Research on water quality and pollution characteristics of a typical coastal plain river network

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Abstract: Pinghu City is a typical coastal city in Zhejiang Province. It has confronted many problems such as low velocity of the river network and poor quality of the water ecological environment. Water pollution has seriously affected the local social and economic development as well as the residential environment. In this study, the plain river network of Pinghu City is selected as an example to analyze the amount of various pollutants. Different types of pollutants are calculated based on the statistic data. The pollution characteristics of the coastal plain river network in Pinghu City is then collected and analyzed. This study will provide further treatment solutions for water pollution in cities with typical coastal plain river network in Zhejiang Province.

1. Introduction
The river network in the central urban area of Pinghu belongs to the Taihu Lake system. There are many rivers in this area and the river network becomes dense and complicated. Numbers of middle and small rivers fill the space and expand in an irregular network, while tidal bores also affect the flow characteristics of the river network in Pinghu City since it is close to the coastal area [1-3].

As an important city in the southeast coast of China, Pinghu City is recognized as one of the most developed coastal cities and its plain river network in Pinghu City is also highly developed and constructed [4,5]. However, due to the complex of the river network, the flow rates in most of the rivers in this city are small. Moreover, the drainage capacity and the self-purification ability of the river network are also weak. In order to enhance the regional flood control and drainage capacity, a certain number of dam pump stations and other hydraulic structures are built in the river network of the Pinghu urban area, which reduces the connectivity of the water body and also makes it easier for pollutants entering the river [6,7]. As a result, serious water environment problems will affect the river network in Pinghu City.

A total of 125 canals belong to the river network of Pinghu City, with a total length of 98.69km, including 11 municipal main rivers with a total length of 38.69km, 114 small and medium rivers with a length of 60km. There are two lakes in the central urban area, East Lake and Ming Lake. The water area of East Lake is 0.48km², and the water area of Ming Lake is 0.12 km². Figure 1 shows the spatial distribution of current water system and water quality in Pinghu City, in which the black canals have bad water quality and blue canals have good water quality.
2. Analysis of river network water pollution characteristics

2.1. Flow characteristics
Pinghu City is located in the large delta plain with high density of water net area, which obtained a high water surface rate. However, because of the process of urbanization gave rise to land filling and water occupation has appeared. It reduces the water storage capacity of the river network, and the water environment capacity and self-purification capacity of the river network are also decreased. Recently, the number of wastes in the central urban area accounts for about 50% of the small and medium sized canals. These stumps located at the end of the river network system, lead to a lower flow rate and worse water quality compared to the main rivers. In addition, artificial remediation projects are widely distributed in these rivers in the central urban area of Pinghu City. Some river slopes are constructed with mortar block stones or covered with ordinary concrete, which destroys the natural structure of the river and isolates the water and land connectivity. The ecological function of the embankment is also destroyed, the natural ecological restoration capacity of the rivers is reduced and the self-purification function of the water body is also declined.

2.2. River network water quality
Based on the water quality monitoring data from 2017 to 2018, including five indicators such as COD (Chemical Oxygen Demand), NH$_3$-N (Ammonia nitrogen), TP (Total phosphorus), pH, and SS(Suspended Solids), the water quality of the river network in Pinghu City is shown in Figure 1. It is confirmed that the main factor of inferior V water bodies in the central urban area is ammonia nitrogen. The distribution of inferior V water bodies in different communities in Pinghu City is also shown in Figure 2.

Water bodies of inferior V are concentrated in the north and middle of the flood control enclosure. Among them, there are 13 rivers distributed in the northern part of the flood control circle such as Songfeng Port, Beicheng River, Beizhang Bridge, etc. 15 rivers are distributed in the middle of the flood control circle such as Xiwangfen Port, Dongwangwen Port, Meiyuan Xincunbang, etc. While 4 rivers are distributed in the central zone of flood control circle such as Yangjiabang, Shiqiao Port, and Nanxiao Port.

Figure 1. Plain river network in Pinghu City.
2.3. *Analysis of current pollution sources*

The sources of pollution in Pinghu City include point sources, non-point sources, endogenous sources and import pollution, as shown in Figure 3. At present, all industrial pollution in the central city enters the sewage pipe network and is discharged into Hangzhou Bay after being treated by the wastewater plant. Therefore, the point source in Pinghu City can be recognized as residents' domestic sewage. Additionally, there is no farmland and livestock in the city, hence, the non-point source can be recognized as surface runoff erosion pollution. The endogenous source is the release of nutrients from the sediment of the rivers [5-8].

