Analysis of changing trend of water resources and water environment quality in china from 2009 to 2019

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Abstract. Based on the statistical analysis of China Water Resources Bulletin, China environmental situation Bulletin and national environmental statistics yearbook during 2008-2019, we summarized the water resources and water environment quality of seven major basins, and the proportion, main pollutants and change trend of various types of water quality are discussed. Meanwhile, wastewater discharge and pollution discharge are also analyzed. The results show that in the recent years, the overall water environment quality in China is improving, but the overall water environment quality is still not optimistic. Water resources are not only the basis for human survival and development, but also a strategic resource for the development of the national economy. According to the <<World Water Development Report 2018>> issued by the United Nations, the current global water demand is increasing at a rate of 1% per year. This demand will continue to increase, and my country's water resources are even scarcer, and the per capita consumption is only 1/4 of the global average. In the face of this situation, understanding the state and changing trends of my country's water resources and water environment, and putting forward targeted resource conservation and pollution control measures are of great significance to alleviating the problem of my country's water shortage.

Keywords: Water resource; water environment quality; changing trend; pollution discharge.

1. Water resources

1.1. Precipitation

According to the <<China Water Resources Bulletin (2009-2018) >>, the average annual precipitation in our country was 657.9 mm. The annual precipitation in 2010, 2012, 2013, and 2015-2018 were all higher than the average annual precipitation. It can be seen from Figure 1 that there is a large difference in annual precipitation in our country. Among them, 2011 was the year with the least precipitation, which was 582.3 mm, and 2016 was the year with the most precipitation, which was 730.0 mm, an increase of 25.4% over 2011. Which increased by 25.4% comparing to 2011.

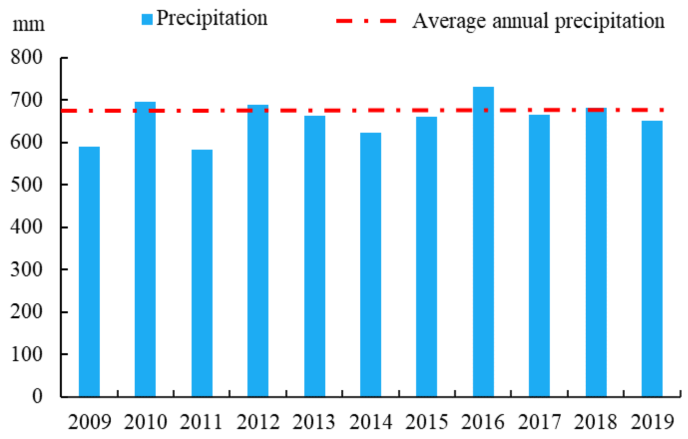

Fig 1. Changes trend of precipitation during 2009-2018.

1.2. Surface water resources

From 2009 to 2018, the average surface water resources amounted to 2688.57 billion m^3. The change trend of surface water resources is shown in Figure 2. It can be seen that the surface water resources exceeded the average surface water resources in 2010, 2012 and 2015-2017. As we can see, 2016 was the year with the largest amount of surface water resources, which was 312.739 billion m^3, the least year is 2011, which was 2221.36 billion m^3, there was a big inter-annual change.

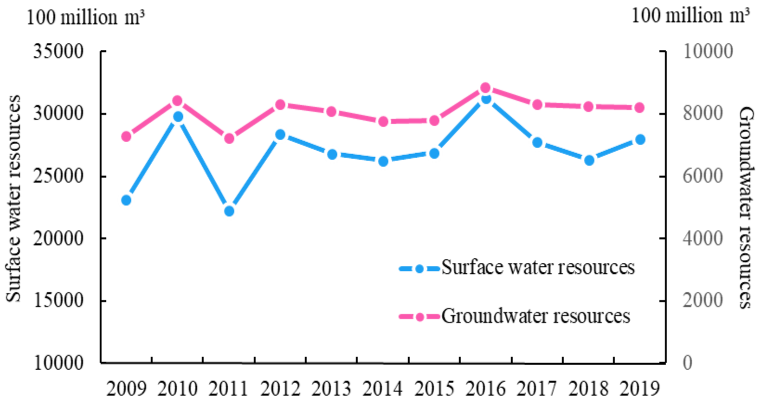

Fig 2. Changes trend of surface water and groundwater during 2009-2018.

