Beneficial Evaluation of Residential Dual Water Supply System

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Abstract. The scientific development and utilization of regional unconventional water resources and the implementation of high-quality water supply at the county level is beneficial both in the water resources allocation and the water shortage alleviation. It is also important in improving the human society as well as protecting the ecological environment, which shows significant economic, social and environmental benefits. The beneficial evaluation analysis of the development and utilization of regional unconventional water resources and the potential of dual water supply are conducted in this study. The reasonable beneficial evaluation of the utilization of unconventional water resources and regional dual water supply system are of great significance to the regional effective water sources allocation and water supply method.

1.Introduction

The total amount of water resources in China is about 2800 billion m^3, ranking the 6th in the world, however, the total amount of water resources per capita in China is only 2400 m^3, which si only 1/4 of the world's per capita level, ranking the 121st in the world. Therefore, China is always recognized as a typical water-poor country. With the development of economy and society, the increasing demand for water resources lead to a series of water resources problems in China. Nowadays, the Chinese urbanization rate has increased from 17.9% in 1978 to 53% in 2020, hence, the urban water shortage is increasingly obvious. Currently, more than 2/3 of 661 cities in China are in water shortage condition, and more than 100 cities face serious water shortage. Due to the limitation of water resources and the difficulty of reservoir construction, as well as the increasing demand for water resources, the rapid economic and social development in recent years, the contradiction between water supply and water demand of the typical Chinese water shortage cities have become increasingly dominant. It is also widely known that the shortage of water resources has become an important constraint factor for the sustainable and rapid development of the Chinese economy [1-3].

This study adopts the comprehensive beneficial method to evaluate the dual water supply system based on quantity and quality analyze of the advantages and disadvantages of water supply system in Yiwu city, which is recognized as a severe water shortage area in China. It plays a positive role in the regional water resources allocation, such as the utilization of Yiwu River water, the industrial tail water recycling, the domestic sewage recycling and other unconventional water resources. Additionally, both the construction of water supply project and the scientific management of the regional water resources are also considered in this study[3-5]. On the basis of the comprehensive benefit evaluation of water supply, the water supply system in Yiwu city will be improved and the application of unconventional water resources in this city will also become more effective and accurate.

Currently, many countries, such as the United States, Japan, Israel and Singapore, have successfully implemented the differentiated water supply in various fields and achieved good results, as shown in Figure 1. Los Angeles city plans to use 69% of the total sewage by 2050, which is equivalent to 42% of the city's total water demand. As a good alternative of fresh water, reclaimed water becomes an important part of urban water supply in the United States. By the end of 2020, Japan has built 2789 reclaimed water utilization facilities, which are mainly used for the reuse of urban sewage and the dual water supply. While Israel has utilized 210 municipal sewage reuse projects to recycle 100% of domestic sewage and 72% of municipal sewage [6,7].

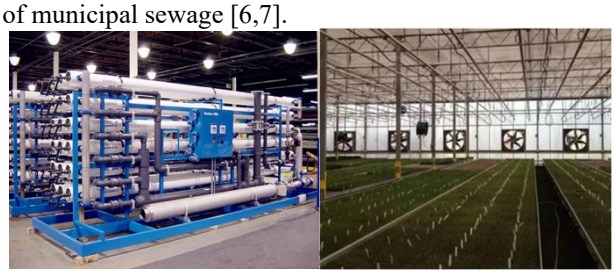

Figure 1. Typical dual water supply system in USA

2.Evaluation method

2.1.Evaluation index

It is not only effective way to alleviate the contradiction

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between water supply and water demand , but also an useful method to reduce the discharge of pollutants, which is helpful to improve the awareness of water conservation and the ecological environment in human society. As a result, in this study, the establishment of effective water supply system and the beneficial evaluation method account for the dual water supply has been focused. The indicators of the beneficial evaluation method established in this study are shown in Table 1 .

Table 1. Setting Word's margins

Target	Criterion	No.	Index	Remark
Comprehensive benefits of differentiated water supply	Social and economic benefits	1	Water saving cost	Mandatory
		2	Water saving in the whole	Mandatory
		3	Amount of fresh water replaced	Mandatory
		4	Yield benefit per cubic meter of	Mandatory
		5	Output of crop irrigation or	Alternative
		6	Sewage discharge	Mandatory
	Ecological and environmental benefits	7	Improvement degree of surface	Mandatory
		8	Benefits of saving fresh and	Mandatory
		9	County-level unified	Alternative
		10	Water-saving awareness	Alternative

2.2.Evaluation formula

The analytic hierarchy process (AHP) is applied in this study, which is widely used around the world to construct different types of evaluation system. According to the principle of analytic hierarchy process, the weight of each evaluation index in the system is determined based on their importance, and the evaluation score is given as [6-8],

$$TG = \sum_{i=1,j=1}^{n}\left[\sum_{j=1}^{m}\left(A_j \times P_j\right)\right]C_i \quad (1)$$

Where TG is the score for a specific index, A_j is the weight of the index, P_j is the evaluation result, C_i is the weight of the criterion.

