Research on Rational Utilization of Urban Water Resources Based on Sponge City Theory-Making Comparison between China and Singapore

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Abstract. Water resources are indispensable for human survival and production activities, but the world's per capita sharing of water resources are not optimistic. With the acceleration of social development and industrialization, people pay more attention to economic development than the protection of water resources. Water pollution and waste have also worsened the issue of water scarcity. China, as the most populous country in the world, is particularly struggling for water shortage. Therefore, the research on the rational use of water resources is of great significance to China's sustainable and healthy development. This paper analyzes the difficulties of water resources utilization and the issue of under-utilization of domestic water resources in China. It then accordingly proposes recommendations by comparing the current situation of sponge city construction at home and abroad. It is found that we are now facing the difficulties of water shortages, water resources waste and pollution in China on water use. What’s more, the fact that sponge city construction is mainly carried out in emerging cities indicates that we can learn from the successful experience of other countries like Singapore to make overall planning for regions and by time according to the national condition of China. Specifically speaking, the problems concerning water resources in different cities will be solved based on their local conditions.

1. Introduction

The rational development and utilization of water resources has received wide attention around the world. For example, the world is watching Singapore, one of the four Asian tigers, who has adopted a water-saving scheme for rainwater harvesting, desalination, sewage treatment and importing water from neighboring countries to make the rational development and utilization of water a reality. China, is in face of a sever issue of water resources owing to its large population yet low occupancy of water resources. Specifically speaking, its water shortages and pollution is deteriorating the ecological environment, which has greatly affected people's lives [1].

It is imperative to make the rational use of the water resources on which human beings depend in order to achieve sustainable and healthy development of the environment. China enjoys abundant amount of water resources and a low per capita occupancy with the total freshwater resources accounting for 28 trillion cubic meters. At present, the amount of fresh water resources in as many as 18 provincial-level administrative districts are below the national average level, and 8 provincial-level administrative regions are facing water shortage or even serious shortage of water. Although the water shortage mainly exists in the northern region, it is a fact that the southern region, traditionally recognized as the land free from water scarcity is lacking in water due to a series of problems caused by the rapid economic development, the backward concept of water use and the impact of extreme
climatic factors [2]. While the shortage of water resources has become the daily norm, water pollution is undoubtedly worsening the situation. Because water pollution will not only cause soil quality degradation and damage to industrial and agricultural equipment, but also cause immeasurable harm to human health and the ecological environment [3]. As the country with the largest population in the world, China is extremely dying for water resources. But more than 100 kinds of harmful substances of 2,000 kinds of harmful substances detected in drinking water in this country may lead to cancer and deformity and other serious damages when drinking. It suggests that the rational development and safe use of water resources in China admits of no delay.

Research on the rational use of water resources can effectively alleviate the “competition for water” and its negative impact around the country. Relevant research at home and abroad has made certain progress, such as the virtual water strategy—the water-scarce region directly obtains products that need to be produced with water resources through virtual water trade, thus replacing the amount of the water resources involved in production [4], and the South-to-North Water Diversion Project, a domestic strategy for solving the imbalance of water resources in the north and south. This paper aims to summarize and compare the research and development of water resources based on the concept of “sponge city” based on the current situation of the water resources utilization in China thus providing suggestions for the rational development and utilization of water resources in China.

2. Problems in the rational use of urban water resources

2.1 Water Scarcity

The total annual water shortage in China stands 30 to 40 billion cubic metres, and more than 400 of the 669 cities confront with insufficient water supply. Among them, more than 100 are in an acute shortage of water. Among the 32 megacities with a population of more than one million, 30 of them always suffer from water depletion. While the water supply in big cities such as Beijing and Tianjin are under risk of shortage [5]. Water resources are the top priority in the process of urban development. Water scarcity will disrupt production activities and daily living in urban area. For example, urban infrastructure construction (road construction, building, etc.) will be hindered by water shortage, and the agricultural production will be affected for lacking of water. In addition, it is not impossible that water scarcity may also lead to water pollution, which threatens human health while causing loss of economic benefits [6].