1.3. Groundwater resources

In 2009-2018, the average groundwater resources were 802.29 billion m^3, The change trend of groundwater resources is shown in Figure 2. The groundwater resources in 2010, 2012, 2013 and 2016-2018 were higher than the average annual groundwater resources, and other years were lower than the average annual groundwater resources. The largest year of groundwater resources was 2016, which was 885.48 billion m^3, and the smallest year was 2011, which was 721.45 billion m^3. The change trend of groundwater resources was basically consistent with that of surface water resources, but the change range was less than that of surface water resources, mainly because surface water can be transformed into groundwater through soil infiltration, there was a dynamic transformation process between surface water and groundwater.

1.4. Total water resources

The total amount of water resources from 2009 to 2018 was shown in Table 1. The average annual total amount of water resources was 2797.5 billion m^3. The total amount of water resources in 2010, 2012, 2016 and 2017 were higher than the average annual total amount of water resources. The largest total amount of water resources was 3246.64 billion m^3 in 2016, and the least was 2325.67 billion m^3 in 2011. It can be seen that the total amount of water resources fluctuated greatly. At the same time, it was found that surface water resources, groundwater resources and total water resources are directly affected by precipitation and have a positive correlation, which provides us with a prediction method of water resources. We can find the model relationship between precipitation and water resources according to historical data and statistical software, and use meteorological data to predict water resources.

Table 1. Total water resources in China from 2009 to 2018 100 million m^3.

Year	Total water resources
2009	24180.2
2010	30906.4
2011	23256.7
2012	29528.8
2013	27957.9
2014	27266.9
2015	27962.6
2016	32466.4
2017	28761.2
2018	27462.5

2. Water environment

2.1. Water quality

According to the data of China's Ecological Environment Bulletin (2017-2019) and China's environmental Bulletin (2008-2016), the number of effective monitoring sections of the national surface water river monitoring network increased from 408 in 2009 to 1610 in 2019, mainly involving seven major water systems: the Yangtze River Basin, the Yellow River Basin, the Pearl River Basin, the Songhua River Basin, the Huaihe River Basin, the Haihe River Basin and the Liaohe River Basin [2]. From 2009 to 2019, the overall surface water rivers in China were slightly polluted, and the overall water quality improved significantly. The proportion of excellent water bodies increased year by year, and the proportion of the five bad water quality water bodies decreased year by year. As shown in Figure 3, the proportion of excellent water bodies increased from 57.3% in 2009 to 79.1% in 2019, it has an increase of 21.8%, and the proportion of the five bad water quality bodies decreased from 18.4% in 2009 to 3.0% in 2019, it has a decrease of 15.4%. In 2019, the main pollution indicators are chemical oxygen demand, permanganate index and ammonia nitrogen. There are different degrees of pollution in the Yellow River Basin, Songhua River Basin, Huaihe River Basin and Haihe River Basin.

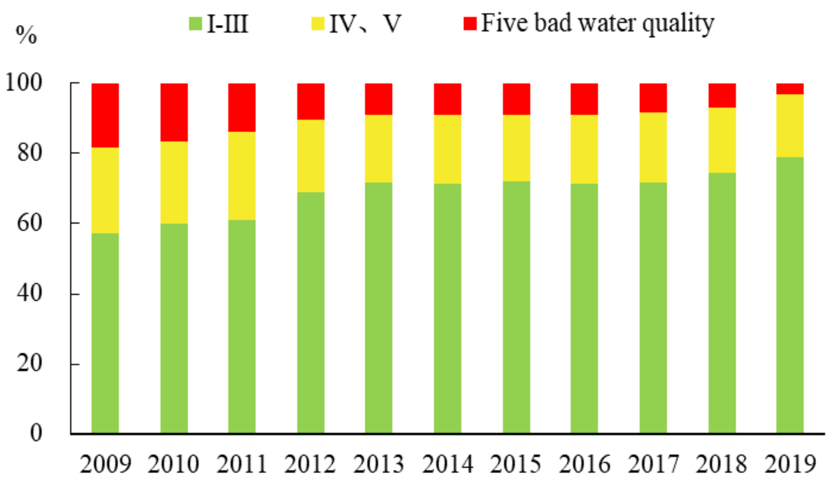

Fig 3. Changes of the overall water quality in rivers of china during 2009-2019.

