Research on Pricing of Renewable Water Resources in Supply Chain Environment

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Abstract. From the perspective of supply chain, this paper explores the pricing method of renewable water. Firstly, the cost range of the recycled water supply chain is defined and the cost structure of the recycled water supply chain is analyzed. Then the cost structure of the recycled water supply chain is systematically classified and the cost price model of the recycled water supply chain is constructed. Finally, this paper takes Hangzhou sewage treatment plant as an example to verify the case and put forward reasonable Suggestions for the price of reclaimed water.

1. Introduction
China is a country with large and small resources. China is rich in water resources, but the per capita amount of resources is very small, equivalent to 1/4 of the world's per capita water resources [1]. With the development of economy, the demand for water resources is increasing, and the shortage of water resources restricts the rapid development of China's economy. As a substitute of tap water, the best way to solve the water shortage in China is to make full use of renewable water resources. However, whether renewable water resources can be fully utilized largely depends on whether the price of renewable water is reasonable. Based on this, in order to promote the full and reasonable utilization of renewable water and expand the market of renewable water, domestic and foreign scholars have made a lot of research on the price of renewable water.

Foreign scholars A.Madi [2] adopted the method of regression analysis model to determine the price of reclaimed water from the perspective of users' willingness to pay. J.S. Thomas [3] adopted the marginal opportunity cost method to set the price of reclaimed water. S.Gercia [4] believes that the price of recycled water should be set according to the price of tap water, and discusses the relationship between tap water and the price of recycled water. R. Cuthbert [5] believed that the price of recycled water should be set on the basis of corporate income. Hurlimann.A [6] studies the price of recycled water from the perspective of user income, and believes that the price of recycled water should be within the economic range of users. Domestic scholars have also made a large number of studies on the formulation of the price of reclaimed water. ShiYing Zhang [7] believes that the price of reclaimed water should be divided into different intervals and the corresponding price should be set according to different intervals. Ming Li and YuCheng Jin [8] used the principle of supply and demand in economics to set the price of reclaimed water. Based on the cost of water production, Mei Li and YiLin Huang [9] established the cost price model of reclaimed water to study the price of reclaimed water. XiaoJun Liu and Chao Ding [10] used the average cost price model to predict the price of reclaimed water in Xi’an.
Tao Duan [11, 12] respectively adopted the independent pricing method and the marginal opportunity cost method to apply to the pricing of urban renewable water. Mei Li [13] used water production cost and annual operating cost to calculate the cost price of reclaimed water. Ning Zhang and Sheng Zhang [14] used the principle of fuzzy mathematics to calculate and analyze the price of renewable water resources in hang Zhou.

More scholars from almost all occurred in the process of water making relevant cost accounting, however, few will be reclaimed water price research studied the whole process in wastewater treatment, it is the lack of a certain accuracy, this paper put the recycled water pricing research in the whole supply chain of sewage treatment, the elaboration of the main body of supply chain and supply chain related costs, as the price of reclaimed water to provide a more reasonable guide.

2. Cost accounting of recycled water supply chain

The purpose of the cost accounting of the recycled water supply chain is to better reflect a series of actual costs and a lot of cost measurement problems involved in the whole sewage treatment process of recycled water. How to deal with these cost measurement problems is also the precondition of studying the price of recycled water.

2.1. Cost definition of renewable water supply chain.

Now many scholars on the research of the reclaimed water supply chain cost most involved in the process of transformation from sewage water cost for cost analysis of recycled water, but the sewage into the cost of the supply chain in the reclaimed water involves far higher than the cost of reclaimed water system of water, making water cost is involved in the process of sewage into part of the cost.

The cost of recycled water supply chain should be the cost invested in the sewage conversion process, the logistics and cash flow costs generated in the operation of the supply chain, and the management costs generated in the sewage conversion process. Therefore, the cost of recycled water supply chain is not limited to the cost of a specific link, but the cost of the whole supply chain. Therefore, the cost of the recycled water supply chain mentioned in this paper should include the sum of related costs of the whole chain.

