Research on Recycle and Utilization of Reused Water in Shenzhen

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Abstract: China has put great effort into alleviating the severe water shortage. Among all the methods, reused water is the most effective and likely to be promoted. This paper gathers data on urban water use, existing domestic sewage treatment, the policy being implemented, and the domestic sewage recycling project in Shenzhen. Through relevant data and surveys, this paper analyses the feasibility of the reused water industry and the barriers it faces. The research has found that reused water can effectively relieve water use pressure, what's more, it also pointed out people's low acceptance, immature market systems, and technology are the problems that need to be solved. Finally, this paper points out that the project of reused water should cooperate with the industrial structure and people's willingness of the city. Besides, in order to make sure the reused water project is steady in the long term, more relevant laws and regulatory measures should also be taken. As an experimental unit, Shenzhen has taken the lead in this country-scale project, so the experiences will contribute a lot to other cities' projects. This research can provide a reference for the reused water projects construction.

1 INTRODUCTION

China is a country with a severe shortage of water resources, per capita water resources is only a quarter of the world standard. Typically, in big cities, like Shenzhen, water management faces a more serious situation. Shenzhen, a first-tier city in China, has an area of 1997 square kilometers and a population of 8806 per square kilometer. As a result of insufficient water storage capacity, over 80% of water use relies on remote flow. The construction land contains a large amount of population, and the industries are mostly high-end manufacturing, which requires huge water consumption. Therefore, seeking an effective way to use water has become one of the most urgent.

Reused water, as a resultful method to manage water resources, has been proven to improve the efficiency of urban water use. Reuse water has rich experience in many countries, such as Singapore, Israel, and America. Singapore has a high-density of population and a shortage of fresh water. Since the '90s, they have put great effort into deep treatment of domestic sewage, and blending the reuse water in tap water. Used water is collected and purified by membrane and ultraviolet rays to become reused water (Teng, 2023). According to data, reused water accounts for 30% of the total water supply. Five water treatment plants produce 227.3 thousand m^3 reused water per day. Israel is located in western Asia, where the average annual rainfall is below 200mm. Since 2000, Israel has invested 750 million dollars in sewage treatment. The proportion of water cycling has ranked high in the world. Thanks to the advanced water purification equipment, 90% of sewage in Israel can become reused water, which will be used in desert agriculture. In America, water distribution is unequal. Some states, such as California, Texas, Florida, and Arizona, still lack water resources and overly exploit underground water. In this respect, not only does America have a detailed plan, but also has a complete law and regulatory system. Take Florida as an example, it has concentrated water use. Based on that, the state uses a double pipes water supply system on a large scale, selling the reuse water to golf courses, rain gardens, and so on with a 40% price of tap water. The method wins considerable benefits for both economy and society. In conclusion, through corresponding government support, process management, and terminal supervision, the reused water industry can be copied into different regions with different climates, environments, and cultures. Shortage of water resources is a barrier to sustainable

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development in China, the reuse of water can be an effective method to ease the contradiction between supply and demand. Those international experiences are positive references to developing the reused water industry.

Based on existing research and data, the paper is aimed at exploring the feasibility of domestic sewage collection, purification, and reuse, and inferring the premises and problems.

2 EXPERIENCE IN REUSED WATER DEVELOPMENT

Reused water is a kind of water that meets certain water quality standards through proper treatment, and reaches the requirement of recycling (Zhang et al., 2024). In general, reused water has three practical features. Firstly, reused water comes from urban sewage, so in theory, the source of reused water is stable (Yang et al., 2024). Reused water is convenient, as a result of receiving little seasonal and geographical influence. From a societal point of view, reused water can promote sustainable development, which brings huge economic and ecological benefits.

The basis of the reused water industry is sewage treatment, so it is important to know exactly how the water is processed. The existing sewage treatment includes three steps. The primary treatment, also named preconditioning, is mostly physical treatment. The grills, grit basins, and settling basins will remove the solid contaminants. The secondary treatment is mostly biochemical treatment, aiming at eliminating organic pollutants in water. So far, the most advanced treatments are the activated sludge process and the biofilm process. The tertiary treatment is also named advanced treatment. It mainly removes nitrogen, phosphorus, and organic pollutants that are hard to remove in the last treatment. Once the water has been advanced treated, it is mostly used for reusing.

So far, the recycling of urban sewage is still in exploration in China. Guiding Opinions on Promoting the Utilization of Sewage Resources, released in January 2021, provides guides for unconventional water resources including reuse water. During the exploration, the pilot project that set up experimental units in 13 cities provided valuable experience. Among them, Shenzhen has used 335 million m^3 of reuse water in the first half of 2023, with a utilization rate of 34% (Fan & Li, 2024). The experience of Shenzhen has shown the update of sewage treatment is beneficial to effectively alleviate the contradiction between the supply and demand of regional water resources and promote the application of water economical application.

