sub-basin named Baiyangdian is the concentrated region for the industrial development of the whole basin, and is also the region where all the environmental loads are the largest; and the receiving water bodies in the region into Baiyangdian mainly include

Baiyangdian, Caohe and Daqinghe. The annual water taking quantity and the annual pollution discharge quantity of Baiyangdian are very high, but due to higher industrial output value in the region and better development condition, the environmental load intensity is not very high, but as the ecological environment of the wetland region of Baiyangdian is weaker, and needs to be better protected, it is very necessary to further reduce the environmental load of Baiyangdian. The water consumption intensity, the wastewater discharge intensity and the discharge intensity of various pollutants in Caohe and Daqinghe are higher, especially Caohe, all the indexes are over the average level of the whole basin, therefore, the improvement and the upgrading for the whole industry in the basin is needed so as to guarantee that the water bodies into Baiyangdian can not cause threat to the ecological environment of Baiyangdian.

The pollution condition of the subbasins of the middle region in Baiyangdian basin is more serious, wherein Zhongyishui and Zhulonghe are two subbasins with more serious pollution condition, the discharge intensities of COD, ammonia nitrogen and BOD of Zhongyishui are over the average level of the basin, especially the discharge intensity of the BOD is highest in the whole basin, so more attention needs to be paid for the industrial enterprises generating BOD discharge near Zhongyishui basin. While the condition of Zhulonghe is better on BOD discharge, the discharge intensity of COD in the basin is near 10 times of the average level, and the discharge intensity of ammonia nitrogen is 60 times of the average level, so the enterprise upgrading of the big enterprises with discharge of the ammonia nitrogen and the COD should be accelerated.

In the upstream region in the west of Baiyangdian basin, the industrial development is weaker than that of the midstream and downstream, the pollution control is better, all the indexes are basically below the average level, but because the water consumption condition of the upstream branch has the important influence on the water quantity balance of Baiyangdian, therefore, the water consumption intensity in the upstream region is further reduced still on water consumption intensity.

#### **Conclusion**

The distribution of the industrial environmental load in Baiyangdian basin has obvious zonality, the industrial enterprises are developed more densely in the subbasins of the midstream and downstream, the environmental load is stronger, while the industrial development in the subbasins of the upstream is more backward, and the environmental load is weaker. However, the environmental load intensities of all the subbasins conform to the feature of higher at the east downstream and lower at the west upstream, but some subbasins have certain difference.

In the aspect of water resource utilization, the water consumption intensity in the regions into Baiyangdian at the downstream of the basin have the obvious increase trend than that of the upstream region, but the water resource utilization condition in Baiyangdian region is better, and in order to keep the healthy water ecological environment of Baiyangdian region and improve the situation that the water in Baiyangdian basin is lack, it is very necessary to reduce the water consumption intensity of the industries in the

basin comprehensively.

In the aspect of discharging wastewater and the pollutants, all environmental loads conform to the geographic feature of industrial distribution, but some environmental loads have certain particularity in certain subbasins, for example, the ammonia-nitrogen discharge load of Zhulonghe is largest in the whole basin, but the discharge quantity of BOD is very little, this is highly possible to have close relation with the industrial type of the industries in the subbasin, because the ammonia-nitrogen discharge in the industries such as textile printing and dyeing and so on is more obvious. For the downstream region of Baiyangdian with more concentrated industry, because all the environmental loads are larger, the whole ecological upgrading of the industry needs to be conducted positively, the intensity of industrial wastewater discharge needs to be effectively controlled, and the treatment of relevant pollutants needs to be enhanced, so as to realize coordinated development between the industrial economic development and the ecological environmental construction.

#### Competing interests

The authors declare that they have no competing interests.

#### Authors' contributions

J.S. MAO performed the design of the study and improved the draft. P. JIANG carried out the data collection & calculation and performed the statistical analysis. L. MA participated in the sequence alignment and drafted the manuscript. C.H. LI participated in the design of the study for water resource. J. WANG participated in its design and helped to collect the local detail data. All authors read and approved the final manuscript.

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