Analysis of Economic Benefits of Reclaimed Water Industry Utilization: A Case Study in Tongxiong

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Abstract. Taking the Tongxiang Urban Sewage Treatment Plant Integration Project (Phase 1) as an example, this paper designs three reclaimed water allocation solutions after investigating the water cost, water quality requirement and reclaimed water using willingness of potential reclaimed water users in the surrounding area. The economic cost-benefit calculations for all three options show that under the circumstance that the existing water policy and charging standards remain unchanged, the large-scale use of reclaimed water in industrial production will increase the water intaking cost of industrial water users by 50%~70%. In order to enhance the enthusiasm of water users for the use of reclaimed water, it is recommended that the government and enterprises could allocate the cost of using reclaimed water reasonably, and the government could provide economic subsidies and preferential policies.

1. Introduction

In the entire urban water use, domestic water and industrial water occupy a considerable proportion. It is not economical to require the entire urban water supply system to treat drinking water quality standards[1]. The continuous development of urban industrial parks not only squeezes high-quality water supply, but also increases the discharge of industrial wastewater, which is not conducive to the urban water environment and ecological environment[2]. How to effectively reduce the demand for high-quality water sources in industrial parks and reduce wastewater discharge are important issues that need to be resolved in urban development.

In response to the above problems, building an efficient, clean and safe industrial symbiosis and resource utilization system is the main development path of my country's eco-industrial parks. The rational utilization of water resources and the scientific allocation of water resources, and the sustainable use of water resources to ensure the sustainable development of the industrial park will be an important part of the eco-industrial park[3]. Due to the particularity of water use in the industrial park, reclaimed water can be used as an alternative water source for the park, while saving high-quality water resources and reducing waste water discharge[4]. This article will take the Tongxiang Urban Sewage Treatment Plant Integration Project (Phase 1) located in Tongxiang (桐乡市) as an example to explore the design of feasible solutions for industrial use of reclaimed water.

2. Project Overview

Tongxiang Urban Sewage Treatment Plant Integration Project (Phase I) is located in the southern part of Tongxiang Economic Development Area, covered an area of 140,600 m². The designed sewage treatment load of the project is 200,000 t/d, of which tail water after treatment is 140,000 t/d and reclaimed water is 60,000 t/d.

After investigation, potential users of reclaimed water are as follows:
2.1. Industrial water users
There are 61 industrial water users who take surface water within 10km of the project. Considering the cost of pipe network construction and water quality pre-treatment costs, this paper selects those with an annual water consumption of more than 400,000 tons as potential reclaimed water users. And through investigation, it's known about industrial water consumption, water quality requirements, the willingness of reclaimed water utilization and pollutant emission quotas of various enterprises.

After eliminating companies with high water quality requirements and low willingness to use reclaimed water, the scope of potential users of reclaimed water was reduced to 9 companies. Among them, there are 8 textile enterprises and 1 power enterprise. The water intake of textile enterprises is directly used to product manufacturing. After the front-end treatment, the water quality requirements refer to the "Standards for drinking water quality" (GB/T 5750-2006). The use of water for power enterprise is used as circulating cooling water. The water quality requirements refer to the "Code for design of industrial recirculating cooling water treatment" (GB 50050-2017).

2.2 Industrial Water supply Plant
In addition, there is an industrial water supply plant in Tongxiang. The current water supply scale is 50,000 t/d, and the water source is surface water. More than 36,000 t/d of water can be used as an alternative water source.

2.3 Artificial wetland
Considering the location of the sewage plant, the surrounding water system, and the water quality of the river network, the Changshan River (长山河) can be selected as the target river channel for the reclaimed water distribution of this project. The target water quality of the Changshan River Water Function Zone is Class III water, which has a certain gap with the target water quality of the project's reclaimed water, which is Sub-Class IV water.

