

Influence factors analysis of water environmental quality of main rivers in Tianjin

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Abstract. According to the evaluation results of the water environment quality of main rivers in Tianjin in 1986-2015, this paper analyzed the current situation of water environmental quality of main rivers in Tianjin retrospectively, established the index system and multiple factors analysis through selecting factors influencing the water environmental quality of main rivers from the economy, industry and nature aspects with the combination method of principal component analysis and linear regression. The results showed that water consumption, sewage discharge and water resources were the main factors influencing the pollution of main rivers. Therefore, optimizing the utilization of water resources, improving utilization efficiency and reducing effluent discharge are important measures to reduce the pollution of surface water environment.

1. Introduction

Located in the downstream of Haihe basin, Tianjin is a confluence and estuary of Haihe's five major tributaries, including south canal, north canal, Ziya river, Daqing river and Yongding river, and it is known as "the lower tip of the nine river" and "major crossroad between river and sea". With the rapid increase of population and rapid development of social economy, the water environment quality of main rivers in Tianjin is deteriorating and the water environment is very fragile. By studying the quality and influencing factors of water environment in main rivers and regulating the influence factors, it is of great significance to the environmental protection of Tianjin and to realize a balanced environment and economy development.

2. Water environment quality of main rivers in Tianjin

There are 19 class-1 river courses flow through Tianjin with total length of 1095.1 km, and 79 class-2 river courses with total length of 1363.4 km. According to the environmental monitoring data, this study selected the main rivers with continuous monitoring from 1986 to 2015, and adopted characteristic index of "proportion of main river severely polluted(%)(PMRSP) = number of rivers severely polluted / number of rivers with monitoring data × 100%".

During the 30 years between 1986 and 2015, water quality of main rivers in Tianjin is relatively poor, as majority rivers can not even reach the surface water standard Grade V and most rivers are heavily polluted. The highest PMRSP had reached over 80%. In particular, water quality had deteriorated rapidly since 1995, with PMRSP rose from 12.5% in 1986 to 88.9% in 2002. After 2003, with water



environment management project such as clean-water project, the main river water quality showed a trend of rapid improvement, PMRSP went down to 30% - 40% and present a trend of fluctuation change. Spearman rank correlation coefficient method was used to check the change tendency of the main rivers severely polluted in Tianjin. The results showed that under the significant level of $\alpha = 0.01$, rank correlation coefficient $R_s = 0.648 >$ the critical value of 0.432. The data indicate the main rivers pollution condition in Tianjin showed a trend of significant deterioration between 1986 and 2015[1].

3. Analysis method and result

3.1. Analysis method

There are a variety of factors influencing the quality of the environment, including the social and economic development, natural geographical conditions, resource utilization, etc., the influence of these factors on the quality of the environment is often cross-connected, positive or negative. In order to study the influence of social, economic, scientific and technological development on environmental quality, this paper converts it into mathematic questions. Namely, for environmental quality index y_1, y_2, \dots , select the social, economic and other factors x_1, x_2, \dots that are relevant to y_i , and find out the relationship between environmental quality index y_i and the influencing factors x_1, x_2, \dots according to the data of previous years. This research adopted the combination method of principal component analysis and linear regression, based on a total of 30 years' statistical data between 1986 and 2015, and found out the key factors affecting the water environment quality of main rivers in Tianjin [2-4].

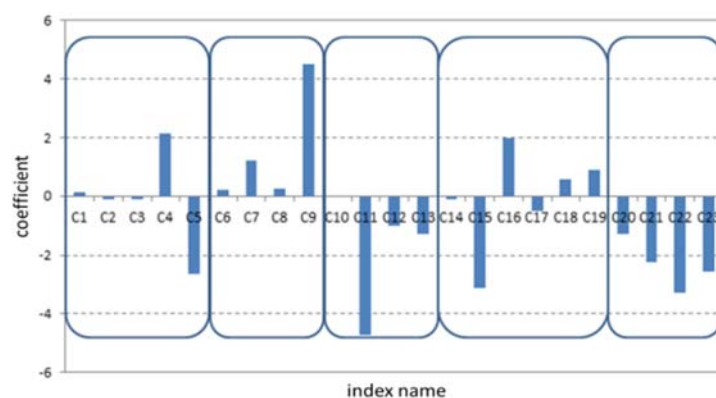
General ideas and steps: (1) Prepare data: determine the PMRSP as the environmental quality indicatory, and select a group of variables that are closely related to it (such as a proportion of industry to total GDP, resident population, etc.) x_1, x_2, \dots and find the data of these variables over the years. (2) Fill in the data: due to the absence of data, the missing value was filled by the linear trend method. (3) Standardization: the filled data will be standardized, making it so that all data will be a series of no dimensionless number with mean values of zero and variance of one. (4) Principal component dimension reduction: using the method of principal component analysis to reduce dimension of variables, get several unrelated principal component unrelated and which can represent more than 85% of the original data information through linear combination of the original data. Supposing extracted n principal components are extracted, the coefficient of the variable x_i to the principal component f_j is a_{ij} . (5) Linear regression: using linear regression method to find the relationship between the variable y and the extracted n principal components: $y = b_1f_1 + b_2f_2 \dots b_nf_n + b_0$ (6) Calculated the final coefficient: $w_i = b_1a_{i1} + b_2a_{i2} \dots + b_na_{in}$ as the function coefficient of the variable x_i for environmental indicatory.

