A Review of Water Reclamation Research in China Urban Landscape Design and Planning Practice

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Abstract. With the continuously growing demand for better living environment, more and more attention and efforts have been paid to the improvement of urban landscape. However, the expansion of green area and water features are at the cost of high consumption of water resources, which has become prominent problems in cities that suffer from water shortage. At the same time, with the water shortage and water environment deterioration problems that shared globally, water conservation has become an inevitable choice to achieve sustainable social development. Urban landscape is not simply a consuming body of water resources, but also are of water-saving potential and able to perform the function of water storage. Thus, recycling the limited water resources becomes a challenge for every landscape designer. This paper is intended to overview the existing effort of reclaimed water recycle research in China landscape designing fields, and raise recommendations for future research and development.

1. Background
The concept of reclaimed water is usually relative to tap water and the waste water (discharged into the pipeline of sewage), refers to the wastewater appropriately treated to meet certain water quality standards, recycled and qualified for certain domestic (not drinkable) and industrial usage. Reclaimed water reuse can not only greatly slow down pace of the natural surface water and groundwater consumption, alleviate the shortage of water resources, ecological and geological problems, but also reduce the discharge of wastewater, effectively inhibit the environmental pollution of wastewater discharge. Therefore, the study of water reuse is of practical significance. This section is to introduce the existing international effort of water reclamation and the water recycle research in China landscape design and planning fields.

2. Overview of water recycling research for landscape design

2.1. Water recycling research for landscape design at international scale
The idea of recycling reclaimed water had already been widely in 1930s, and those reclaimed water were mostly used for urban landscape scenic water [1]. Internationally, the study of water reuse has been developed relatively well in some developed countries, where supportive policies have been introduced as well.

The United States has been one of the first counties to implement water reuse. According to the US Environmental Protection Agency, the reclaimed water shall not be used as drinking water and is mainly limited to landscape, ecological and industrial use. In 1923, the first large-scale sewage water recycling
project for landscape usage was established in San Francisco, which filled the lake in parks with reclaimed water and had aroused significant impact over the world. Since then, more than 300 cities in the United States have establish sewage treatment projects, the recycling of reclaimed water has been further improved, greatly alleviated the contradiction between water and achieved the efficient use of water resources to some extent [2].

In Australia, a project located in the residential area around the Moxon Lake in Adelaide has been established to collect the sewage water and the rainwater from rooftop, and to meet the supply of Monson Lake water, residential water and landscape land irrigation after reclamation treatment.

In Japan, with its complex terrain and short rivers, the shortage of fresh water resources has urged the promotion of water reuse research in Japan. Currently, about 65% of the total population in Japan are using reclaimed water, and the national average annual use of circulating water has amounted to 1.5 × 108m³. A guideline for the reuse of water resources was introduced by Tokyo government in 1984, requiring the use of recycled water in buildings where construction area exceeded 3 × 10⁴ m² or daily water consumption reached 100 m³. Reclaimed water has been widely used in four aspects in Japan: household water reuse system, regional water reuse system, regional water reuse system and industrial water use system [3].

In 2000, the Jurong Island Industrial Park of Singapore, a set of urban sewage depth treatment device was constructed, with the scale of reclaimed water production of 30,000 m³·d⁻¹, and the treated water was mainly used for landscape water and fire water system (Chenxiang Xia, 2007).

South Africa, one of the countries with the most serious water shortage problem, has been relatively more mature in its research on water treatment and reuse. About 22% of the country's water resources are recycled water. South Africa has established a dedicated sewage treatment agency to reclaim waste water and deliver to various areas for reuse, to meet the country’s water needs [1].

European countries, Saudi Arabia, Mexico and other countries are also actively studying the methods and forms of reclaimed water reuse, and has achieved a series of results for the recycling of water resources to contribute [1].

2.2. Water recycling research for landscape design of China

Compared with foreign countries, China's water shortage has been paid attention relatively later, and the water reuse technology related research and development were first carried out in late 1980s. From 1986 onwards, the China government included the urban sewage resources exploitation in the "Seventh-Five" "Eighth-Five" and "Ninth Five-Year Plan", and gradually accept and explore the water reuse in the urban landscape fields.

The water pollution control and urban sewage technology were included in the national "Seventh-Five" research program (1986 - 1990). Tianjin, Beijing, Dalian, Taiyuan, Xi'an and other water-saving cities have carried out on the sewage regeneration technology and technology research, among which, Tianjin developed a "Tianjin landscape river water quality standards", beginning the attempt of applying Class two treated water that treated by Jizhuangzi sewage treatment plant for the landscape supplement [4].

