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# Analysis of environmental carrying capacity of Beijing-Hangzhou grand canal basin in Zhejiang Province

Zhenhua Peng, Kaiping Xu, Qiannan Jin, Lei Fu

Zhejiang Institute of Hydraulics & Estuary, Hangzhou, Zhejiang, 310020, China

\*Corresponding author's e-mail: bachzh@126.com

**Abstract.** The harnessing and protection of water environment is critical in the comprehensive treatment of the Beijing-Hangzhou grand canal. Zhejiang section of the canal is located in the Hangjiahu plain, and some parts of the canal are still difficult to reach the water quality requirement. Therefore, it is necessary to investigate and analysis the pollutant discharge and water environment capacity. This paper evaluates the current situation of water environment carrying capacity of grand canal in Zhejiang Province, and puts forward pollution control Strategies. Suggestions are also made based on existing problems.

## 1. Introduction

The Beijing-Hangzhou grand canal is one of the oldest and longest canals in the world. It was listed in the world heritage content in 2014. The grand canal is about 193km long in Zhejiang Province. The canal system covers most of the Hangjiahu plain. The harnessing and protection of water environment is critical in the comprehensive treatment of the grand canal, however, the canal water was once seriously polluted due to the severe district pollutant discharge. In recent years, by fully implementing various pollution control measures, the canal water quality has been greatly improved, but some parts of the canal are still difficult to reach the water quality requirement. The water quality of canal are III~IV class. Therefore, it is necessary to investigate and analysis the pollutant discharge and water environment capacity. This paper evaluates the current situation of water environment carrying capacity of grand canal in Zhejiang Province, and puts forward pollution control Strategies. Suggestions are also made based on existing problems.

## 2. Rrange of the basin

The Beijing-Hangzhou grand canal starts from the Sanbao gate in Hangzhou, flows across the Hangzhou urban area with separating to east and west routes in Yuhang, and re-unites into one canal in Jiangsu province. The eastern route is now called "Beijing-Hangzhou ancient canal" and the western route is now called "Beijing-Hangzhou canal". The section of the Beijing-Hangzhou canal in Zhejiang Province is located in the Hangjiahu plain, where flow direction of rivers is complex and variable. Hence, it is difficult to declare the basin boundaries. According to the water flow direction and current situation of water diversion and distribution in Hangjiahu river network, the approximate basin scope can be determined, which was extended to the administrative boundaries of towns. The basin control scope was determined, as shown in Figure 1.



