Exploration on water environment control scheme of black and odorous water body in Houhai River Basin

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Abstract. Black smelly water around the economy, society and people's livelihood development has a very bad influence, seriously affects people's production and life style, in order to further remove black smelly water bodies, this article takes the water environment treatment scheme of Houhai River in Nanshan District of Shenzhen as an example, this paper considers the treatment of water environment as a whole with systematic thinking. On the basis of in-depth analysis of the sources of pollutants in the basin, the quantitative analysis method of current pollutants in the present situation was established, and a technical route of “pollution control and interception, endogenous treatment, ecological restoration and raising quality of living water” was established according to the quantitative analysis of pollutants. In the process of treatment, the concept of sponge city should be implemented simultaneously; the river ecosystem should be improved by revetment ecological promotion, drainage outlet landscape treatment and so on. The implementation effect evaluated by model showed that all indicators could reach the design goal. The purpose of this paper could provide reference for water environment treatment schemes in other similar areas.

1. Introduction

With the continuous development of industrialization, the city has grown, the ecological environment more and more challenges, lack of water resources and water environment deterioration, exacerbating the city river black smelly, become urban environmental problems, one of the main factors of black smelly river and urban river water pollution problems become the urgent need of city development, not only affect the natural environment of the city, also seriously affects the quality of people's lives[1-2]. It is a worldwide problem to control the black and odorous water in urban river course, especially in high-density built-up areas. For example, the governance of Danube River and Thames River in Europe has a span of decades or even hundreds of years [3-4]. High-density development and construction will cause problems such as insufficient renovation space, complex black and odor causes, lack of hydrophilic space, serious non-point source pollution, etc., which will make the treatment difficult and difficult to maintain long-term clean water environment. In this paper, the water environment treatment scheme of the black and odorous water body of Houhai River in Nanshan District, Shenzhen City was taken as an example to consider the water environment treatment as a whole with systematic thinking. The Houhai River in Nanshan District is a severely black and odorous water body under the supervision. In the process of its treatment, the water environment quality improvement task is arranged according
to the characteristics and needs of each drainage area in the Houhai River Basin [5]. The scheme proposed in this paper has well solved many problems in the comprehensive treatment of black and odorous water bodies in high-density built-up areas, and its planning and construction process has many experiences worth learning and popularization.

2. Overview and problem analysis of Houhai River Basin

2.1. Watershed Overview
Houhai River Basin is located in the southeast of Nanshan District, east of Dananshan Mountain and south of Binhai Avenue, with a total area of 12.8km², including 12.62km² of construction land, including two sub-basins of Nanhe and Beihe. Land use planning is given priority to with housing, public service, the types of commercial office, including Houhai district as an important part of Shenzhen center, financial center, Shenzhen southwest portal, comprehensive service center of Nanshan, and its main developing headquarters economy, business finance, cultural industries, such as regional modern service industry, both live and form a complete set of comprehensive function. The south river is 2.27km in length and 20-50m in width. At the junction of Dongbin Road, the south side of Dongbin Road is connected with the rainwater in the box and culvert. Along the way, it receives the rainwater in the branch and culvert of Gongye No.7 Road, Gongye No.8 Road and Yucun Road, and finally drains into Shenzhen Bay, with a basin area of 4.63km². The north river is 1.68km in length and 15-40m in width, accepting the rainwater from the third Haide Road, Chuangye Road, Dengliang Road and Dongbin Road in the north, and entering Houhai Inner Lake along the sixth planning branch road, and finally discharging into Shenzhen Bay, with a basin area of 3.62km².

2.2. Causes analysis of water environment problems

2.2.1. Sewage interception box culvert system. The Basic sewage box culvert system ensures the dry season water directly into the river, but the rainstorm period of rain, river sand inflow water quality with sewage purification plant, due to not equipped with the end of the corresponding light rain in the early treatment facilities caused by water quality purification plant overload operation, influence the water effect, overflow sewage into the river at the same time, the adverse effects on the river water quality.

2.2.2. Along the river pollution. With the operation of Shenzhen Bay Sewage Discharge Intersection Phase II Project and other projects, Houhai River sewage collection system is basically improved, but the mixing of rain and sewage in the surrounding areas of the basin is not complete, and part of domestic sewage is discharged into the river, and there is also the risk of sewage overflow in the rainy season.