The designed output water quality of the project and the water quality requirement of the three kinds of potential users are as follows:

| Index               | COD\textsubscript{Cr} | COD\textsubscript{Mn} | CaH | ALK | SS | NH\textsubscript{3}-N | Fe | Cl\textsuperscript{-} | TN  | Quantity (10\textsuperscript{4}t/d) | Pre-processing cost (¥/t) |
|---------------------|------------------------|------------------------|-----|-----|----|-----------------------|----|---------------------|-----|-------------------------------------|--------------------------|
| Reclaimed water     | 30                     | 6                      | *365* | 325* | 5  | 1.5                   | 0.19* | 1356*               | 10  | 6.0                                | --                       |
| Textile enterprises | --                     | 3                      | 20   | 120  | -- | 0.5                   | 0.1   | 120                 | --  | 3.2                                | 8.0                      |
| Power enterprise    | 60                     | --                     | 250  | 200  | 10 | 5.0                   | 0.5   | 250                 | --  | 2.4                                | 2.0                      |
| Industrial water supply plant | 19.6* | --                     | --   | --  | -- | 0.563*                | --    | 3.37*               | 3.6 | 1.5                                |                          |
| Class III water     | 20                     | 6                      | --   | --  | -- | 1.0                   | --    | 1.0                 | --  | --                                 |                          |

* This is the measured value.

3. Reclaimed water allocation solutions

3.1 Centralized allocation solution
This allocation solution plans to jointly accept all the reclaimed water from the project by power enterprise and industrial water supply plant, of which the power enterprise receive 24,000 tons of reclaimed water per day, and the industrial water plants receive 36,000 tons of reclaimed water per day.

There is still a certain gap between the quality of the reclaimed water produced by the project and the water quality requirements of the accepted users. The cost of water pre-processing and transportation for power enterprise is ¥ 2/t, which is about ¥ 17.5M/a, and the cost of water pre-processing and
transportation for industrial water supply plant is ¥1.5/t, which is about ¥20M/a. In total, the pre-processing cost is about ¥37.5M/a.

The pipeline to the power enterprise is built by DN400PE pipe with a total length of 1.5km and the construction investment is about ¥3M; the pipeline to the industrial water supply plant is built by DN1000 ductile iron pipe with a total length of 16.8km and the construction investment is about ¥50M. The total pipeline construction investment ¥53M.

3.2 Regional allocation solution
This solution plans to accept reclaimed water by power enterprise, with a water volume of 24,000 t/d, and the rest of the reclaimed water will be distributed to regional rivers, with a water distribution scale of 36,000 t/d.

The pipeline construction cost and pre-processing cost of thermal power enterprises is as Sub 3.1 described.

The water quality of the reclaimed water cannot meet the water quality requirements of the Changshan River as the target river. Therefore, the reclaimed water needs to be pre-processing before the water distribution of the river. Refer to the Research about Subsurface Flow Constructed Wetland studied by Ge Yuan\(^5\), Gao Pingping\(^6\), Yang Xiaotong and Xu Jingtao\(^7\), horizontal subsurface flow constructed wetlands can be used in sewage treatment around the outlets of the plant. Through the interception and adsorption of wetland substrates and wetland plant roots, suspended pollutants and phosphorus-containing pollutants can be removal. Through the biofilm on the wetland substrate surface, organic pollutants could be degraded; Through the anaerobic-aerobic microorganisms environment around the substrate bed and plant roots, nitrification-denitrification removes nitrogenous pollutants in sewage. According to the amount of reclaimed water to be treated, the constructed wetland needs to cover an area of no less than 28 hectares, and the construction cost is about ¥68M.

3.3 Distributed allocation solution
This solution plans to accept reclaimed water jointly by power enterprise and textile enterprises. The power enterprise will accept 24,000 tons of reclaimed water per day, and the remaining 36,000 tons of reclaimed water will be accepted by textile enterprises.

The pipeline construction cost and pre-processing cost of thermal power enterprises is as Sub 3.1 described.

The pre-processing cost and transportation cost of textile enterprises is ¥8/t, which is about ¥110M/a. According to the spatial distribution of the enterprises and the water demand of the enterprises, two DN800 ductile iron pipes need to be arranged as main lines. The total length of the main lines is 14.2km and the construction cost is ¥29M. The branch pipes connected to the enterprises have three ductile iron pipe diameters: DN600, DN400, and DN200. It needs respectively to build 12.1km, 16.0km and 0.4km, and the construction cost is about ¥19.2M, ¥15.2M and ¥0.4M respectively. The total cost of pipeline construction is ¥63.8M.