Later, the national "eight five" research program has included the sewage resources and sewage reuse into the major research projects. During the "Eighth Five-Year Plan" period, Beijing Gaobeidian sewage treatment plant, the North River sewage treatment plant, Jixianqiao sewage treatment plant, Shijiazhuang West sewage treatment plant, Shandong Tai'an City sewage treatment plants and some other recycle water plants that were intended for urban landscape water usage had been completed and put into production [4]. After being recycled and treated to certain standard of purification, part of the water would be supplied to urban landscape and river water body. Among them, the Beijing Beixiaohu sewage treatment supplied 20000m³ / d of recycled water to greening, river water supplement; Shenzhen Glacier City Sewage Treatment Plant secondary effluent 20000m³ / d reclaimed water for three-level treatment for park greening and landscape water [4]. Supplying reclaimed water as a city landscape ecological water source revealed that China began to gradually accept and explore the use of reclaimed water in urban landscape [5].
In the "Ninth Five-Year Plan" (1996-2000), China began to study the key technologies of sewage treatment and water industry. During the period of the 10th Five-Year Plan (2001-2005), the water reuse was formally written into the document. The research on the utilization technology and demonstration projects of urban sewage resources was also carried out in a comprehensive manner. Beijing, Tianjin, Qingdao and other cities have set up a batch of landscape water reuse demonstration projects to demonstrate the reuse of recycled water in China's landscape water engineering practice. Subsequently, in the "Eleventh Five-Year" plan (2006-2010), the water reuse and urban sewage treatment works were listed as one of the nine key projects supported by the government. During the 12th Five-Year Plan period, China has further promoted the recycling of sewage in the landscape. Beijing, Dalian and other cities have increased their use of reclaimed water every year. The reclaimed water has been used to remedy the drying rivers and rebuild the river landscape. Currently, many cities in China has started to rectify rivers and water bodies heavily polluted which due to various improper maintenance. However, plenty of available water resources were wasted and thus led to harsher environmental problems. Blindly using clean water resources to replace the polluted rivers and water bodies without in-depth study of how to better maintain the purification of water would eventually lead to gradually deteriorating water quality and require more water for replacement, which would undoubtedly be a great waste of existing resources. In recent years, Beijing, Shenzhen and other cities has been dealing with the reclaimed sewage water after further purification and put it into the use as urban landscape water, which has played a positive role in promoting China's urban landscape water recycling research.

3. Reclaimed water quality standards and remediation methods

3.1. Reclaimed Water Quality Standards
The main control indicators of recycle water quality are pH value, color, turbidity, BOD_5, CODcr, dissolved oxygen and phosphorus, nitrogen, etc. These indicators reflect the evaluation of equipment corrosion, sensory comfort, water safety and water quality maintaining and so on. Among several standards for water quality published by China government, The Reuse of Urban Recycling Water. Water Quality Standard for Scenic Environment Use (GB / T18921-2002) has been the standard for the assessment of landscape water quality, which suggests water reuse for urban landscape scenic water quality indicators in table 1 as followed:

| Index | Indicator                          | Recycle Water Quality Standards                   |
|-------|------------------------------------|---------------------------------------------------|
| 1     | Basic requirements                  | No floating matter, No unpleasant smell and flavor |
| 2     | PH value                            | 6.0~9.0                                           |
| 3     | Chroma (degrees)                    | ≤30                                                |
| 4     | Turbidity (NTU)                     | ≤10                                                |
| 5     | Suspended solids (mg / L)           | ≤15                                                |
| 6     | Soluble solids (mg / L)             | ≤1000                                              |
| 7     | BOD5 (mg/L)                         | ≤10                                                |
| 8     | CODcr (mg/L)                        | ≤50                                                |
| 9     | Total phosphorus (calculated as P) (mg / L) | ≤1.0                                               |
| 10    | Total nitrogen (mg / L)             | ≤15                                                |
| 11    | Ammonia (in N) (mg / L)             | ≤5                                                |
| 12    | Residual chlorine (mg / L)          | ≥0.05                                              |
| 13    | Dissolved Oxygen (mg / L)           | ≥1.5                                               |
| 14    | Anionic Surfactant (mg / L)         | ≤0.5                                               |
| 15    | Fecal coliform (a / L)              | ≤10000                                             |
4. Remediation methods

4.1. Physical and chemistry remediation
Among several factors that impact the sustainability of water resources and runoff pollution, water pollution is particularly prominent and cause the waste of water resources in urban landscape construction process. For scenic water that of strong liquidity, purification facilities, such as the filter dam, the filter sand tank, etc. are applicable in the early stage of design, to maintain water quality and reduce the turbidity naturally with the natural flow of water. However, for artificial water with poor fluidity, slow flow, small size, and were mostly closed, the water body itself is often of poor self-purification capacity, vulnerable to secondary pollution, and would indirectly affect the visual effects of the landscape. Thus, to control the water resource exogenously, restore water body physically while adding chemical agents to remove water pollutants are commonly used as solution to achieve water purification and maintenance.