2.2. The cost composition of the recycled water supply chain

The link of recycled water supply chain is relatively simple with relatively few nodes. The main body of the supply chain is generally composed of users and recycled water plants. The link of the supply chain is composed of sewage transportation link and recycled water transportation link. A complete supply chain is formed when the waste water discharged by the user is transported to a sewage plant for treatment, further processing and conversion into reclaimed water, and then recycled water that meets the standard is transferred to different users. See figure 1.

![Figure 1](image URL)

**Figure 1.** Schematic diagram of reclaimed water supply chain.

In reclaimed water supply chain, from to the sewage processing, deep processing link to the final sewage into the hand of renewable water to the user experience collection, production, sales, and other three links, involves the costs associated with specific refers to recycled water to sewage collection, processing, production and delivery to the user cost of some columns, mainly by the production cost, operation cost and management cost, transportation cost. Among them, the production cost mainly refers to the investment cost and annual depreciation cost involved in the construction of renewable water.
project, and the investment cost mainly refers to the two parts of investment in the treatment of renewable water plant and pipeline construction. The operation cost mainly refers to the power cost, pharmaceutical cost and maintenance cost when sewage is transformed into reclaimed water. Management cost mainly refers to the wages and benefits, financial expenses and sales expenses of the staff involved in the sewage treatment plant; Transportation cost mainly refers to the transportation cost involved in the process of sewage transportation and reclaimed water transportation.

2.3. Modeling the cost of renewable water supply chain

Based on the above analysis of the cost of the recycled water supply chain, the cost of the recycled water supply chain is the sum of various costs. Before establishing the cost model of the recycled water supply chain, this paper needs to make a hypothesis on the applicable scope of the cost model of the recycled water supply chain.

1. The overall operation of the renewable water plant is effective, and the overall strategic model of the supply chain of the renewable water plant has been determined.
2. The supply chain environment of the renewable water plant is relatively simple, and all links are located in the same region without any tariff.
3. Research on the premise of a certain demand for reclaimed water, and there is no factor of inventory occupation.
4. The research was carried out on the basis of laying pipelines between the reclaimed water plant and the users.

For the calculation of production cost, operation cost and management cost of reclaimed water, referring to Mei Li's research [9], we use E1 to represent production cost, E2 to represent operation cost, E3 to represent management cost and E4 to represent transportation cost. For the transport cost of reclaimed water, the calculation formula is as follows, referring to the research of Xiao Su on the transport cost of sewage recovery:

\[ E_4 = 16.72Q0.78L \times (2\% + 3.5\%) \]  

Where, Q represents the sewage treatment capacity, L represents the length of sewage pipeline, then the calculation formula of annual water cost of recycled water from the perspective of supply chain is:

\[ E = E_1 + E_2 + E_3 + E_4 \]  

Then the unit water production cost model of reclaimed water:

\[ P_0 = \frac{\sum E_i}{Q} \]  

The cost-plus method can be adopted to determine the price of recycled water in Hangzhou. If the profit rate is taken as the average social profit rate, the formula for calculating the price of recycled water is:

\[ P = P_0 \times (1 + r) \]  

3. Empirical analysis

3.1. Sewage treatment plant reuse investment scale
Hangzhou qige sewage treatment plant is located in xiasha qige village, downstream of qiantang river. Its service scope is mainly sewage treatment in the third district of the main city and sewage treatment in xiasha economic development zone. The sewage system is mainly divided into short-term and long-term projects. The short-term sewage treatment capacity of the sewage plant is 900,000 tons/day, the treatment scale is 100,000 m3/d, the deep treatment investment is 80 million yuan, the pipe network
scale is 18.3 kilometers, the pipe network investment scale is 25.527 million yuan, and the total investment is 105.527 million yuan.