2.2.3. Release of endogenous pollution. End-source pollution is mainly organic silt of river course. Sediment is mainly composed of organic pollutants, which is rich in shells, snail remains, animal and plant remains, etc.

2.2.4. The tide jacking. In the rainy season, part of the overflowing sewage from the sewage intercepting box culvert enters the water body. However, due to the influence of tidal action, the water body cannot be fully exchanged at this time, and the sea water enters the Hainan River twice a day. At high tide, the water depth at the most upstream is relatively shallow (about 1m), and there is basically no peculiar smell. When the tide ebbs, the tide will bring out the pollutants in the river, the upstream riverbed surface, there are more serious odor.

2.3. Page Numbers

2.3.1. Pollution source analysis. The exogenous pollution of Houhai River mainly includes: the point source pollution discharged through the mixed drainage outlet of diversion system of rainwater and sewage; Non-point source pollution discharged through divergent rainwater drainage outlets, divergent
rainwater pollution mixed drainage outlets, and closed overflow drainage outlets [6]. The sewage quantity of Houhai River in dry season is shown in Table 1.

| Items | Before renovation/after renovation |
|-------|----------------------------------|
| Drainage discharge into the river during the dry season/(10⁴m³·d⁻¹) | 0.21 | 0 |
| The amount of sewage entering the box culvert in the dry season/(10⁴m³·d⁻¹) | 1.12 | 1.08 |
| Sewage closure rate in dry season/% | 84.20 | 100 |

2.3.2. **Determine the pollution calculation method.** When monitoring data are available, the point source pollution caused by diverging rainwater and sewage and mixing with drainage outlets can be calculated directly by using the monitoring data of water quantity and water quality. When there is no monitoring data, the amount of sewage is converted according to the index of water use per unit land, and the relevant research results of sewage quality in Shenzhen are combined for estimation.

A SWMM model was used to simulate the annual rainfall conditions, different underlying surfaces and the accumulated scour of pollution, aiming at the non-point source pollution discharged by the divergent rainwater drainage outlet and the mixed drainage outlet of divergent rainwater pollution, and the estimation was made according to the simulation results.

Aiming at the non-point source pollution discharged by the stop-type overflow outlet, the SWMM model was used to continuously simulate the annual rainfall conditions, the process of runoff production and confluence of different underlying surfaces and the accumulated scour of pollution. The overflow frequency was calculated and estimated according to the simulation results.

2.3.3. **The pollution calculation.** The model simulation shows that the total amount of COD in the rainy season overflow pollution is 187.36t/a, and the reduction rate of the total amount of COD in the current pollutant is 47.8%. The COD overflow flow in rainy days after the closure of the mixing outlet is about 27.95t. The COD of non-point source pollution of rainwater outlet and overflow outlet is about 151.53t.

3. **Comprehensive treatment plan for black and odorous water body of Houhai River**

3.1. **Source control and pollution interception**

In the process of black and odor control in Houhai River, the improvement of river outlet control and pipe network has been basically solved. Therefore, in order to further improve the environmental quality of Houhai river water, emission reduction at the source is the core and key point. Among them, source control and pollution interception mainly includes two parts, point source and non-point source, as shown in Table 2.
Table 2. Source control and pollution interception schemes

| Items                        | Technical solution                                                                 | Note                                                                                   |
|------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| **Point source pollution control** | Disposal of sewage outlet into river                                                  | The implementation has been completed, access to the sewage interception box culvert, dry season without direct sewage discharge |
|                              | The pollution interception system has been improved                                  | Upgrade sewage pipes and plants that do not meet the requirements after review          |
|                              | Community original source project                                                    | By 2020, all the original projects will be renovated                                  |
|                              | Urban village rain and pollution diversion                                            | Change the "rain and pollution mixing, around the village to cut the pollution" to "cut the pollution pipe, into the village into the household" |
|                              | Initial stormwater treatment facilities                                              | Power supply pollution shall be implemented after thorough control                     |
| **Non-point source pollution control** | Source sponge reconstruction                                                          | Adapt measures to local conditions, classification transformation                        |
|                              | Stormwater outlet renovation                                                         | Areas with serious non-point source pollution                                          |
|                              | Junk reconstruction                                                                  | Areas with serious non-point source pollution                                          |
|                              | The end of the purification                                                          | Cyclone separation device, etc                                                         |
|                              | Pipeline dredging                                                                   | Regular desilting                                                                      |