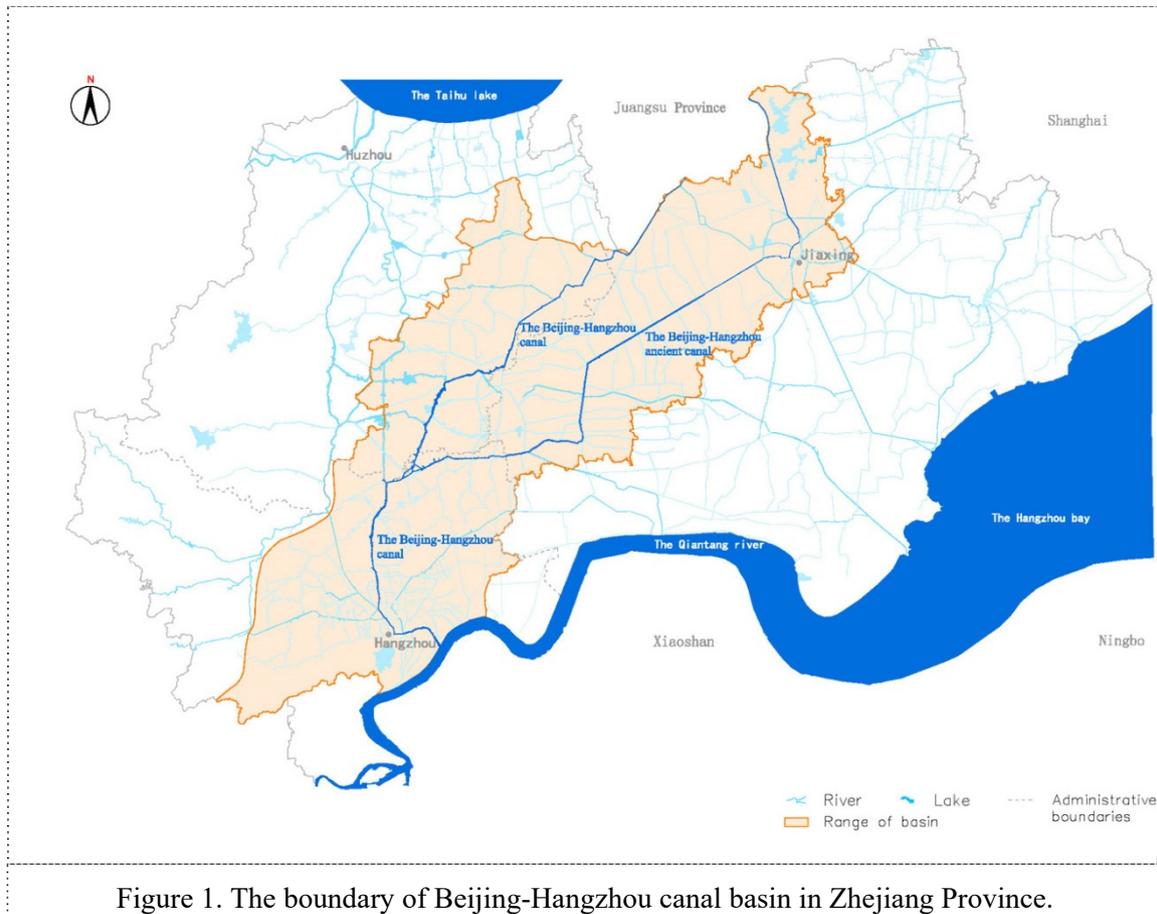


Figure 1. The boundary of Beijing-Hangzhou canal basin in Zhejiang Province.

The Beijing-Hangzhou canal basin covers most of urban area of Hangzhou, the west lake scenic area, the southeast area of Huzhou city, most of urban area of Jiaxing city and most areas of Tongxiang city. The total area of the canal basin is about 2,700 square kilometers. It is also noted that the surface runoff of the Biejing-Hangzhou canal not only comes from precipitation in the basin, but also from the water diversion from Qiantang river.

### 3. Analysis of water environmental capacity

The analysis sections composed of Hangzhou downtown section, Yuhang-Huzhou-Tongxiang section and Jiaxing downtown section. While the chemical oxygen demand(COD) and ammonia nitrogen( $\text{NH}_3\text{-N}$ ) are selected as analysis indices according to the requirement of the 13th five-year plan for environmental protection.

#### 3.1. Calculation methods and parameters

The calculation area is located in the plain river network area. Some rivers have long-sequence flow data, so the one-dimensional model for river is used to calculate the water environmental capacity according to the measured data. Some rivers do not have measured flow data, so the zero dimensional model for plain river network is used to calculate according to the measured water level data.

The formula for the one-dimensional model is given as,

$$W = 31.536 \times B \times (C_s - C_0 \times e^{-KL/u}) \times \frac{QKL}{(1-e^{-KL/u}) \times u} \quad (1)$$

The formula for the zero dimensional model is given as,

$$W = 31.536 \times K \times V \times C_s \times B \quad (2)$$

Where  $W$  is environmental capacity, t/a;  $V$  is river storage under the designed water level,  $m^3$ ;  $K$  is pollutant degradation coefficient, 1/s;  $C_s$  is the concentration of pollutants specified in water quality standards, mg/L;  $C_0$  is pollutant concentration at the beginning of the section of river, mg/L;  $L$  is length of the section of river, m;  $Q$  is the design discharge,  $m^3/s$ ;  $U$  is the design velocity, m/s;  $B$  is nonuniform coefficient.