![](image)

**Figure 3.** Different types of pollution sources.

3. *Calculation of total amount of pollutants into river network*

3.1. *Point source pollution*

The point source pollution includes urban domestic sewage and pollutants in sewage produced by industries such as service industry and urban public industry. The amount of domestic sewage and pollutants entering the river is calculated as follows [5,8,9].

\[
W_p = W_{pp} (1 - \theta) \times \alpha_1
\]  

(1)

where \(W_p\) is the amount of domestic pollutants entering the river (t/a), \(W_{pp}\) is the amount of urban domestic pollutants generated. Based on previous studies, \(W_{pp} = 365 \times NC \times F \times 10\), where \(NC\) is the resident population in the central urban area, \(F\) is the source of urban life (g per/d), \(\theta\) is the sewage interception rate, which is taken as 0.6 in this study based on previous research. \(\alpha_1\) is the coefficient of pollutants entering the river, which is taken as 0.9 in this study based on previous research. The calculated total amount of pollutants into the river network in Pinghu City is shown in Table 1.
Table 1. Current annual amount of point source domestic pollutants entering the river (t/a).

| Zones                                | COD      | NH₃-N    | TP       |
|--------------------------------------|----------|----------|----------|
| Northern part of the flood control circle | 149.39   | 13.30    | 1.48     |
| Southern part of the flood control circle | 653.73   | 58.20    | 6.49     |
| Outside of the flood control circle   | 613.47   | 54.61    | 6.09     |
| Total                                | 1416.60  | 126.11   | 14.07    |

3.2. Endogenous pollution
Due to the high water temperature and artificial disturbance, some of the organic pollutants deposited in rivers can be easily re-released, which is recognized as endogenous pollution. The endogenous pollution is calculated as follows [8,9].

\[ W_e = A \times \beta \] (2)

where \( W_e \) is the endogenous pollution (t/a), \( A \) is the water area (m²), \( \beta \) is the pollutant release rate of bottom sediment (mg/m² d). According to the current annual dredging situation and the planned annual dredging project data, the amount of pollutants released from the river sediments in different areas is calculated and shown in Table 2.

Table 2. Current annual amount of endogenous pollutants entering the river (t/a).

| Zones                                | COD      | NH₃-N    | TP       |
|--------------------------------------|----------|----------|----------|
| Northern part of the flood control circle | 10.66    | 4.80     | 0.80     |
| Southern part of the flood control circle | 36.56    | 16.47    | 2.74     |
| Outside of the flood control circle   | 63.98    | 28.82    | 4.80     |
| Total                                | 111.21   | 50.09    | 8.35     |

3.3. Runoff pollution
Due to the different underlying surfaces of the watershed, the concentrations of rainfall and runoff pollutants are also different. According to the reality of the central urban area of Pinghu City, the underlying surface types are mainly urban hard land and greening land, such as building roofs, roads, squares, parks. The formula for calculating the amount of runoff pollutants entering the river is as follows [9-11].

\[ W_{rf} = A_{rf} \times P \times r \times C \] (3)

where \( W_{rf} \) is the amount of pollutants flowing into the river from the surface (t/a); \( A_{rf} \) is the area of the underlying surface (m²); \( P \) is the net annual rainfall (mm), \( r \) is the runoff coefficient, \( C \) is the various types of underlying averaged pollutant concentration of surface rainwater (mg/L).

During the calculation, the annual net rainfall is selected as 1318mm, which is measured by the Pinghu meteorological station. The \( C \) values are taken on the basis of previous research [8-10], which is given as COD = 150 mg/L, NH₃-N=6.88 mg/L, TP=0.85 mg/L. Runoff coefficient is 0.75 for the impermeable ground, and other areas runoff coefficient is 0.15. Eventually, the calculated runoff pollution into the river network in Pinghu City is shown in Table 3.

Table 3. Current annual amount of runoff pollutants entering the river (t/a).

| Zones                                | Rainfall (10000 t/a) | Runoff pollution (t/a) |
|--------------------------------------|----------------------|------------------------|
|                                      | COD                  | NH₃-N                 | TP       |
| Northern part of the flood control circle | 232.19               | 130                   | 5.98     | 0.74     |
| Southern part of the flood control circle | 902.65               | 508                   | 23.26    | 2.88     |
| Outside of the flood control circle   | 902.62               | 508                   | 23.26    | 2.88     |
| Total                                | 2037.46              | 1146                  | 52.52    | 6.50     |
4. Analysis of pollution components in the river network

According to the calculation results of different pollution sources, the current annual amount of COD pollution in the Pinghu river network is 2673.9t/a, NH\textsubscript{3}-N is 228.71t/a, and TP is 28.92 t/a. From the perspective of the emission ratios of various pollution sources, COD and NH\textsubscript{3}-N are mainly come from domestic sources and surface runoff pollution, while TP entering the river mainly comes from domestic sources and bottom sediments. The composition of the sources of pollution into rivers in the downtown areas of Pinghu City can be seen in the following figures.

As shown in Figure 4, the annual amount and the components of pollutants in the Pinghu river network is variable in different areas. The southern part and outer zones of flood control circle show worse water quality and heavier pollutant amount, while the northern part of the flood control circle is better than the other two zones. It is also confirmed that due to the lower flow rate and more population in the southern part of flood control circle, the point source pollution is more severe in this zones rather than the other two zones.

![Figure 4. Proportion of different pollution sources in the Pinghu river network.](image)

5. Conclusions

In this study, different types of pollution sources of current water pollution in the river network in Pinghu City are calculated and analyzed. The amounts and components of pollutants in various zones in Pinghu City are also analyzed in this study to show the spatial distribution of pollutant discharge. Long-term improvement of the water environment is required due to the large amount of pollutants in the river network in Pinghu City, fully usage of existing water conservancy engineering facilities will be the best way to improve the water environment in this city.
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