4.2. Bioremediation methods
Aquatic plants have been playing a certain role in the purification of sewage, they can absorb and filter contaminants in the water through roots, thus cultivation of aquatic plants in landscape water is an effective way to repair the reclaimed water quality. The ecological repair technology has its unique advantage. The cost of this repair technology and adverse effects on natural environment are relatively low, and a reasonable design with aquatic plants can also create a rich aquatic landscape and enhance the environment. Nevertheless, the water purification function of aquatic plants produces the desired effect relatively slower compared with other artificial technology, and would also be impacted by seasons and temperatures.

5. Problems and suggestions for improvement of reclaimed water reuse in China

5.1. Existing problems of water reuse in China

5.1.1. Public awareness. Public awareness is the prerequisite and basis for supporting water recycle for landscape use. In southern China, especially in some coastal cities, it is generally believed that water resources are rich, thus lead to weak consciousness of water recycle and water resources, and a considerable part of the public has not yet formed the concept of water reuse. Without public awareness and acceptance of water reuse, even in those northern cities that short of water resources, the reclamation and recycle of water difficult would be hard to achieve. Moreover, the lack of confidence in the safety of water quality from the public also restricts the domestic water reuse for landscape development.

5.1.2. Lack of policy support. Using reclaimed water for urban landscape construction is conducive to the sustainable development of society, and is of no doubt should be given policy support and concession by the Government. To attract stakeholders who reuse water for landscape construction, the use of water should be more cost-effective than using tap water. For the water production enterprises, currently, the production of water that meet the quality requirements request additional costs, thus, the preferential policies from government would be preferable for those enterprises. At present, the policies to enhance water reuse in China urban landscape design field are still almost blank and in urgent need of development.

6. Suggestions of improvements

6.1. Public awareness.
Water reuse plays an active role in social sustainable development and environmental protection. However, it is not sufficiently concerned in southern China, where water resource is currently abundant. Meanwhile, urban landscape water reuse is facing the same problem. Therefore, it is necessary to make the public aware of the social, economic and ecological significance of the reuse of reclaimed water in
the landscape and to enhance its advocacy. The government needs to popularize the water reuse technology, landscape water quality standards, and introduce domestic and foreign successful landscape reclaimed water reuse examples to educate the public, make them willing to accept and trust in reclaimed water, and gradually change the current incorrect impression of water reuse from the public.

6.2. Develop relevant policies
Recycling reclaimed water for landscape use is part of public service, appropriate policy support from the government is necessary. Especially in the early stages of the implementation of the water reuse in the landscape, subsidies and preferential treatment should be given to stakeholders who invest and operate water reclamation facilities. Adoption of advanced and economical reclaimed water reuse technology and equipment is ought to be encouraged, so that both producers and consumers are able to benefit from the water reuse. The government and its policies should guide the reclaimed water reuse in urban landscape with the development of water reuse technology, and gradually achieve a sustainable landscape water system.

6.3. Increase the relevant design for water purification
At present, most of the landscape water design in China cities are intended towards the landscaping and improvement of the landscape yet ignore the landscape water quality maintenance and purification. With the growing shortage of water resources in the world, the reuse of water for urban landscape is bound to become a trend. Thus, while landscape designers are trying to beautify the water bodies, consideration of water quality and purification facilities are also necessary. Continuous filtration and maintenance of the recycled water would contribute to a better environment for city residents as well as a beautiful landscape.

7. Conclusion
With the increasing demand for urban landscape, landscape construction water consumption raises, and water quality standards are more stringent. Using clean water to create urban landscape not only causes a lot of waste of water resources, but also impedes the sustainable development of society. Reasonable use of reclaimed water resources, reusing recycle water that is purification processed and meets the landscape water quality standards in landscape construction, would not only be the future trend of urban landscape development, but also able to alleviate the shortage of water resources crisis, and produce positive social effect on sustainable development. Therefore, China should pay attention to the problem of water reuse landscape, learn from the relevant foreign success stories, and develop a more effective method of water treatment. Meanwhile, exploring how to integrate water purification facilities and landscape design reasonably will become the critical issue of reclaimed water reuse in urban landscape design.

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