2.3.Evaluation level

The social and economic benefits as well as the ecological and environmental benefits of the qualitative water supply system in Yiwu city is calculated and analyzed in this study, and final evaluation score of the target layer on the basis of the grading of each level is shown in Table 2. Indeed, the comprehensive benefits of the regional dual water supply system are divided into four levels, which have different evaluation status as shown in Table 2 and Table 3.

Table 2. Evaluation weight of different level

Target	weight	Criterion	Weight	Index	Weight	Remark
Comprehensive benefits of dual water supply	1.0	Social and economic benefits	0.6	Water saving cost	0.2	Mandatory
				Water saving in the whole process	0.2	Mandatory
				Amount of fresh water replaced by	0.3	Mandatory
				Yield benefit per cubic meter of water	0.3	Mandatory
				Output of crop irrigation or industrial	0.2	Alternative
				Sewage discharge reduction	0.4	Mandatory
		Ecological and environmental benefits	0.4	Improvement degree of surface water	0.3	Mandatory
				Benefits of saving fresh and high-	0.3	Mandatory
				County-level unified management	0.1	Alternative
				Water-saving awareness	0.1	Alternative

Note: If optional indicators are included, then the total weight score benchmark will be 1.2, and the corresponding criterion layer score should be multiplied by the transformation coefficient: 0.833 (1/1.2).

Table 3. Evaluation level used in this study

Level	Target	Status	Color
I	[80,100)	Excellent	
II	[60,80)	Good	
III	[30,60)	Qualified	
IV	[0,30)	Unqualified	

3.Case study

Yiwu city located in the middle of Zhejiang Province, southeastern China. Yiwu city has an average annual precipitation of 1406.2mm, the surface water runoff of 730 million m^3 and a total groundwater resource of 128.29 million m^3. Hence, the total water resources of Yiwu city is only 820 million m^3. There are 106 reservoirs built in Yiwu city, with a total storage capacity of 195 million m^3. The total storage capacity of those reservoirs basically meet the requirements of urban water supply demands, however, the water supply capacity is still worse during the dry season. At the same time, although several water diversion projects are constructed in the last decades, the water supply capacity is still embarrassing since the high

quality water resources are still precious in Yiwu city as shown in Figure 2. It is anticipated the river water source can be developed and utilized through environmental improvement and engineering measures to serve as industrial water, municipal water and landscape water in the future.

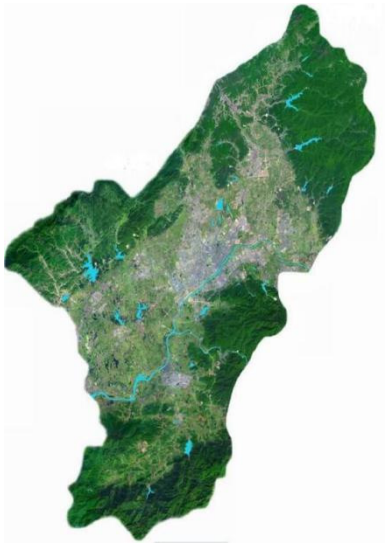

Figure 2. The topographic map of Yiwu city

In the year of 2020, the water supply capacity of the dual water supply system in Yiwu city is relatively high. There are four water supply plants in Yiwu city, namely, Shuangjiang industrial water plant, Yijiashan industrial water plant, Choujiang industrial water plant and Sufu industrial water plant, with the water treatment capacity of 50400 m^3/d, 18100 m^3/d, 10100 m^3/d and 49700 m^3/d, respectively. The utilization of unconventional water in Yiwu city reached 20.44 billion m^3 in 2020, the utilization rate of the unconventional water reached 8%.

Hence, based on the data collected in this study, the water saving cost in Yiwu city of the dual water supply in 2020 is 57.232 million yuan, which is calculated according to the average guiding price of the residential reclaimed water of Yiwu, which is approximately 1.7 yuan/m^3, and the average guiding price of the regeneration level for non-residents of 2.8 yuan/m^3. Additionally, and the amount of unconventional water replacing fresh water is 43.143 million m^3 in 2020, which is relatively higher that the other cities in Zhejiang province. As a result, the net benefit per cubic meter of water is about 483.1 yuan/m^3 considering both the unconventional and conventional water resources.