2.2. Water quality of seven major water basin

2.2.1. Yangtze River Basin

The Yangtze River originates from the Qinghai Tibet Plateau, flows through Qinghai Province, Tibet Tibetan Autonomous Region, Sichuan Province, Yunnan Province, Chongqing, Hubei Province, Hunan Province, Anhui Province, Jiangsu Province and Shanghai, and enters the sea from the East China Sea. The drainage area of the Yangtze River Basin is more than 1.8 million km^2. The average rainfall is 1087 mm for many years, and the amount of water resources is 995.8 billion m^3, accounting for 35.9% of the country (data from 1956 to 2000) [3-4]. The number of effective state-controlled monitoring sections has increased from 103 in 2009 to 509 in 2019. The increase of monitoring sections improves the representativeness of monitoring data and can more comprehensively reflect the water quality situation. As shown in Figure 4, the overall river level in the Yangtze River Basin was excellent from 2009 to 2019, the proportion of excellent water bodies remained stable, and all exceeded 80%, the proportion of the five bad water quality bodies decreased from 3.9% in 2009 to 0.6% in 2019, it has a decrease of 3.3 percentage points.

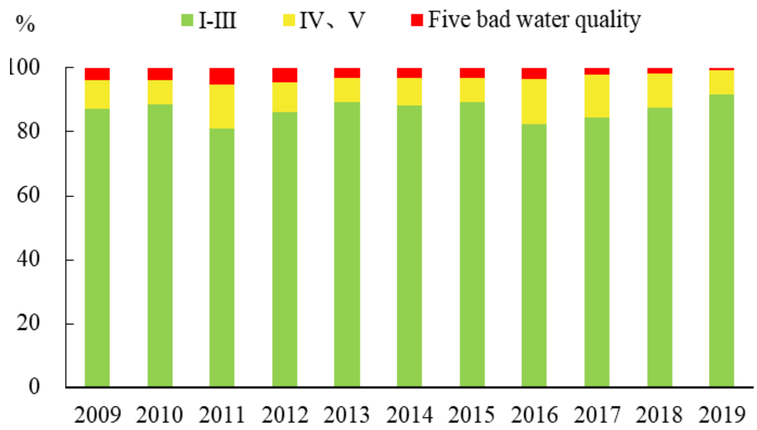

Fig 4. Changes of water quality in Yangtze River Basin during 2009-2019.

2.2.2. Yellow River Basin

The Yellow River originates from Bayankala Mountains, flows through Qinghai Province, Sichuan Province, Gansu Province, Ningxia Hui Autonomous Region, Inner Mongolia Autonomous Region, Shaanxi Province, Shanxi Province, Henan Province and Shandong Province, and flows into the Bohai Sea. The annual average rainfall was between 200-600mm and the annual natural runoff was 58 billion m^3 [5]. The number of effective state controlled monitoring sections in the Yellow River Basin increased from 44 in 2009 to 137 in 2019. The water quality of the Yellow River Basin has been continuously improved. Since 2011, the overall water quality has increased from moderate pollution to mild pollution, and has been continuously and stably maintained at mild pollution. As shown in Figure 5, the proportion of excellent water bodies was 73.0%, and the proportion of the five bad water quality bodies was 8.8% in 2019. The main pollution indicators were ammonia nitrogen, chemical oxygen demand and total phosphorus.

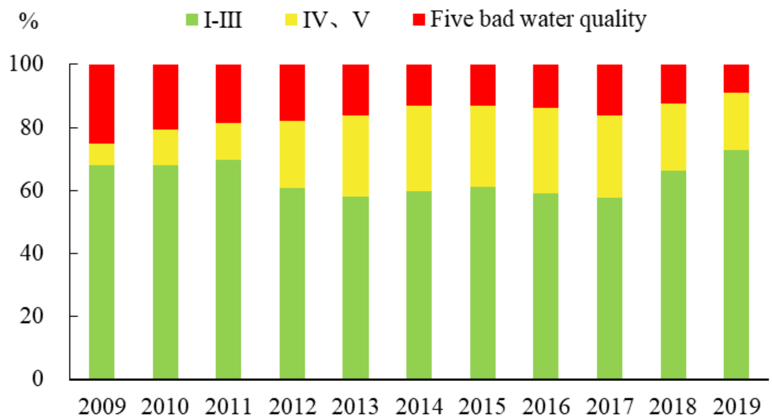

Fig 5. Changes of water quality in Yellow River Basin during 2009-2019.