Main parameters of water environmental capacity calculation is given as follows,

- Design hydrological conditions: According to relevant regulations, 90% guarantee rate of the lowest average monthly flow (water level) is used as the design hydrological conditions.
- Water quality target: The main stream of the Beijing-Hangzhou canal and the important tributaries in the water function area are required to reach the water quality target of the water function area.
- Pollutant degradation coefficient: According to the author's research results in Hangzhou and Jiaxing, pollutant degradation coefficient of COD and  $NH_3-N$  are 0.02~0.05 d-1.

### 3.2. The calculation results

According to the water quality target of the water functional area in the Beijing-Hangzhou canal basin, the calculation results of water environmental capacity in each section of the Beijing-Hangzhou canal are shown in the following table.

Table 1 Environmental capacity of Beijing-Hangzhou canal basin in Zhejiang Province.

	Name of the section	Environmental capacity (t/a)	
		COD	$NH_3-N$
1	Hangzhou downtown section	12408	748
2	Yuhang - Huzhou - Tongxiang section	35310	2283
3	Jiaxing downtown section	16342	919
	Total	64060	3950

According to the calculation results, under the condition of 90% guarantee rate of the lowest monthly average flow (water level), the environmental capacity of the Beijing-Hangzhou canal basin in Zhejiang Province is: chemical oxygen demand 64060t/a, ammonia nitrogen 3950t/a.

## 4. Pollution Sources investigation

Corresponding to the analysis of water environmental capacity, the Beijing-Hangzhou canal in Zhejiang Province is also divided into three sections, namely Hangzhou downtown section, Yuhang-Huzhou-Tongxiang section and Jiaxing downtown section, for the purpose of pollution sources investigation and pollutant discharge calculation.

### 4.1. Town living pollution

In the basin of Zhejiang section of Beijing-Hangzhou canal, the economy is highly developed and the population is dense. The urban population (the population within the scope of urban drainage pipe network services) is more than 5 million, but the urban drainage infrastructure construction lags behind the social and economic development. The mixed flow of rainwater and sewage exists in residential areas and commercial districts. The problems in old urban areas, urban villages and suburban areas are prominent, and branch sewage pipes are not fully covered in some towns. In some areas, although most of the sewage has entered the sewage pipe in sunny days, the overflow sewage

beyond the pipe transportation capacity in rainy days will still pollute the river, resulting in a low sewage collection rate. In order to evaluate the discharge of urban sewage and pollutants, the sewage centralized treatment rate should be calculated. The calculation formula is given as,

$$\text{Sewage centralized treatment rate} = \frac{\text{The amount of sewage centrally treated}}{\text{The amount of sewage produced}} \quad (3)$$

In the formula, the amount of sewage centrally treated is the amount of treated sewage in the urban sewage treatment plant. Groundwater, rainwater and river water are often mixed in the sewage to the sewage treatment plant due to abundant rainfall in the canal basin and incomplete separation of rainwater and sewage. The actual amount of sewage is lower than the measured inflow. If this factor is not taken into account, the calculated sewage treatment rate will be higher than the actual value. Therefore, it is necessary to clarify the amount of non-sewage mixed in the urban sewage collection pipe network.

- Amount of groundwater infiltration: according to “Code of Urban Wastewater Engineering Planning (GB 50318-2017)”, the groundwater infiltration amount can be calculated as no less than 10% of the sewage amount; According to “Code for Design of Outdoor Wastewater Engineering (GB50014-2006)”, the amount of groundwater infiltration can be calculated according to 10-15% of the average daily total amount of domestic sewage and industrial wastewater. Referring to the results of related studies in and around the region [1,2], the amount of groundwater infiltration into the sewage pipe network in the canal basin can be calculated according to 10-20% of the sewage amount.

- Amount of mixed rainwater: referring to relevant research results [3,4,5], the annual amount of rainwater entering the sewage pipe can be calculated as 7.5%~10% of the amount of sewage in the areas with combined sewerage system and similar rainfall distribution rules in Hangjiahu plain. According to the distribution of area with combined sewerage system in the canal basin, the annual amount of rainwater entering sewage pipes is about 2~10% of the amount of sewage.

- Amount of river water infiltration: the height of some sewage pipes in the area is lower than the water level of the river, and the pipeline leakage causes the water to enter the sewage pipes. According to the daily inflow data of the sewage treatment plant and the measured data of river water level during the dredging period, the annual amount of river water infiltration into the sewage pipe network in the area is about 5-15% of the amount of sewage.