Therefore, based on the scoring criteria in Table 2 and Table 3, the index evaluation score of the criterion layer of social and economic benefits of the dual water supply in Yiwu city is obtained in Table 4.

Table 4. Social and economic benefits

Criterion	Index	Factors			Criterion
		Score	Weight	Result	
Social and economic benefits	Water saving cost	100	0.2	20	96.7
	Water saving in the whole process	80	0.2	16	
	Amount of fresh water replaced by unconventional water	100	0.3	30	
	Yield benefit per cubic meter of water	100	0.3	30	
	Output of crop irrigation or industrial reuse products	100	0.2	20	

In 2020, the water supply projects in Yiwu city received a total of 3.68 million m^3 of tail water from the wastewater treatment plant, and the internal recycling treatment rate of some industrial enterprises reached more than 50%. In this study, 40% of the internal recycling water efficiency of enterprises is considered, and the sewage discharge of some enterprises in low water consumption industries was reduced. While the output of industrial water plant in Yiwu city is about 56 million m^3/year, and it is estimated that the annual sewage reduction in Yiwu city reaches 17.68 million m^3/year. According to the calculation of the annual wastewater reduction in Yiwu city, the wastewater treatment plants in Yiwu city generally meet or exceed the Class I A standard of the National Effluent Standard for Urban Sewage Treatment Plants. The annual improvement of surface water quality in Yiwu city is calculated by COD concentration, and the annual COD reduction reaches 884 tons. At the same time, according to the calculation in the previous section, Yiwu city saves 43.143 million m^3 of fresh and high-quality water every year by promoting dual water supply system. The water resource fee is 0.2 yuan/m^3 for the fresh water, 2.2 yuan/m^3 for the water used by regional household, and 3.6 yuan/m^3 for the water used by industrial enterprises. It is estimated that 81.72 million yuan is saved annually by using the reclaimed water. The unified management rate of Yiwu municipal wastewater recycling project reaches 100%, and the four reclaimed water plants are under the jurisdiction of the county level. The residents of Yiwu city have a strong awareness of water conservation since Yiwu is a region of extreme water shortage in Zhejiang province, China.

Eventually, according to the scoring criteria in Table 2 to Table 3, the evaluation score of ecological and environmental benefits of dual water supply system in Yiwu city is obtained in Table 5.

Table 5. Ecological and environmental benefits

Criterion	Index	Score	Factor Weight	Result	Criterion
Ecological and environmental benefits	Sewage discharge reduction	80	0.4	32	88.3
	Improvement degree of surface water quality	80	0.3	24	
	Benefits of saving fresh and high-quality water	100	0.3	30	
	County-level unified management rate of sewage regeneration and reuse project	100	0.1	10	
	Water-saving awareness	100	0.1	10	

According to the comprehensive analysis in this study, the total score of the dual water supply system in Yiwu city is 96.7 at the level of social and economic benefits and 88.3 at the level of ecological and environmental benefits. As a result, the total score of comprehensive benefits of dual water supply in Yiwu reaches 93.3, which is shown in Table 6.

Table 6. Evaluation results of the comprehensive benefits

Target	Weight	Criterion	Weight	Criterion	Result
Comprehensive benefits of dual water supply	1.0	Social and economic benefits	0.6	96.7	93.3
		Ecological and environmental benefits	0.4	88.3	

Generally, the qualitative water supply evaluation model is established in this study and is used to comprehensively evaluate the social and economic benefits and ecological environmental benefits of the qualitative dual water supply system in Yiwu city. The evaluation results show that the score of the criterion level of social and economic benefits is 96.7, and the score of the criterion level of ecological environmental benefits is 88.3, both reaching a high level. Combined with the grading weight of the AHP evaluation model, the total score of the comprehensive benefit of water supply in Yiwu is 93.3.

According to the classification in Table 3, the comprehensive benefit of water supply in Yiwu is Grade I, with excellent comprehensive benefit.

4.Conclusion

This study evaluated the comprehensive benefits of the dual water supply work in Yiwu city, and then the social economic benefits and ecological environmental benefits of the differentiated water supply is visualized. Based on the AHP method, this study establishes a qualitative water supply evaluation model. On the basis of data collecting and analyzing, different weight coefficients are given to the three-level index system respectively. At the index level, 10 evaluation indicators are set, of which 7 are mandatory indicators and 3 are optional indicators. According to the different evaluation objects, based on the evaluation system, different scoring standards and index weight coefficients are set for 10 evaluation indicators. Finally, a comprehensive benefit evaluation model of dual water supply system in Yiwu city is formulated and evaluated, the total score of the comprehensive benefit of water supply in Yiwu is 93.3, and the comprehensive benefit of water supply in Yiwu is Grade I, with excellent comprehensive benefit.

Acknowledgments

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