2.2.3. Pearl River Basin

The Pearl River originates from Yunnan Guizhou Plateau, flows through Yunnan Province, Guizhou Province, Guangxi Zhuang Autonomous Region, Guangdong Province, Hunan Province and Jiangxi Province, and flows into the South China Sea. The annual average rainfall was 1200-2200 mm and the annual runoff is 330 billion m^3 [6]. The number of effective state-controlled monitoring sections increased from 33 in 2009 to 165 in 2019. As shown in Figure 6, from 2009 to 2019, the proportion of excellent water bodies remained above 80%, especially in 2012 to 2015, which reached more than 90%, and the water quality was excellent, and it was good in other years. In 2019, the proportion of excellent water bodies was 86.1%, Comparing 2009, there was an increase of 1.2 percentage points, and the proportion of the five bad water quality bodies was 10.9%, which has an increase of 7.9 percentage points compared with 2009. From 2015 to 2016, the water quality changed from excellent to good, which may be due to the increase of effective monitoring sections from 54 to 165, and the water quality of the new sections was poor.

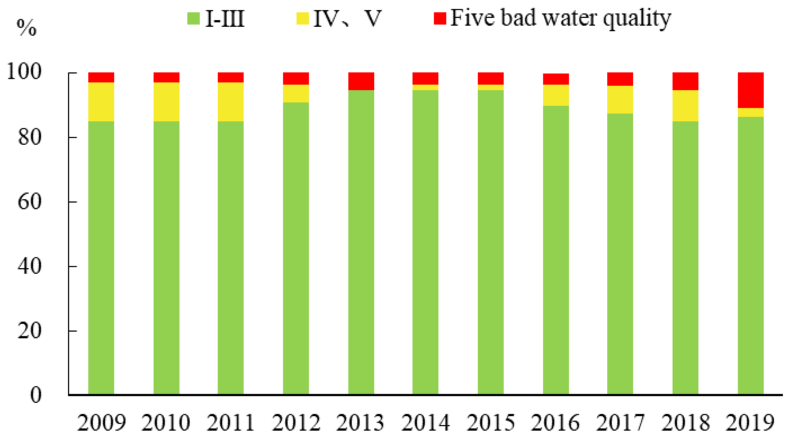

Fig 6. Changes of water quality in Pearl River Basin during 2009-2019.

2.2.4. Songhua River Basin

Songhua River is 1070 km long from north to South and 920 km wide from east to west. It flows through Inner Mongolia Autonomous Region, Jilin Province and Heilongjiang Province, with a drainage area of 556800 km^2 and an average annual rainfall of about 500 mm [7-8]. The number of effective state-controlled monitoring sections increased from 42 in 2009 to 107 in 2019. The water quality in Songhua River Basin was slightly polluted from 2009 to 2019. As shown in Figure 7, the proportion of excellent water bodies in Songhua River Basin was 40.5%, and the proportion of the five bad water quality bodies was 9.5% in 2009. The main pollution indicators were permanganate index, petroleum and ammonia nitrogen. By 2019, the proportion of excellent water bodies was 66.4%, and the proportion of the five bad water quality bodies was 2.8%. The main pollution indicators were chemical oxygen demand, permanganate index and ammonia nitrogen. The proportion of excellent water bodies increased by 25.9 percentage point, while the proportion of the five bad water quality bodies decreased by 6.7 percentage points compared with 2009. The overall water quality was improving.

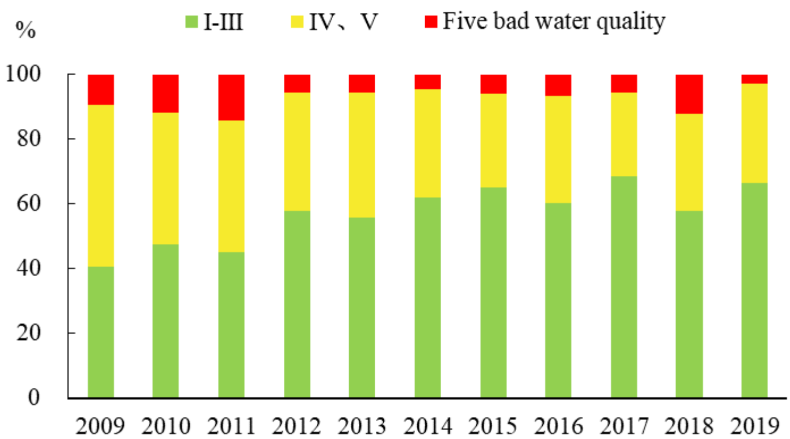

Fig 7. Changes of water quality in Songhua River Basin during 2009-2019.

