Discussion on the Selection and planning of Sewage Outfall Into the sea—a case of Gaoqi Sewage Treatment Plant

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Abstract. Scientific selection of the sewage outfall into the sea plays an important role in rational utilization of Marine self-purification capacity, reduction of land sewage discharge and ecological risk, and protection of the Marine environment. In this paper, the selection and layout of the sewage outfall into the sea of Gaoqi sewage treatment plant is taken as an example. First, the primary sewage outfall is selected according to the sewage outlet selection and delimiting principle. Then, the hydrodynamic and water quality model is established to predict and analyse the effects of sewage discharge from each primary outfall on marine water quality and sensitive areas of ecological environment. Finally, the final discharge outfall is determined by considering the environmental impact, engineering economic conditions. The results show that the recommended scheme is in line with the Marine function zoning, with good pollutant diffusion conditions, far away from the ecologically sensitive areas, and with the minimum project investment.

1. Introduction

The self-purification capacity of the ocean is a valuable natural resource, and the ocean has been the final acceptor of the discharge of water pollutants for a long time. Discharging domestic sewage into the sea after centralized treatment is one of the main ways of sewage discharge in the coastal areas [1,2], which can utilize the self-purification capacity of the marine environment [3,4]. However, with the acceleration of urbanization and the rapid development of coastal society and economy, the pollutants discharged into the sea are increasing, leading to increasingly serious environmental pollution in coastal waters [5]. Marine environmental pollution is still an important factor limiting the development of Marine economy and the health of Marine ecology [6]. Therefore, the site selection of the sewage outfall into the sea needs scientific demonstration, so that it can make reasonable use of the self-purification capacity of the sea area, which can reduce the impact of pollutant discharge on the environment [7].

The numerical model is a useful tool to evaluate the water exchange capacity of the sea area and calculate the diffusion range of pollutants [8], so as to determine the optimal discharge outfall [9]. At present, the main research methods are to establish the hydrodynamic model, the Lagrange particle tracking model [10], the water quality model [11] and other numerical models to selection the location.

This study configured a hydrodynamic model and water quality model to assess the impact of effluent discharges from outfalls. Considering the environmental status, ecological sensitivity, economic and technological conditions, location of the sewage outfall is determined by scientific demonstration based on the MIKE3 model. The research can provide scientific basis and decision support for the selection of sewage outfall and Marine environmental management.
2. Materials and Methods

2.1. Study areas
Xiamen Bay is located in southeast coast of Fujian Province, adjacent to Jinmen Island in the east. The total marine zone of XMB has an area of 390 km² located between latitudes 24° 15’N to 24° 45’ N and longitude 117° 48’E to 118° 36’E.

In this case, the planned sewage treatment plant named Gaoqi is located near the northeast coast of Xiamen Island. The sewage treatment plant mainly collects domestic sewage in the northeast of Xiamen Island for treatment. The planned sewage discharge scale is 300,000 tons per day. The purpose of this paper is to choose a suitable discharge location for effluent from sewage treatment plant. The topography of XMB and location of the Gaoqi sewage treatment plant are shown in Figure 1 and Figure 2.

2.2. Methodology
A water quality model of XMB Xiamen is built based on the MIKE hydrodynamic module and water quality module. MIKE is professional engineering software [12]. The formula for the water quality model is as follows:

$$\frac{\partial C}{\partial t} + \frac{\partial}{\partial x}(uC) + \frac{\partial}{\partial y}(vC) + \frac{\partial}{\partial z}(wC) = \frac{\partial}{\partial x}(D_x \frac{\partial C}{\partial x}) + \frac{\partial}{\partial y}(D_y \frac{\partial C}{\partial y}) + \frac{\partial}{\partial z}(D_z \frac{\partial C}{\partial z}) + S$$

(1)

Where C is the concentration; u, v, w is the velocity; D_x, D_y, D_z is the diffusion coefficients.

Figure 1. Topography of Xiamen Bay and location of monitoring stations.

2.3. Sewage outfall primary election
The principle of selecting and delimiting sewage outlets mainly includes [13,14]:

1. Comply with laws and regulations;
2. Conform to the Marine function zoning and without hinder the normal use of the sea area;
3. With favourable hydrodynamic conditions and deep water(> 7 m);
4. The impact on the ecologically sensitive areas of the surrounding sea should be reduced as far as possible.

In accordance with the above sewage outlet selection principle, this paper determined the preliminary site selection scheme of sewage outlet through analysis, the location of the sewage outfalls is shown in Figure 2.
3. Results

3.1. Model verification
The tidal elevation measured at Wutong station was selected for comparison with simulated values from November 24 to 28 in 2018. While, three tidal currents station are selected to verify by continuously measured sea current values for 25 hours from November 24 to 25. The station positions are shown in Figure 1. And the comparison results are shown in Figure 3 and Figure 4.