3 EXISTING SEWAGE WATER PROJECT

Urban sewage can be classified into domestic sewage, industrial sewage, and incipient rainwater. This paper mainly discusses the reuse of domestic sewage.

3.1 Features of Domestic Sewage and Frequently Used Sewage Water Treatment

Domestic sewage is mainly from residential buildings and public buildings. Domestic sewage has three features. First of all, its quantity and quality changes with the seasons. Secondly, in terms of composition, it hardly contains toxic and harmful substances. And the last, it can be easily processed by biochemical methods. However, bacteria and odor of the sewage can spread the disease easily, and untreated emissions may cause serious environmental issues. That is why sewage treatment is an important research project.

Advanced treatment is an indispensable part of reused water production. The methods that are commonly used can be classified as physical, chemical, and biological methods. One of the industrialized water treatment methods is adsorption, using adsorption resin to remove organic pollutants. It can control the SS under 5mg/L and reduce the chroma to 1/20 of the sewage (Huang et al., 2024). However, due to the material capacity, the speed of treatment is slower than other methods, limiting its development. Ozone catalytic oxidation is the most advanced chemical method, which is useful when there are complex organic pollutants. However, it is not universally used due to the uncomprehending produce condition and the limited technology. Biological methods include the activated sludge method, ecological revetment, solar restoration, and constructed wetlands. Among them, the constructed wetland is one of the most promising methods because of its high penetration and low emission. The constructed wetland has low cost and less secondary pollution. 60 acres of wetland of reeds and wild rice stems in Linfen County can degrade 404.8kg BOD_5 per day (Gao, 2024). Constructed wetland is the most promising method if seasonal and regional constraints can be solved. To sum up, these treatments have some barriers that limit their development. Technology needs to be improved to become the foundation of the

reused water industry.

3.2 Present Situation of Reused Water Treatment in Shenzhen

According to the data released in 2022, Domestic sewage in Shenzhen is 844 million m³, accounting for 38.9% of total sewage. Shenzhen does not have any technical reused water plant, but it has 43 water purification plants that produce 5.84 million m³ reused water per day, which meets the demand of water quality standards (Cai et al., 2024).

Not only Shenzhen but also most big cities in China have similar problems in developing the reused water industry. Firstly, the proportion of reused water use is low. And, the supply target users is simplex. The reasons for this situation are obvious. The higher cost, immature technology, insufficient investment, and the low accept rate of users. To deal with these barriers, the government and the market took different measures. Governments made relevant laws and set experimental units in different provinces, which reaped great experience in Shenzhen.

4 REUSE THE PROCESSED WATER

4.1 Analysis of Concentrated Use of Reused Water in Shenzhen

Relative agencies conducted a detailed survey of 83 potential users, including municipal and industry use. The survey made the regions and industries that need reused water more clear. The result revealed that the potential reused water will likely replace conventional water resources for 100 million m³ in 2025, and the consumption of reused water will reach 85-106 billion m³in 2030 (Liu et al., 2024). In Shenzhen, reused water was mostly industry cooling water, urban miscellaneous water, and river recharge.

In the new reused water project, three phases target different users. In the first phase (to 2025), the reused water will be used for industry cooling water and municipal miscellaneous water, such as road flushing and greenbelt watering. In the second phase (2025-2030), the reused water will be also used for central cooling. In the last phase (2030-2035), it will be gradually used in electronic equipment manufacturing, communication, the computer industry, and other high-quality users. These are the most economical uses for reused water in existing technology, and they are more acceptable to people than delivering the reused water directly to the urban water supply pipes.

4.2 Reused Water Programme

As one of the first experimental cities, Shenzhen made great achievements in the reused water industry. Moreover, Shenzhen set 4 experiment units in the city to detail the goal, providing valuable experiences for reused water development in the big city. There are Guangming District, Pingshan High-tech zone, Longhua District Jiulong mount region, and Longgang District Henggang region. As built-up areas, these regions have complete water supply projects and balanced population and industry density, which provides a good condition for building a water recycling system. These regions have 4 reasons why they were chosen to be the experiment units: big demand for reused water, concentrated object, strong using willingness, and high feasibility of facility construction. Reused water systems were first built in these regions to explore constructed experiences. These experiences will be used for building water recycling systems in other regions and other cities. Shenzhen is a template for efficient and sustainable development of domestic sewage reuse.