2.2.5. Huaihe River Basin

The Huaihe River basin covers an area of 270000 km^2 and flows through Henan Province, Anhui Province, Jiangsu Province and Shandong Province, the annual average runoff is 62.1 billion m^3 [9-10]. The number of effective state-controlled monitoring sections increased from 86 in 2009 to 179 in 2019. The water quality in the Huaihe River Basin was slightly polluted from 2009 to 2019. As shown in Figure 8, the proportion of excellent water bodies was 37.3%, and the five bad water quality bodies was 17.4% in 2009. The main pollution indicators were permanganate index, five-day biochemical oxygen demand and petroleum. By 2019, the proportion of excellent water bodiesand the five bad water quality bodies were 63.7% and 0.6% respectively. The main pollution indicators were chemical oxygen demand Permanganate index and fluoride, the proportion of excellent water bodies increased by 26.4 percentage points, and the proportion of the five bad water quality bodies decreased by 16.8 percentage points compared with 2009. The overall water quality of Huaihe River Basin shows an improvement trend.

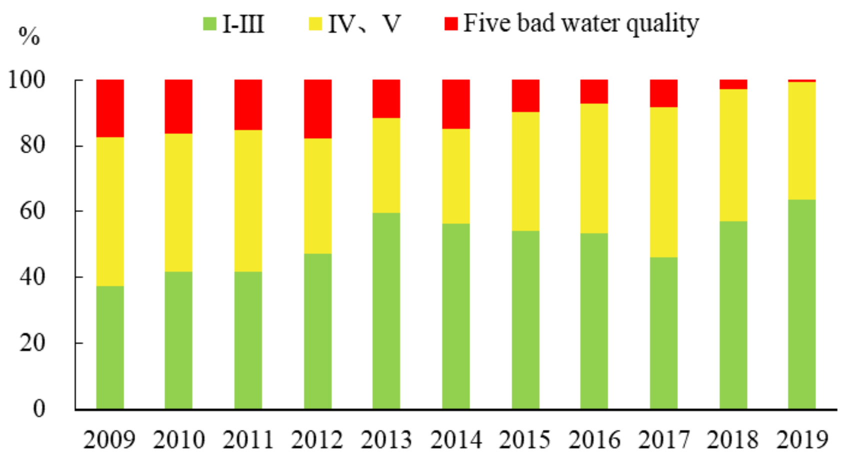

Fig 8. Changes of water quality in Huaihe River Basin during 2009-2019.

2.2.6. Haihe River Basin

Haihe River Basin crosses Beijing, Tianjin, Hebei, Shanxi, Henan, Shandong, Liaoning and Inner Mongolia Autonomous Region. The basin area is 318000 km^2 and the annual average rainfall is 539 mm [11]. The number of effective state-controlled monitoring sections increased from 64 in 2009 to 160 in 2019. The water quality showed an overall improvement trend, but the pollution situation was still serious. There was severe pollution in 2009, 2010 and 2016, and the proportion of the five bad water quality bodies exceeded 40%. The pollution indicators were mainly permanganate index, five-day biochemical oxygen demand and ammonia nitrogen, and it was moderate pollution in other years. As shown in Figure 9, the proportion of excellent water bodies was 51.9%, and the proportion of the five bad water quality bodies was 7.5% in 2019. The main pollution indicators were chemical oxygen demand, permanganate index and five-day biochemical oxygen demand. The proportion of excellent water bodies increased by 17.5 percentage points, at the same time the proportion of the five bad water quality bodies decreased by 34.7 percentage points compared with 2009. The water environment quality was significantly improved.