4. Allocation solutions economic balance analysis

4.1 Surface water intake cost reduction
If potential reclaimed water users use reclaimed water instead of surface water as their main water source, they do not need to pay surface water resources fees. According to the current charging standards in Tongxiang, the water resource fee for surface water is ¥0.2/t. When current potential reclaimed water users take surface water, they also need to pre-process the surface water. After the reclaimed water used, this part of the cost will no longer be incurred. At present, the pre-processing cost for textile enterprises is ¥2/t, the pre-processing cost for power enterprise is ¥0.4/t, and the pre-processing cost for industrial water supply plants is ¥0.2/t.
At present, Tongxiang implements a strict environmental protection policy. Enterprises must pay sewage charges for discharging sewage to the sewage pipe network. This part of the cost will be used to keep the sewage treatment plant running. If potential reclaimed water users carry out large-scale use of reclaimed water, they will bear the sewage treatment plant tail water which should be directly discharged into the environmental water body, and the pollution discharge fee should be reduced or exempted.

4.2 Economic balance analysis
According to the above analysis, using reclaimed water instead of surface water will cause the following economic influences. Water resource fee and pollution discharge fee will be reduced or exempted. The pre-processing cost of surface water will be replaced by the pre-processing cost of reclaimed water, which is dependent on water quality requirements. In addition, the use of reclaimed water requires a one-time investment in the construction of pipe network. The detailed cost comparison is shown in the table below.

| Enterprises                  | Pre-processing cost of reclaimed water (¥/t) | Pre-processing cost of surface water (¥/t) | Water resource fee (¥/t) | Pollution discharge fee (¥/t) | Balance (¥/t) |
|-----------------------------|---------------------------------------------|------------------------------------------|-------------------------|-------------------------------|---------------|
| Textile Enterprises         | 8.0                                         | 2.1                                      | 0.2                     | 1.5                           | -4.2          |
| Power Enterprises           | 2.0                                         | 0.4                                      | 0.2                     | 0.04                          | -1.36         |
| Industrial water supply plants | 1.5                                         | 0.2                                      | 0.2                     | --                            | -1.1          |

| Solutions                  | Annual running cost increase (RMB million) | Pipeline construction cost (RMB million) |
|----------------------------|-------------------------------------------|-------------------------------------------|
| Centralized               | 26.4                                      | 53.0                                      |
| Regional                  | 11.9                                      | 68.0                                      |
| Distributed               | 67.1                                      | 63.8                                      |

Due to the large gap between the water quality of reclaimed water and the water quality requirements of potential users, the economic cost-benefit analysis of all users shows that large-scale acceptance of reclaimed water for industrial production, even if the cost of pipe network construction is not considered, will also bring a big burden to the receiving users.

5 Conclusion
Taking the Tongxiang Urban Sewage Treatment Plant Integration Project (Phase 1) as an example, this paper designs three reclaimed water allocation solutions after investigating the water cost, water quality requirement and reclaimed water using willingness of potential reclaimed water users in the surrounding area. The economic cost-benefit calculations for all three options show that under the circumstance that the existing water policy and charging standards remain unchanged, the large-scale use of reclaimed water in industrial production will increase the water intaking cost of industrial water users by 50%~70%.

In fact, the industrialized utilization of reclaimed water can effectively increase the reuse rate of water resources and the treatment rate of water pollutants in the urban industrial system, and to a certain extent alleviate the burden of government pollution control. Therefore, the government should take the initiative to bear part or all of the pipeline network construction costs, and provide economic subsidies or policy preferential treatment to reclaimed water users, such as increasing pollution rights, preferential
participation in resource or pollution indicator trading, and so on. On the other hand, the low economic benefits of reclaimed water are the result of current low water resources and sewage charges, which can hardly prevent enterprises from wasting resources. How to make water resource fee and sewage charge play a role in guiding water conservation and reducing water pollution requires further research.

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