There are three types of water shortages: resource-based water shortage, quality-induced water shortage, and engineering water shortage. The resource-based water scarcity, the most common type of water scarcity, is caused by a poor average per capita water resource by a shortage of water resources or an enormous population. The low per capita water resources will hinder the daily life and work, and disrupt some urban expansion projects. The solutions to resource-based water shortage are as follows: 1) Control the size of the city and determine a reasonable industrial structure; 2) Strengthen efforts for the recycling of sewage and supplementing the urban non-potable water source; 3) Make plans to construct a rainwater collecting and storage facility to promote the use of rainwater resources; 3) Carry out desalination technology to use seawater to supplement urban freshwater resources [7].

Quality-induced water shortage is caused by the deterioration of water quality generated by pollution and other reasons. At present, one third of China's rivers are polluted to varying degrees, and nearly one-third of the urban population lacks water security. Water quality and water shortage can cause irreparable damage to human health. The solutions include the following steps: 1) Strengthen the protection of water sources, divide the functional division of water bodies thus ensuring water quality from the source; 2) Make overall plans for the construction of urban emergency water sources in accordance of different water basins and watershed; 3) Build the urban emergency water sources in order to cope with various emergent accidents concerning with the water pollution and provide the basic living water for residents.
Engineering water shortage is the result of the aging or the lack of water supply in urban water use, which will slow down the production process and damage machinery and equipment. There are several solutions here: 1) Improve municipal-level infrastructure planning, and unify the construction of water distribution and distribution network; 2) Reserve municipal infrastructure corridors in the planning, which are strictly forbidden to occupy for any reasons [5].

2.2 Waste of water resources
In the case of water shortages, water waste will undoubtedly worsen the case. In recent years, China has continued to strengthen its farmland water conservancy infrastructure, but even so, most of the irrigation facilities are low standard, unsupported, and aging and disrepair. These poor irrigation facilities have caused the emergence of “flooding irrigation” with excessive water supply, leading to the waste of large water resources. This kind of problem is not only found in rural areas where agriculture is concentrated, so does in cities. Drainage systems are a major culprit in the waste of water resources in cities because of the aging and poor maintenance of equipment. In addition, the phenomenon of waste is commonplace in our life: for instance, brushing teeth with faucets running, water wasted for washing vegetable while preparing for cooking and faucets that are not closed after use in public places. Improper construction and redundant landscape installations can also result in wasting water, such as water pipes that are damaged by delivery vehicles and leak watering water pipes. From a macro perspective, it is an effective ways for avoiding water waste to strengthen the moral and civilization construction of residents and to promote the good living habits of “Resource conservation”. While from the perspective of urban planning, rigorous and rational urban planning layout is an effective measure to avoid water waste [4].

2.3 Water pollution
Water pollution in urban areas mainly comes from the discharge of urban domestic sewage and industrial wastewater affecting the water quality of surrounding rivers, reservoirs and groundwater [3]. At present, the qualified rate of water source in most cities in China is not high. It generally shows the tendency of good quality in south while poor quality in north [8]. In general, the quality of rural water sources is far less than that of urban water sources. Currently, people in remote rural areas still rely on deep wells for water which, being poorly fluid and more likely to develop heavy metal accumulation, is detrimental to nerves, urinary and reproductive systems [9]. Water pollution can be roughly divided into three types: urban pollution, industrial pollution, and agricultural pollution [10]. Urban pollution comes from various sources like domestic sewage, manure, garbage, etc. in daily life. Industrial pollution is caused by industrial wastewater and industrial sewage generated during industrial production. Agricultural pollution refers to the pollution of groundwater resources by organism from farmland, fertilizer, and farms.

The feature of the necessity of water, one of the most important assets in production and life, has made the harm of water pollution immeasurable. Water pollution will lead to the water quality deterioration and the disruption of the ecological balance damaging the ecological environment permanently [11]. What is more, water pollution also brings certain harms to the development of industry and agriculture. It can be demonstrated by the fact that the contaminated water will damage mechanical equipment in industrial production and contaminated water using in agricultural production will result in a decrease in the quality and output of crops, and changes in the soil structure and even accumulation in plants then entering into the body by food. As the pollutants in the water are mainly anthropogenic nitrogen and phosphorus, heavy metals, organic matter and pathogenic bacteria, when they enter the human body through the food chain, it will lead to some diseases and at worse some adverse effects on human health and even cause death [12].