3.2. Hangzhou city regeneration level average cost calculation

1. Production cost of reclaimed water. Mainly refers to the depreciation cost of the reclaimed water project, which is obtained by the depreciation rate of the construction of the reclaimed water project and the water transmission pipe network. According to the relevant data of the seven-grid sewage treatment plant, the depreciation cost of fixed assets is 5.276 million yuan.

2. The operating cost of recycled water. It mainly refers to the relevant costs incurred during operation. According to the operation experience of similar related reclaimed water projects, the operation cost of deep treatment of reclaimed water per cubic meter is about 0.48 yuan/cubic meter. The annual treatment scale of the recycling project of qige sewage treatment plant is 900,000 m³/d, and the annual operation cost is 157.68 million yuan. The length of the sewage pipeline of the sewage treatment plant is 18.3 kilometers. The annual maintenance cost of the unit sewage pipeline is 20,000 yuan/km, and the annual maintenance cost of the water delivery system is 366,000 yuan.

3. Management costs. It is mainly related to wages, benefits, management and other related expenses. Generally, the depreciation amount is taken from wages, benefits, management and other expenses, and then 15% of the total of the above expenses is calculated. Then the management cost is: 

\[(527.6+15768+36.6) *15%= 24.498,000 \text{ yuan}.\]

4. Transportation cost. As can be seen from formula (1), the transportation cost is mainly affected by the length of sewage pipeline, the amount of sewage and the depreciation rate, so the transportation cost is 5.628 million yuan.

By the sum of the above costs, the cost of reclaimed water is 193,448 million yuan.

Then the unit water cost is calculated as:

\[
P_\text{w} = \frac{19344.8}{365*90*60%} = 0.98
\]

3.3. Hangzhou city renewable water price calculation

In order to encourage sewage recovery and promote the development of reclaimed water, the national policy requires the research and development of tax policies to encourage the production and use of reclaimed water. According to the "measures for the administration of urban water supply price", the price of reclaimed water in Hangzhou is 0.98* (1+6%) =1.03 yuan/m³ if the average profit rate of the recycled water industry is 6%. According to the price approved by Hangzhou price bureau, the tax-inclusive price of reclaimed water is 1.32 yuan per cubic meter. The price predicted by the price model of recycled water in the supply chain environment is not much different from that of tap water, as shown in table 1.

| Use                        | Residents live | Non-operating water | Commercial water | Water for special industry |
|----------------------------|----------------|---------------------|------------------|---------------------------|
| Tap water price            | 2.58           | 3.85                | 3.95             | 12                        |
| The ratio of reclaimed water to tap water | 0.36           | 0.26                | 0.26             | 0.08                      |

Can be seen from table 1, water is the lowest price, the price of the recycled water is only 36% of the price of water, for the management and running water, reclaimed water price for 26% of the price of water, reclaimed water price advantage is very obvious, therefore, according to the reclaimed water price under the environment of supply chain model of price is acceptable.
4. Advice
This article mainly from the Angle of the supply chain to the reclaimed water price formulation study, through the establishment of reclaimed water supply chain cost model to study of reclaimed water price, the results show that under the environment of supply chain, making the recycled water price is acceptable, in order to make more reasonable reclaimed water price, this paper puts forward three Suggestions as follows:

(1) As a substitute of tap water, the price of reclaimed water should be set according to the tap water price. The price of tap water is different for different USES. Therefore, when setting the price of reclaimed water, we should not only refer to the tap water price, but also make the corresponding price according to the different USES of reclaimed water.

(2) Establish and improve water pricing system to promote the demand of renewable water market. As shown in table 1 above, there is a certain water price proportional relationship between the prices of reclaimed water and tap water. Therefore, it is necessary to establish a reasonable price comparison relationship between the costs of reclaimed water, tap water and sewage treatment, so as to provide a basis for formulating a reasonable price of reclaimed water.

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