Generally, the amount of groundwater, rainwater and river water entering the sewage pipe network in the study area is about 17-40% of the amount of sewage. When calculating the amount centralized treatment of sewage, it is deducted from the inflow of urban sewage treatment plants. According to this method, the calculation results of urban sewage centralized treatment rate in major urban areas in the canal basin in 2017 are shown in the table below, and there are significant differences with the values in the yearbook.

Table 2 Urban sewage centralized treatment rate in major urban areas in the canal basin in 2017.

Areas	The calculated value	Values in the yearbook
Hangzhou downtown	85.1%	95.25%
Jiaxing downtown	70.9%	89.44%

#### 4.2. Rural domestic pollution

In the canal basin, the rural population is nearly 1 million, and the sewage treatment rate in rural areas is over 80%. The treatment modes include three types, such as municipal sewage pipe network, decentralized micro-power treatment stations and decentralized non-power treatment stations. More than 14,000 decentralized treatment stations have been built. The treatment standard is Class I-B of GB18918-2002 or local standard of Zhejiang Province (DB33 973-2015). However, problems are still existed, such as stations are widely distributed, which leads to the difficulty of daily supervision. The operation and maintenance of facilities are also difficult, and the treatment effect is poor in winter.

Some facilities need to be modified. The villagers have a weak sense of maintenance.

#### 4.3. Industrial pollution

The Zhejiang section of the Beijing-Hangzhou canal located in the Yangtze river delta region, where the private economy is developed. Traditional industries such as printing, dyeing, papermaking and chemical industry, as well as high water consumption industries account for a high proportion. The industrial waste water output reaches 130 million tons per year. Although most of the industrial sewage in the region has entered the sewage pipeline, and most of the treated tail water is discharged into the ocean, the overflow of sewage into the river is still embarrassing due to the fact of large amount of sewage and pollutant discharge and the incomplete separation of rainwater and sewage in some regions.

#### 4.4. Agricultural non-point source pollution

In the basin of Zhejiang section of the Beijing-Hangzhou canal, the cultivated land covers an area of 130,000 hectares, where crops includes rice, cotton and rape, etc. The aquaculture industry is also developed. The main livestock and poultry breeding species are pigs, with an annual stock of about 140,000. Ecological management have been implemented in most of livestock and poultry farms.

#### 4.5. Analysis of pollutant discharge and environmental carrying capacity

Corresponding to the analysis of water environmental capacity, the Beijing-Hangzhou canal in Zhejiang Province is also divided into three sections (Hangzhou downtown section, Yuhang-Huzhou-Tongxiang section and Jiaxing downtown section), for the purpose of pollution source investigation and pollutant discharge calculation.

According to the investigation of pollution sources and various basic data, the pollutant discharge amount of the canal basin in 2017 is calculated, and the comparison between the calculated pollutant discharge and the environmental capacity is shown in table 3 and table 4.

Table 3 Comparison of COD emission and environmental capacity in the canal basin.

Name of the section	COD Emission (t/a)					Environmental Capacity (t/a)	Amount to be reduced (t/a)
	Town living pollution	Rural domestic pollution	Industrial pollution	Agricultural pollution	Total		
1 Hangzhou downtown section	12320	403	182	548	13452	12408	1045
2 Yuhang-Huzhou-Tongxiang section	18644	5007	4053	11808	39512	35310	4202
3 Jiaxing downtown section	11164	612	5090	1768	18633	16342	2292
Total	42128	6022	9325	14124	71598	64060	7538

Table 4 Comparison of NH<sub>3</sub>-N emission and environmental capacity in the canal basin.

Name of the section	NH <sub>3</sub> -N emission (t/a)					Environmental Capacity (t/a)	Amount to be reduced (t/a)
	Town living pollution	Rural domestic pollution	Industrial pollution	Agricultural pollution	Total		

1	Hangzhou downtown section	1417	78	14	42	1551	748	803
2	Yuhang-Huzhou-Tongxiang section	2108	977	335	651	4071	2283	1788
3	Jiaxing downtown section	1325	132	245	132	1834	919	915
Total		4850	1187	594	825	7456	3950	3506

The proportion of pollutants discharged by various pollution sources is shown in the figure below.