In addition, the government set five directions to explore the decentralized utilization of reused water. Combined utilization of reused water and rainwater, distributed reused water circulation, regional water recycling without sewage discharge, reused water utilization in high-density development zones, and diverse reused water source construction and utilization. Aiming to build high-efficiency and low-discharge water recycling systems, incentive measures are also taken to fuel policy implementation.

5 POSITIVE CONDITIONS AND PROBLEMS OF REUSED WATER DEVELOPMENT IN SHENZHEN

Setting Shenzhen as one of the first cities that built a comprehensive reused water system has five aspects of the reasons. First of all, Shenzhen, an economic special area, is where most policies are preferred. Governments are likely to set Shenzhen as an experimental zone because of its flexibility and containment. Secondly, the economy is booming. The market plays an important role in reused water. Beijing, also a first-tier city, attracted private company investment to promote the government

project. The mainstream of reused water facilities in Shenzhen is business format franchising, the government invests to build most infrastructure and private companies account for a small part (Zhang, 2023). Thirdly, infrastructure construction is easier than in other cities with a longer history. Shenzhen is a young and dynamic city, the space for creation is abundant and the technology it applies is mostly first-tier, and it is more adjustable and flexible. Moreover, Shenzhen released policies and welfare for scientific and technological talents. The last is high social inclusion. According to the data in August 2023, the average age of Shenzhen citizens is 32.02, which is the lowest in first-tier cities. Creation has been a fashion in the city since the Reform and Opening Up. So, people have a higher acceptability of new water resources, which makes policy implementation easier.

However, there are problems in promoting reused water recycling. Four existing problems limit the development of reused water. Firstly, the relative laws and the supervision systems are inadequate. Secondly, the price and the ROI do not have an acknowledged standard. Thirdly, the immature technology restricts the speed and quality of reused water production. And last, many people do not accept reused water because of the worry of water quality. Subsequent projects should emphasize these barriers.

To deal with these problems, governments have taken corresponding measures. In policy, the Shenzhen reused water layout project (2008-2020) has expired, as the requirements have changed. So, the new Shenzhen reused water layout project (2021-2035) is in progress. In the market, exploration of a combination of government-led and market-based models is necessary for the operation of reused water. Referring to the pricing principle of tap water, the price of reused water should be set by the government (Hu & Yang, 2021). However, the key to breaking the barriers is letting people accept reused water.

6 OUTLOOK

Over decades, Shenzhen has long been constrained by severe water shortage, which has made it necessary to explore effective ways to promote reused water. For the call from the central government, Shenzhen will be the model for the future establishment of reused water systems in different cities, which means it shoulders great responsibility and lack of experience. A lot of work has been invested in policies, standards, technology, infrastructure, and markets. Undoubtedly, a lot of problems need to be summarized. In the future, Shenzhen will keep developing high-tech industries including chips and precision instruments, which require a lot of water. However, the domestic sewage system still has multiple barriers before industrialization. One of the most important factors is the will of people. It is not only in consideration of the safety but also the water rate. So the publicity of the process of water treatment and the formulation of supervise laws are necessary. Meanwhile, it is essential to reduce the water rate by researching reused water technology. The reused water industry is the foundation of Shenzhen's economy in the future, so the project is of great significance. What's more, the project of reused water in Shenzhen is very useful for other cities, especially coastal cities with developed economies.

7 CONCLUSION

Through research, this paper summarizes the situation of reused water in Shenzhen and finds the prospect of reused water in Shenzhen is promising. In detail, this paper finds that the most practical method is constructing wetlands at present, and the processed water can be mostly used for industrial cooling water, urban miscellaneous water, and river recharge. To ensure the normal operation of the reused water system, the government has put forward many related policies, such as reducing water costs and attracting investment. However, this paper also finds several problems to solve. For example, supervision systems and pricing standards are not mature yet. What's more, the safety of reused water causes a low willingness of people to use it. As a result, reused water lacks market vitality and is difficult to expand. Although the government has put great effort deal with these problems, it will still take a long time to solve the problem of water shortage. So far, the study still has shortcomings. Firstly, the judgment of reused water quality can be more detailed. Municipal departments can classify water use according to its quality to save the cost of treatment. Secondly, more surveys can be conducted. The government should know which regions and industries need more reused water. Based on that, sewage treatment plants, pipes, and other facilities can be set up in proper places. Finally, industrial structure and funding are very important for a city that is going to construct reused water systems. Before construction, research and surveys are necessary. This paper's investigation can contribute to future water infrastructure, and provide experiences for water system construction in other cities.

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