3.2. Influencing factors analysis index system

Selected 23 representative indicators from 5 aspects such as the economic development, social development, resource utilization, pollution control and natural factors, established influencing factors analysis index system (table 1), and conducted analysis of influence factors. The results of the analysis are shown in figure 1.

Table 1. Influencing factors index system of water environmental quality.

index classification	serial number	index name	index classification	serial number	index name
economic development	C1	GDP	pollution control	C14	industrial waste water discharged
	C2	total industrial output value		C15	municipal sewage discharge
	C3	fixed assets investment volume		C16	standard-meeting rate of industrial wastewaters
	C4	GDP proportion of tertiary industry		C17	sewage treatment capacity
	C5	GDP proportion of industry		C18	urban sewage treatment rate
social development	C6	permanent resident population	natural factors	C19	Investment in wastewater treatment
	C7	urbanization rate		C20	amount of precipitation
	C8	construction land area		C21	spontaneous runoff
resource utilization	C9	daily water consumption per capita		C22	surface water resources
	C10	industrial water consumption		C23	influx
	C11	Industrial fresh water consumption			
	C12	water consumption for every 10 thousand yuan worth of industrial value added			
	C13	fresh water consumption for every 10 thousand yuan worth of industrial value added			

**Figure 1.** The multi influence factors analysis result on the PMRSP.

4. Result analysis

It could be seen from figure 1 that, the top ten factors influencing the quality of water environment in the main rivers : industrial fresh water consumption (C11), daily water consumption per capita (C9), surface water resources (C22), municipal sewage discharge (C15), GDP proportion of industry (C5), influx (C23), spontaneous runoff (C21), GDP proportion of tertiary industry (C4), discharge standard-meeting rate of industrial wastewaters (C16) and fresh water consumption for every 10 thousand yuan worth of industrial value added (C13), the distribution was even in 5 aspects. Considering the actual situation:

(1) Economic development and resource utilization

From the analysis results, the industrial structure had great influence on the water environment quality of main rivers. As an old industrial base, the scale and proportion of Tianjin's heavy chemical industry is large, with high water consumption and high emission, such as metallurgy and chemical industry. It has a serious impact on the water environment quality of main rivers. At the same time, from the perspective of historical development, the proportion had risen rapidly since 1995, and the impact of pollution of township industrial enterprises could not be ignored. In the end of 1995, there were ten thousand township industrial enterprises in the whole city, and the annual output accounted for 40% of the city's industrial output value. However, due to the large number of waste water discharge points and wide distribution, low treatment rate and no proper discharge way, more than 80 percent waste water was directly discharged into farmland or nearby ditches and pits, causing large area of farmland and water pollution, caused serious damage to the main river water environment.

Although the influence coefficient of GDP index on ratio of main rivers severely polluted in the analysis result was small, the impact of economic development on the water environment quality of main river could not be ignored. Judging from the relative change trend of GDP and main rivers polluted proportion alone, from 1995 to 2001, with the increase of economic aggregation, the proportion was rapidly rising, water quality deterioration even went faster than GDP growth; after 2002, with the increase of economic aggregation, the proportion presented a tendency of ladder-like decreasing, and the improvement rate of water quality was basically in line with the trend of GDP growth. This was because of Tianjin's intensified efforts to implement water environmental governance, especially green-water project in model construction, water project in ecological city construction, the main pollutant emissions reduction, and sewage treatment facilities construction, etc.

It also could be seen from the relative relationship between ratio of main rivers serious polluted and GDP per capita (figure 2), with the growth of the GDP per capita, ratio of main rivers serious polluted showed a change trend of "inverted U". In some sense, at the moment, the serious pollution degree of main rivers in Tianjin was in line with the trend of environmental Kuznets curve, that is to say the water environmental quality deteriorated with the economic development in accumulated stage of economic development. Then efforts to the protection of the environment increase when economic development reached a certain extent, and water environmental quality would improve gradually as the economy continues developing. For Tianjin, this turning point happened in GDP per capita reached 35000-40000 yuan, between 2004 and 2005. Tianjin was in the peak stage of model construction, water environmental management was more powerful, and water environmental treatment improved obviously.