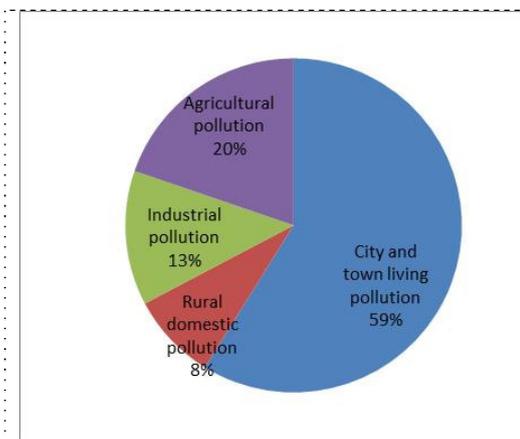


Figure 2. The proportion of COD emission by various pollution sources.

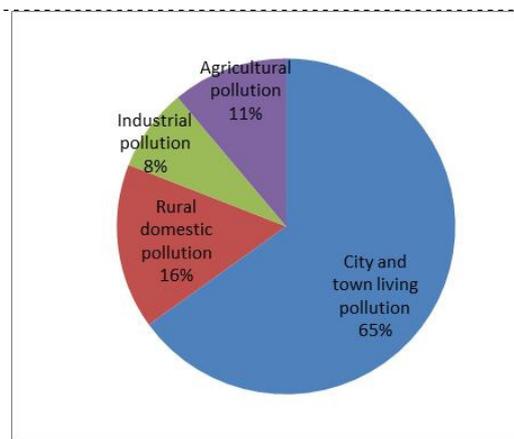


Figure 3. The proportion of NH<sub>3</sub>-N emission by various pollution sources.

According to the above calculation results, it can be seen that:

First, in the basin of Zhejiang section of the Beijing-Hangzhou canal, the total discharge of chemical oxygen demand and ammonia nitrogen has exceeded the environmental capacity under the designed conditions (dry season), between which the ammonia nitrogen emission exceeds by a large margin. Although the average pollutant concentration of most monitoring points in Zhejiang section of the canal has reached the water quality requirement in 2017, the water quality will still be unsatisfactory during the dry season if the pollutant discharge is not further reduced.

Second, among all kinds of pollution sources, city and town living pollutant discharge accounts for the largest proportion. The discharge of industrial pollutants is also large, but most of which goes into the sea, so the amount of industrial pollutant discharge into rivers is small. However, compared with domestic pollution, industrial pollution is more risky and difficult to control, so it should be focused.

Third, the key work of environmental protection for Zhejiang section of canal is the treatment of town living pollution and industrial pollution. Comprehensive prevention and control of other types of pollution sources should also be carried out.

### 5. Strategies and suggestions

Pollution control is critical in Beijing-Hangzhou canal water quality protection. Necessary measures include sewage collection, distribution of rainwater and sewage, strengthening environmental

supervision, etc. The following strategies are recommended.

First, strengthen water consumption control, reducing sewage discharge. Since the sewage treatment rate cannot reach 100% and the reduction degree of pollutants in the sewage treatment process is also limited, the key to reduce the total discharge of pollutants in the basin lies in controlling and reducing the output and discharge of sewage. Specific methods include: eliminating backward process, strengthening water quota management in high-water consumption industries, strengthening water-saving and reducing industrial sewage discharge; Optimize the distribution of labor-intensive industries, control the amount of the population, reduce the amount of domestic sewage, and improve the wastewater reuse rate.

Second, strengthen the rainwater regulation. The water resources in Hangjiahu plain are unevenly distributed, and a large amount of rainwater resources are lost in the form of flood in flood season. On the one hand, rainwater regulation can greatly reduce the river pollution caused by the initial rainwater. On the other hand, the stored rainwater can be used to regulate the river flow, increase the environmental capacity in the dry season, and reduce the pollution of the river.

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