3. The connotation of sponge city theory

3.1 The background of sponge city
In recent years, the urban surface water resources have been enormously damaged, which mainly reflected in urban flood disasters, runoff discharge of harmful pollutants and water shortage due to natural causes such as natural disasters and human activities [13]. In response to the above problems, many countries are committed to studying a new method for managing rainfall, aiming at improving the quality of drinking water, enhancing the flood resistance and repairing urban runoff systems [14]. Against such backdrop, sponge city theory thus emerges. The rationale behind the spongy city theory lies in the fact that we can turn the city into an area of water collecting and get rid of the traditional ideas of drainage thus improving our ability to prevent and mitigate floods and disasters. Besides, we can build more green infrastructures to reduce hardening of road, make our city more beautiful and functionally relieve the urban heat island effect, and provide leisure places for people. While at the same time, we can also improve the water quality and ecological environment of rivers in urban areas to solve the root causes of water resources (precipitation) [14].

3.2 Specific methods for building a sponge city

The principle of the construction of sponge city guided by the overall planning of the government puts the ecological environment and safety a top priority and and meets the local conditions [15]. The overall planning of the government determines the construction content (including the overall plan and the specialized plan) by the construction units at all levels, and proposes scientific and reasonable planning and specific measures from a global perspective in the macro planning (urban water system planning, drainage flood control planning, specialized planning of road traffic ), and middle-level planning (building, community, road, grassy areas, squares, urban water systems), and micro-planning covering permeable pavement, grassy ditch, sinking green land, rainwater wetland, water conservation forest) reflecting scientific and authoritative nature of the urban planning. Ecology first means adapting to nature and respecting nature in urban construction without sacrificing the ecological environment for economic benefits [16]. Making safety a priority is to put people's property safety in the first place and ensure the water safety for people. The principle in light of the local conditions means that the runoff control target should be specified in combination with the natural geographical conditions, hydrological characteristics and precipitation laws in different places [17].

In building the sponge city, we can control rainwater runoff from the source through small-scale decentralization measures for different regional categories (Figure 1). Detailed speaking, we can build permeable pavement and grassy ditch in the construction of municipal roads, parking lots and sidewalks, adopt green roofs or building roof gardens on the building floor, and build sinking green spaces and bio-retention facilities in public areas such as plazas to make the city more environmental friendly while ensuring the functionality of the city. (Lv Qi, analysis and discussion of key points in sponge city construction)
4. Comparison of construction of sponge city at home and abroad

4.1 Current situation of construction of China's sponge city
China, as a populous country, is facing severe water challenges. In order to cope with the “urban diseases” such as urban water logging and heat island effect caused by water shortage and pollution, China is actively carrying out the “sponge city” pilot construction [18]. On April 10, 2015, it was officially announced the first sponge city pilot cities, namely Qian'an, Baicheng City, Zhenjiang, Jiaxing, Chizhou, Xiamen, Pingxiang, Jinan, Hebi, Wuhan, Changde, Nanning, Chongqing, Suining, Gui'an New Area and Xixian New Area on the website of the Ministry of Finance[14, 19].

Jinan, the capital of east China's Shandong Province, bordered by Mount Tai in the south and the Yellow River in the north, enjoys dramatic expressions of the overall topography in urban area. The feature of low-lying south north high can easily lead to floods and disasters. Taking Jinan as an example can help us to understand the effectiveness of domestic sponge city construction. The Xinglong area of Daming Lake as pilot sponge city of Jinan City also shares the same feature of the landscape being high in south and low in north. There are many leakage belts in the area which is important for groundwater recharge and ensuring the continuity of downstream spring water. In carrying out the pilot project of the sponge city, the researchers used the GIS and SWMM software to analyze the terrain in the pilot area in detail, and partially upgrade the local landscape and green space system based on the original rivers, green spaces and pitches for the purpose of closure irrigation and water drainage, which has achieved perfect results [20]. Although China is experiencing the pilot phase of building the sponge city, this kind of concept will be promoted and practiced in more and more emerging cities over time.
4.2 Current situation of construction of sponge city in Singapore