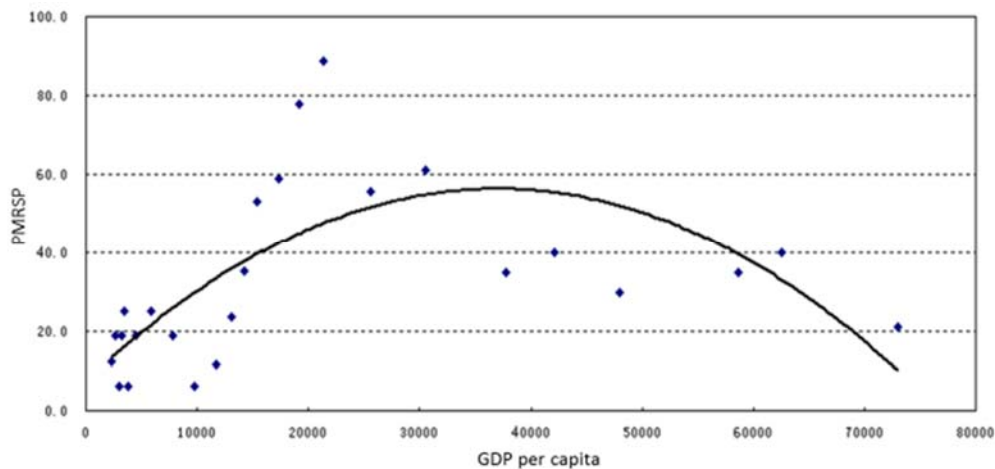


Figure 2. The relationship schematic between the PMRSP and GDP per capita.

(2) Social development and pollution control

The effect of urbanization on water environment was remarkable. The expansion of city size and population size will inevitably lead to greater quantity of sewage and increase the pressure of surface water environment. From relationship between the ratio of main river serious polluted and urban construction area and sewage treatment capacity, after 2000, the city scale expanded rapidly, the area greatly increased, and water environment quality of main rivers was deteriorating. But the urbanization process also improved the treatment level of waste water, thus reducing the actual discharge of sewage and pollutant discharge. After 2003, although the size of the city continued to increase, the construction of urban sewage treatment facilities entered the stage of rapid development, and the capacity of sewage treatment was greatly improved. Since 2007, Tianjin had initiated the construction of 34 urban sewage treatment plants, and expanded water collection area of the central urban sewage treatment works. By 2015, the capacity of municipal sewage treatment plants reached 2.8 million tons/day, the urban sewage treatment rate reached 91.6 percent, and the water quality of main rivers improved significantly.

(3) Natural factors

Water environment has the function of self-purification under the natural conditions of sufficient surface water resources. The river can be fully hydrated while water flows. The amount of surface water resources depends on the spontaneous runoff and the inflow of water brought by natural precipitation. In recent decades, with the increase of upstream population, economic development, water consumption, a large number of water conservancy project constructions, the amount of incoming water to Tianjin is decreasing year by year, from 8 billion cubic meters in the 1960s to more than 2 billion cubic meters now. Coupled with successive years of climate drought, the water shortage in Tianjin is very serious. In 1972, 1973, 1975, 1981 and 1982, Tianjin adopted Diversion Yellow River water to Tianjin for five times to solve the urban water supply crisis. After Water Diversion Project from Luanhe River to Tianjin in 2000, due to the continuous drought in 1997-2000, it was forced to conduct Diversion Yellow River water to Tianjin again. Tianjin was faced with a serious water crisis in 2002 and desperately needed the support of external water sources. But the entire north China region continues to dry, and the Yellow River itself is not enough. The maintaining of industrial and agricultural production relies heavily on groundwater, causing severe subsidence on the ground in Tianjin. The shortage of water resources has become an obstacle to the development of Tianjin's social-economic development, let alone ecological water supply to ensure the health of the water environment. The ecological water supply gap is larger. According to the preliminary calculation, there are about 800 million cubic meters of ecological water gap in the city, and the water quality cannot be changed without water input.

5. Conclusion

In summary, the influence of water environmental quality of the main river in Tianjin is various and in many fields. Heavy industrial structure, urbanization process, pollution control measures such as sewage treatment, self-produced runoff and water inflow and other influence jointly caused surface water environment situations and trends of main rivers in Tianjin. Therefore, it can be seen that optimizing industrial structure, transforming the development mode, improving the capacity of sewage treatment and increasing the ecological water use in multiple ways are important measures to improve the environmental pollution of main rivers.

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