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"Sponge City" Plan in China

— Breakthrough and Development Prospect in the New Era

Wenzhe Wang[1,a,*]

[1]Environment Faculty, Beijing Jiaotong University, Beijing, China, 100044
a. 20723029@bjtu.edu.cn
**corresponding author*

Abstract: China's fast urbanization development over the past few decades has led to a loss in urban permeable pavement and an uneven distribution of water resources, hence the Chinese government proposed the concept of sponge cities. Utilizing the method of literature review, this research conducts a systematic examination of sponge cities and uses the city of Ningbo, Zhejiang Province, as an example of the ecological and environmental benefits sponge cities provide. After examining the constraints of the development of the three green facilities and the contrast with the sophisticated systems in foreign countries, the conclusion is formed that the development of sponge city is a long-term process and establishes the future research direction of green infrastructure.

Keywords: sponge city, drainage system, environmental benefits, green infrastructure

1. Introduction

China has experienced tremendous urbanization in recent decades. During the rainy season, urban surface runoff will increase due to the impermeability of pavement, which is worsened by the presence of numerous structures and infrastructure. One of the major causes of natural disasters such as flooding is surface runoff that escapes control. In addition, the expanding population accentuates the unequal distribution of water resources. Through traditional drainage systems and water treatment plants, sustainable development and "Dual Carbon" policies do not appear to be kept up with. The Chinese government offered the "sponge city" strategy to effectively address this problem (SCP). Low impact stormwater development system, commonly known as Sponge City. The city is able to respond to the changing water environment like a sponge and realize the circulation and migration of water [1]. China extensively investigated sponge city and performed pilot projects in 30 cities in an attempt to identify a development model fit for China after this concept was suggested. The evolution of SCP is depicted in Figure 1. SCP is not a completely novel technology, but rather an upgrade on conventional drainage systems that enables it to serve six purposes. SCP is not a completely novel technology; rather, it is an enhancement on conventional drainage systems that enables it to perform six functions: infiltration, stagnation, storage, purification, usage, and discharge [2]. In fact, some industrialized nations began focusing on new urban building many years ago, including low-impact development (LID), green infrastructure (GI), best management practices (BMP), and resilient cities [3].

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Due to a lack of knowledge of the SCP, numerous pilot city measures have not yet produced satisfactory results. Tao et al. investigated the synergistic link between green infrastructure and gray infrastructure in Jinan for flood mitigation. They suggested that, depending on the weather circumstances, various LID techniques should be integrated with drainage systems to tackle the flooding problem [4]. By a method of literature study, this paper provides a systematic analysis of sponge city, explains the breakthrough under the concept of sponge city using specific cities as examples, and compares it to the old drainage system. The paper then assesses the current shortcomings and development challenges of sponge cities and investigates if they might learn from the experiences of developed nations.

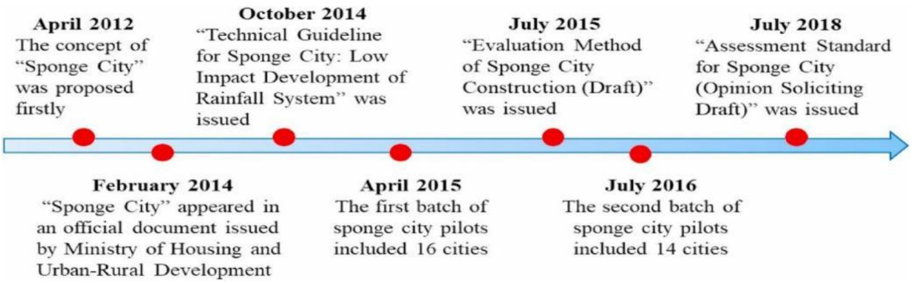

Figure 1: The development of sponge city [3].

2. The Breakthrough in SCP

2.1. A Review of Traditional Drainage Systems

Currently, the majority of cities still employ the conventional drainage system. Common solutions to flood concerns include pipe networks, high diameter pipes, and pumping stations, which are frequently referred to as grey infrastructure [5]. Typical components of such systems are drainage pipes and sewage treatment plants. Rainwater and sewage are typically collected and treated separately using the shunt collection system. As sewage enters the pipeline, it is treated at a sewage treatment plant and either discharged into a body of water or recycled. Rainfall is channeled into adjacent water bodies. Obviously, there are difficulties with this system.

First, the pipeline is connected to both rainwater and sewage, and the volume of sewage increases during rains, resulting in sewage overflow and environmental contamination.