Singapore, located in the south of Malaysia, is adjacent to the Straits of Malacca. Its unique location acts as a double-edged sword that brings economic benefits while limiting its own development. Singapore has a land area of only 719.1 square kilometers and a population density of nearly 8,000 people per square kilometer. The scarcity of natural resources, especially water resources, has forced Singapore to seek solutions for energy shortages [21]. Since the founding of the country, Singapore has closely linked its economic development to the environmental protection. In the 1970s, the government of Singapore spent 3 million Singapore dollars on river pollution management for 10 years, greatly improving the living environment of its people [22]. Since then, a number of planning strategies for water use have been put forward, among which the most shining example is its central catchment and new wastewater treatment plants [14]. The catchment in central Singapore covering an area of 2,889 hectares is made up of virgin forests and reservoirs designed to collect freshwater from rain. In addition to alleviating the demand for water resources, the central catchment also provides a place for recreation and entertainment. As the “green lung” of the whole country, the central catchment area best reflects Singapore’s emphasis on building the “sponge city”. In addition to the central catchment area, drains on the roadsides and water-saving devices in public toilets can be found everywhere in Singapore. The collected sewage enters into the sewage treatment plant through the drainage system and becomes drinkable after three major purification steps. The reputation of Singapore as the “Garden City” is attributed to the reason that its government has attached great importance to water conservation. In the process of rapid economic development, it also pays attention to environmental protection. It has poured into a lot of money to treat river pollution and made tireless efforts to resettle its people and install the drainage system for ten years. During the process, the government gave its strong support and further introduced foreign advanced technology in seawater desalination and sewage treatment after the end of the river cleaning. The road of treatment is thorny and difficult yet with remarkable results. Singapore has become one of the most famous tourist attractions and active economies in the world.

5. Conclusion and prospect

5.1 Obstacles in the construction of sponge city in China

We are confronting with obstacles of basic data shortages, the disconnection between theoretical planning and actual implementation, and the lack of integration of urban planning and natural ecology in the construction of sponge city [23]. Compared with the qualitative method based on descriptive research report, the quantitative method based on statistical analysis of various data is more objective. However, due to the difficulty in collecting basic data, there is a shortage of data in actual planning and design. In the current urban planning, there is a lack of efficient and rapid feedback mechanism between land use planning and specialized planning such as roads and green spaces. Once the city's overall planning system is initially established, it has legal effects meaning that it is difficult to make major adjustments in the future construction stages. The disconnection between land use planning and specialized planning often results in the inefficient use of land for the building roads, green spaces and municipal infrastructures and others. The urban vertical planning refers to the planning and design covering the use and transformation of the natural terrain, the determination of slope, control of elevation and balance of earth and stone in order to meet the comprehensive requirements of road traffic, drainage, building layout and urban landscape in urban development and construction areas [20, 24].

5.2 Recommendations on the rational use of water resources in China

China boasts limited per capita water resources and the considerable various spatial distributions of water resources. We can make plans from the perspective of regional condition and time to solve this problem. First of all, we must establish a whole picture of current situation of water use in China, specifically understanding the situations in each residential area and different areas. We must not
neglect the importance of coordination and cooperation and information sharing among various government departments when doing the task of visiting, investigation and data backing-up. In particular, we must pay attention to the implementation of solutions in various departments after the plan was determined. China has complex geomorphological features and uneven population distribution. Different solutions are needed for different regions and different groups especially for the urban population and rural population. The implementation of the sponge city plan can effectively alleviate the current situation of urban floods and water shortages, and make water accessible to the majority of the population. At the same time, once the difficulties of water resources in urban areas are addressed, it can greatly reduce the burden of rural water, so that they can still rely on their traditional ways to get water from reservoirs and nearby water bodies. It is worth noting that the sponge city plan can be applied to the construction of emerging cities at best. It is difficult to implement such plan for large cities with dense populations and complicated infrastructure. But it can be implemented in phases, like starting with micro-planning including installing permeable pavement, grassy ditch, sinking green land, rainwater wetland, water conservation forest and other facilities; Then the middle-level planning and macro-planning can be carried out concurrently with the implementation of urban facility maintenance project in right time, thus minimizing the impact on people’s normal life.

When building a sponge city, it is also necessary to raise people’s awareness of the protection of water resources. The criterion for spreading the concept of water conservation is starting from child education. We need to instill the preciousness of water resources and carry out some interactive activities for our children since their entering the kindergarten, such as visiting sewage treatment plants and cleaning up water pollution areas. At the same time, relevant departments need to step up the enforcement of enterprises and individuals who get out of line, improve the legal system for protecting water resources, and hold those violators who are greedy for the short-term benefits and ignore the long-term benefits accountable. We can take into account of the experience of foreign countries and advanced enterprises to avoid ineffective efforts. We need to develop our cities while protecting our environment. It is essential to find a model suitable for our country’s current situation in light of our own conditions when learning from others.

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