Though the comparative verification of the tidal levels, current values and direction, the calculation results of the hydrodynamic model in this study agree with the measured values. The established model can well simulate the tidal fluctuation and tidal current movement of XMB, which can provide hydrodynamic field for the water quality model.
3.2. Environmental impact analysis

According to the seawater water quality survey results of the Third Institute of Ocean Research in 2015 and 2019 in Tong'an Bay, the COD background value is set as 1.5mg/L from a conservative perspective. The COD distribution at each discharge outlet is shown in Figure 5.

As can be seen from Figure 5, the COD envelope of Case 1 is centered on the sewage outlet and radiological diffused outwards in an elliptical form. The maximum concentration increment is about 2.1mg/L in the flood tide time. The area of COD concentration exceeding class I seawater water quality (COD concentration greater than 2.0 mg/L) is about 0.14km², and the area of COD concentration exceeding class II seawater water quality (COD concentration greater than 3.0 mg/L) is about 0.75km². The COD affected area and distance of water quality over class II are not large.

With sewage outlet of Case 2 as the center, COD concentration is elliptical and diffuses outwards. Because of the topography, the pollutants will migrate to the land area. The maximum concentration increment is about 3.2mg/L in the flood tide time. After superimposed background, the area of COD concentration exceeding class I is about 0.21km², and the area of COD concentration exceeding class II is about 1.02km².
With the sewage outlet of Case 3 as the center, COD concentration also diffused outwards in an elliptical shape. Due to the effect of the flood tidal current, the pollutants obviously spread to the Tong'an Bay, and are not easily transported to the offshore area, which will aggravate the pollution of the Tong'an Bay. After superimposed background, the area of COD concentration exceeding class I is about 0.39km², and the area of COD concentration exceeding class II is about 4.72km². Pollutant discharge has a great impact on the surrounding marine environment.

3.3. ecologically sensitive areas impact analysis
As can be seen from the figure, the environmentally sensitive targets in the waters near the Gaoqi sewage treatment plant include the core area of Chinese white dolphins, mangroves and aquaculture area. In the core area of Chinese white dolphins, the first-level standard in the Seawater Quality Standards implemented; in the mangrove and aquaculture areas, the second-level standard is implemented.

The nearest distance to the core area of Chinese white dolphins in the Case 1, Case 2 and Case 3 is 0.9km, 1.3km and 3.1km respectively. It can be seen from the simulation results that the COD pollutant will not affect the sensitive targets around it.

3.4. Engineering economic analysis
Gaoqi Sewage Treatment Plant is located at the seaside, and the tailwater pipeline is directly discharged into the sea through the high sea drainage well in the plant. The routing scheme of the three primary sites is mainly different from that of the construction of the sea pipeline. The project investment estimate is shown in Table 1. The route length of Case 1 is about 1600m long offshore pipeline, with a long construction period and the need to cross the nearby island. The total investment
of the project is about 180 million RMB. The route length of Case 2 is about 500m long, and direct excavation can be adopted. The construction period is short, and the total project investment is about 60 million RMB. The route length of Case 3 is about 3,300m long offshore pipeline, with a longer construction period and the need to cross the nearby island. The total investment of the project is about 390 million RMB.

Table 1. The Project investment estimation of sewage outfalls.

| Case  | Route Length (m) | Project investment (million RMB) |
|-------|------------------|----------------------------------|
| Case 1 | 1600             | 180                              |
| Case 2 | 500              | 60                               |
| Case 3 | 3300             | 390                              |

4. Discussions

Comparison to the simulation results and engineering economy, it is found that the optimal schemes obtained from different evaluation angles are not completely consistent.

1. From the perspective of the impact of water environment, the minimum area exceeding the water quality of Class II seawater in Case 1 is 0.75km²; The next one is Case 2, the area exceeding the water quality of Class II seawater was 1.02 km², The most one is Case 3, the area exceeding the water quality of Class II seawater is 4.72 km².

2. From the perspective of impact on ecologically sensitive areas, none of the three Cases will affect the ecologically sensitive targets in the nearby sea areas.

3. From the analysis of project economic conditions, Case 2 has the shortest offshore route, simple construction and the least project investment. Case 1 and Case 3 have longer construction routes, are responsible for construction and have the largest investment.

To sum up, Case 1 and Case 2 have little difference in the impact on the environment, but the project investment of Case 2 is far less than that of Case 1, so Case 2 is selected as the recommended scheme.

5. Conclusions

According to the basic principle of the selection and allocation of the sewage outlet, the initial outlet location of Gaoqi sewage treatment plant is selected in this paper. Then, the influence of the three schemes of tail water discharge on the Marine water environment and sensitive targets is analysed by the tidal current model and the water quality model. Combined with the economic analysis of the project, the recommended method of the sewage outlet is determined. This method takes various factors into consideration, enriches the method system of sewage outlet selection and allocation, and provides scientific basis and basic support for the selection and allocation of sewage outlet into the sea.

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