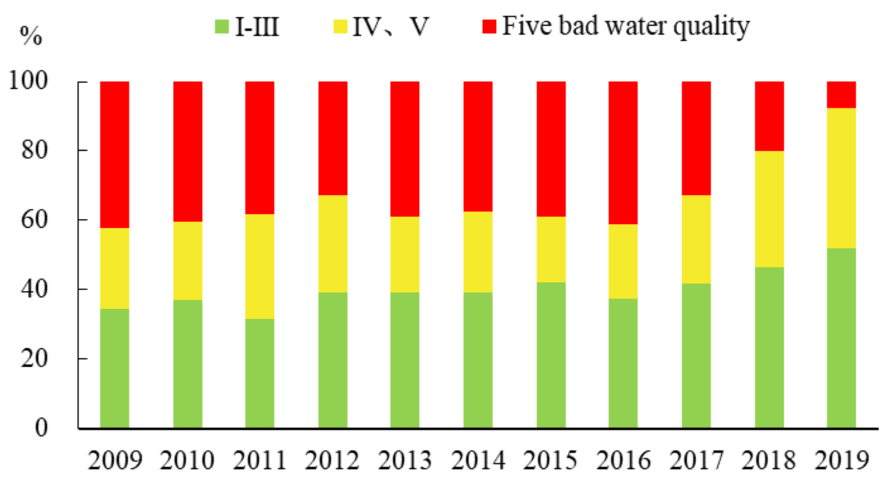

Fig 9. Changes of water quality in Haihe River Basin during 2009-2019.

2.2.7. Liaohe River Basin

Liaohe River Basin is located in the south of Northeast China, involving Jilin Province, Liaoning Province, Hebei Province and Inner Mongolia Autonomous Region. The basin area is 219000 km^2 and the annual precipitation is 350-1000 mm. [12]. The number of effective state-controlled monitoring sections increased from 36 in 2009 to 103 in 2019. From 2009 to 2018, the proportion of excellent water bodies was relatively stable, fluctuating between 40. 0% to 60. 0% the proportion of the five bad water quality bodies changed greatly, showing an n-type change. There was a difference of 30.7 percentage points in 2009 and 2013. It was moderately polluted in 2009, 2010 and 2018, and mild pollution in other years. As shown in Figure 10, the water quality improved greatly, the proportion of excellent water body was 56.3%, and the proportion of the five bad water quality bodies was 8.7% in 2019. The main pollution indicators were chemical oxygen demand, permanganate index and five-day biochemical oxygen demand. The proportion of excellent water body increased by 14.6 percentage points, while the proportion of the five bad water quality bodies decreased by 27.4 percentage points compared with 2009.

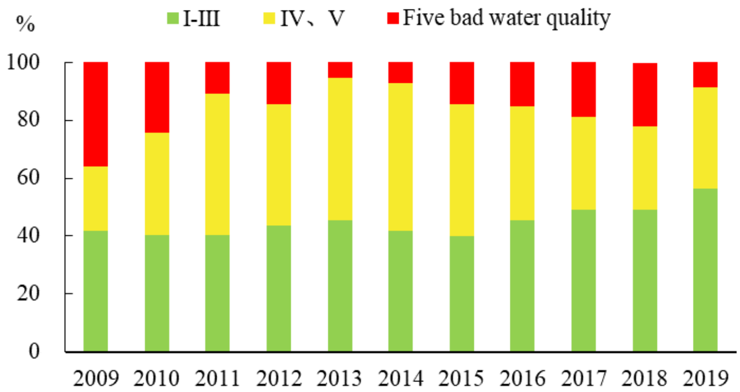

Fig 10. Changes of water quality in Liaohe River Basin during 2009-2019.

3. Contaminants

According to the data of the National Environmental Statistics Yearbook (2008-2017), the wastewater discharge showed an increasing trend year by year from 2009 to 2015. As shown in Figure 11, the wastewater discharge was the largest in 2015, with 73.53 billion tons, the fastest growth rate of 5.6% in 2011. From 2016 to 2017, the wastewater discharge decreased, with 71.11 billion tons and 69.97 billion tons respectively. Compared with the previous year, it decreased by 3.3% and 1.6% respectively. Due to the full implementation of the water pollution prevention and control action plan, the wastewater discharge decreased for the first time in 2016. The water pollution control has achieved certain results, and the wastewater discharge has decreased.

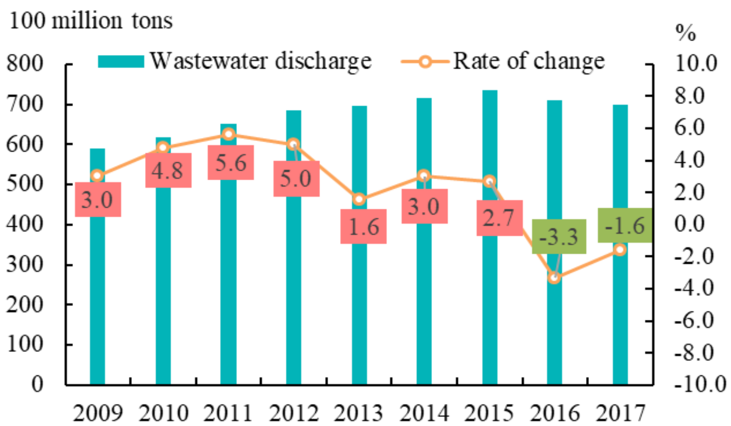

Fig 11. Discharged and changes of total waste water during 2009-2017.