3.1.1. **Point source pollution.** Point source pollution treatment was carried out in stages. In the first stage, there were some direct sewage outlets and some rainwater and sewage mixed flow outlets in Haibei River around 2016. This stage mainly carried out along the river sewage interception project, has implemented rain and sewage diversion, sewage interception pipe network, sewage interception box culvert construction and river dredging and renovation. The construction of 16 river drainage outlets was completed, and no direct sewage was discharged into Houhai River in the dry season. The first level enhanced temporary sewage treatment station at the end of the sewage interception box culvert reaches the standard and then enters Shenzhen Bay.

With the operation of the second phase of Shenzhen Bay drainage cut-off project, the dry season sewage and initial rainwater treated by the temporary sewage treatment facilities have been greatly reduced. With the further transformation of the source and the complete completion of the original source clearance work, the sewage intercepting box culvert will be adjusted to the initial rainwater tank culvert (see Figure 1.). The current temporary enhanced treatment facility at the end is suggested to be transformed into a permanent ecological initial rainwater treatment facility.

![Figure 1. Schematic diagram of initial rainwater culvert](image_url)
3.1.2. Non-point source pollution. Common urban non-point source pollution control measures mainly include source sponging transformation, that is, by changing the existing underlying water to intercept the initial rainfall. In addition to conventional green facilities, the sponge renovation can also replace environmentally friendly rainwater grates to intercept large sundries such as ground garbage and leaves so that they do not enter the pipe network system to reduce non-point source pollution. There is no old industrial zone in Houhai area. The control of non-point source pollution in Houhai area is mainly constructed from the reconstruction of original source of old villages and the addition of environmentally friendly rainwater outlets, permeable pavements and other sponge facilities in source projects. Among them, the sponging transformation mainly adopts the combination of green and gray to realize the overall control of non-point source pollution.

3.2. Endogenous governance

3.2.1. River dredging. In order to further improve the water quality of Houhai River, reduce sediment pollution, at the same time restore the flood passage section, improve the flood control capacity, and reduce the impact of dredging on the surrounding environment. According to the field survey, the internal pollution of Houhai River has been eliminated at the present stage, so it is not necessary to remove the sediment in the river. However, the endogenous release of river sediment pollution is one of the important reasons for the deterioration of river water quality. The river desilting methods treat the symptoms but not the root causes, and the river sediment will be resilted after a few years. In view of the endogenous pollution caused by sediment pollution release is still one of the key problems to be solved at present, it is suggested to adopt in situ mulching and in situ biochemical treatment technology first.

3.2.2. Pipeline dredging. The pipe dredging and pipe repair project for Houhai River sewage box culvert has been implemented. It is still necessary to carry out regular maintenance, dredging and evaluation of the established rainwater sewage pipe network in the basin, and timely repair and replacement of the problematic pipe segments. Curing frequency is shown in Table 3.

Table 3. Maintenance frequency

| Items                        | Pipeline division | Check well | The rain mouth |
|------------------------------|-------------------|------------|----------------|
| Rainwater and confluence pipes | Small 1 Medium 0.5 Large 0.3 Oversize | 4           | 4              |
| Sewage pipe canal            | 1                 | 1          | 0.3            | 0.2            |

3.3. Ecological restoration

Improvement of revetment ecology. In the future, the ecological improvement of Hainan River will be taken as an example. The current situation of the later Hainan River is basically the primary ecological shoreline, so it is suggested to keep the current situation and set horizontal platforms in combination with local box culverts to upgrade the landscape plant level of the slope bank, and the freshwater estuarine species will be transferred to the coastal mangrove park. The estuary reach is close to the mangrove bay, and the coastal tidal flats are suitable for the growth and cultivation of shallow sea fish and shellfish. There are abundant tidal flats to protect the areas with abundant water exchange and repair the areas with insufficient water exchange. The original brackish water intersection abundant area, should focus on conservation, reduce hard construction; In the areas where water exchange is insufficient, ecological protection should be attached importance to protect the growth conditions of mangroves to the greatest extent.