As shown in Figure 12, the interannual variation trend of chemical oxygen demand and ammonia nitrogen is basically the same. From 2009 to 2017, the emission of chemical oxygen demand and ammonia nitrogen increased sharply in 2011, which were 24999.9 and 2604000 tons respectively. By comparing the growth rate of 5.6% of wastewater discharge in 2011, it can be seen that the increase of pollutant discharge was related to the increase of wastewater discharge. At the same time, the statistics of chemical oxygen demand and ammonia nitrogen before 2011 were the emissions of industry and life. After 2011, agriculture and centralized emissions were added, which was also one of the important reasons for the surge of chemical oxygen demand and ammonia nitrogen emissions. The emissions of chemical oxygen demand and ammonia nitrogen showed a declining trend year by year from 2011 to 2017. In 2017, the emissions of chemical oxygen demand and ammonia nitrogen were 10.22 million and 1.395 million tons respectively, they decreased of 20.0% and 13.8% respectively compared with 2009. In 2017, the discharge of wastewater increased by 18.6% compared with 2009. It can be seen that the concentration of discharged wastewater was lower than 2009.

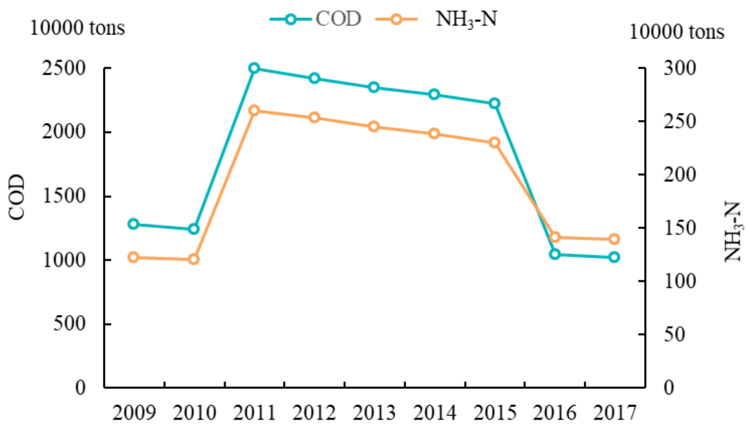

Fig 12. Interannual variability of the COD and NH_3-N during 2009-2017.

4. Conclusion

(1) The average annual precipitation was 657.9 mm, the average annual amount of surface water resources was 2688.57 billion m^3, the average annual amount of groundwater resources was 802.29 billion m^3, and the total annual amount of water resources was 2797.5 billion m^3 from 2009 to 2018, it has a great interannual change.

(2) From 2009 to 2018, the overall surface water rivers in China were slightly polluted, and in 2019, the overall water quality was improved significantly. The proportion of excellent water bodies increased year by year, and the proportion of the five bad water quality bodies decreased year by year. In 2019, the proportion of excellent water bodies was 79.1%, which increased of 21.8 percentage points compared with 2009, and the proportion of the five bad water quality bodies was 3.0%, a decrease of 15.4 percentage points compared with 2009, The water environment quality showed an overall improvement trend.

(3) From 2009 to 2019, the water quality of the Yangtze River system and the Pearl River system was good or above, and the other five major water systems were polluted to varying degrees. The Haihe River system was the most polluted. In recent 11 years, there were three years of severe pollution, seven years of moderate pollution and one time of mild pollution. The water pollution situation needs to be improved.

(4) With the increase of investment in pollution control and the development of treatment technology, wastewater discharge has decreased year by year since 2016. In 2017, wastewater discharge was 69.97 billion tons, down 1.6 percentage points from 2016. From 2011 to 2017, chemical oxygen demand and ammonia nitrogen discharge also showed a downward trend year by

year. The emissions of chemical oxygen demand and ammonia nitrogen were 10.22 million tons and 1.395 million tons in 2017 respectively, and the overall pollutant status showed a decreasing trend.

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