3.4. Mention living water quality

Houhai River is a rain-source artificial river, whose main functions are flood control and landscape. In the dry season, there is no rainwater inflow, the estuary gate is closed, and the sea water mainly enters
the river through tidal action. During the flood season, the estuarine gate is opened to discharge flood water, and the rainwater in the basin is discharged into the river through the drainage system, and finally into Shenzhen Bay.

By replenishing the water in Houhai river, it can avoid the cut-off of river flow and the exposed bottom, and realize the functions of diluting pollutants into the river, activating hydrodynamics, restoring water ecology and creating water landscape, etc. Houhai River is a man-made rain-source river with no original base flow. Three methods, i.e., maximum utilization of basin area discharge, Montana method and landscape water demand method, were adopted to predict the water demand respectively, and the maximum predicted water quantity was taken as the water demand of Houhai River. The results are shown in Table 4. In order to meet the ecological and landscape water requirements, the plan uses the sea water of Shenzhen Bay and the lake water of Talent Park to supplement the water of the river, and uses tidal action to carry the sediment into Shenzhen Bay to keep the river clean. There are two water intake points of Houhai River, namely Shenzhen Bay and Talent Park.

According to the analysis of water source, the reclaimed water supply in Nanshan is mainly used for municipal utilities, and there is no surplus water for Houhai River water supply. Therefore, it is planned to reserve the seawater replenishment channel of Shenzhen Bay for the replenishment of Houhai River in the near future. In the long term, the tail water of Nanshan Recycled Water Plant can be considered as the source of Houhai River water supply after the upgrading of the plant.

| Items                        | Maximum use of basin area | Montana method | Landscape needs water |
|------------------------------|---------------------------|----------------|-----------------------|
| Calculate the point          | The amount of water       | Use 10% of the annual | According to the river section, the water depth of landscape surface was considered to be 1.0m and the water changing period was 7d |
|                              | replenishment is calculated according to the area of river basin | base flow as the ecological base flow to protect aquatic habitats |                                                                  |
| Distribution of water        | 2.5                       | 0.5            | 2.0                   |

4. The simulation results

SWMM model was used to establish a water quality model of Houhai River Basin to evaluate the compliance of the scheme. Input typical annual rainfall, hydrological and hydraulic parameters of different underlying surfaces, etc., and the accessibility of calculation indexes of the model is shown in Table 5.

| Items                                      | The target | Upon completion of implementation | Standard analysis                                                                 |
|--------------------------------------------|------------|-----------------------------------|-----------------------------------------------------------------------------------|
| Control proportion of direct sewage discharge in dry season | 100        | 100                               | To reach the standard, combined with the original Qingyuan and Houhai River sewage interception pipe network to achieve dry season sewage full interception |
| Non-point Source Pollution Control (SS)    | ≥60        | 62.4                              | To reach the standard, combined with the comprehensive sponge construction and sewage interception pipe network to achieve non-point source pollution interception |
| Annual Reduction Rate of Total Pollutants Into Rivers (SS) | ≥70        | 77.84                             | To reach the standards, combined with the original clean source, sponging construction and Houhai River sewage pipe network to achieve dry season sewage full closure |
| The water quality target                   | Quasi IV class¹ | Quasi IV class¹               | To reach the standard, combined with the comprehensive pollution intercept of pollutants, and supplemented by the live water quality improvement project to achieve all the water quality indicators to reach the standard |

Note:¹ Except TN, fecal coliform and water temperature.
5. Conclusion
High-density development and construction will cause problems such as insufficient reconstruction space, complex black and odor causes, lack of hydrophilic space, serious non-point source pollution, etc., which will make it difficult to treat black and odor water in high-density built-up areas and make it difficult to clean the water for a long time. Taking the Houhai River in Shenzhen City as an example, the path and idea of comprehensive treatment of black and odorous water in high-density built-up areas were preliminary explored, and attempts were made in simulation analysis by using the model and combining with sponge city construction, so as to provide reference for improving the water ecological environment quality of Houhai River Basin and even Nanshan District. In the next step, further exploration will be made on how to carry out fine design, underground development and intensive design.

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