Second, a portion of the pipeline placement is illogical, the rain pipe width is often tiny, and the water capacity is insufficient, resulting in frequent overflowing during the flood season. Due to the tiny diameter of the sewage main pipeline, it is impossible to evaluate the project's benefits.

Thirdly, the stormwater sewage discharge system lacks unified planning and design, and the regional drainage system cannot function as an organic whole.

Fourthly, the drainage system, irrigation canal, urban flood control system, and water feature lake are not coordinated, thus they cannot complement one another.

2.2. The Promotion of SCP -- Taking Ningbo as an Example

Ningbo, Zhejiang Province, is situated on the southeastern coast of China, and the region's plentiful rainfall and complex hydrological circumstances make it a suitable location for a sponge city pilot program. According to data, the average annual rainfall in Ningbo is 1400 millimeters, and summer and early autumn are the wettest seasons. In addition, the unique physical features of the Yangtze River Delta place Ningbo in the top 20 global coastal cities with the highest flood risk [6]. Moreover, Ningbo's rapid development has decreased the area of permeable pavement. Between 1997 and 2012, the built-up area of Jiangsu, Zhejiang, and Shanghai nearly tripled, as depicted in Figure 2 (a and b).

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Under the Sponge City program, the Chinese government has proposed the "Blue-Green City" concept. The goal of "Blue-Green City" is to connect water bodies with green infrastructure, re-establishing a naturally-oriented water cycle in the city in order to create a variety of environmental, economic, and social benefits [7]. Ningbo municipal government attempts to connect old waterways with newly installed blue-green facilities (urban forests, wetland waterfalls, natural waterways, etc.) to increase the density of Ningbo's surface water network, which is preferable to surface waterways that rely solely on pipe drainage and concrete piling. Not only can the implementation of blue-green infrastructure lessen the risk of flooding, but it also mitigates the effects of urban heat island effect and traffic noise, making it an excellent practice for sponge cities.

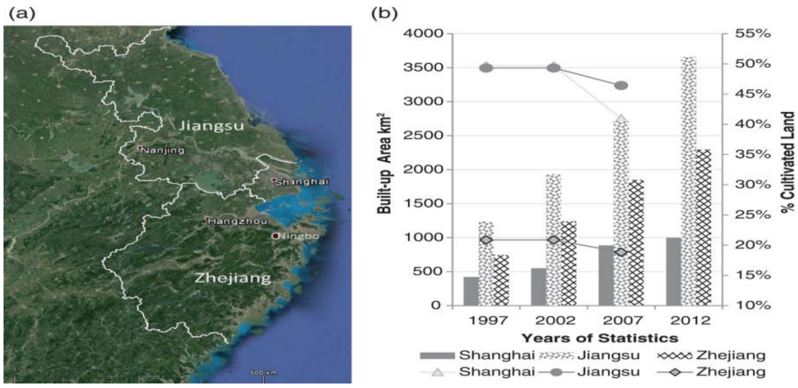

Figure 2: (a) Delineation of the Yangtze River Delta on an aerial photo of east coast of China and (b) statistics of land use [5].

3. The Prospect of SCP

3.1. The Current Limitations of Sponge Cities

The growth of SCP in China has not always been easy, but its outcomes in certain cities have been significant. Adapting to local conditions through the use of distinct green infrastructure in different cities is one of the greatest obstacles to sponge city growth. The constraints of three types of green infrastructure under the SCP idea are highlighted.

The first is a rain garden, also known as a rain wetland, which is a system of growing flowers, plants, and trees in naturally or purposely produced shallow areas to collect, infiltrate, and cleanse storm water runoff. Many do not, however, comprehend the function of rain gardens in enhancing the environment and ecology, hence enhancing social and economic benefits. The SCP's purpose is not to construct a rain garden. It can only be considered a system if it is a cohesive system that optimizes benefits [8]. Furthermore, the administration should learn how to interconnect various rain gardens throughout the city to establish a multi-layered system.

The second is the rooftop garden. Green vegetation on the surfaces and tops of buildings appears to be an innovative method of sustainable development. However, there are valid reasons why these amenities are not frequently utilized now. Owing to the variable environment variables, only shrubs and local plants with high temperature and drought tolerance can be selected. In addition to topographical characteristics (limited soil depth), the selection of wind-resistant, adaptable plants with short roots should be attempted. There are two obstacles to implementing green infrastructure, notwithstanding the fact that green roofs are effective at removing SS. One is the absence of a legal basis. The property right of dwellings is an impediment to the promotion of green roofs, given the current domestic scenario [9]. The one-time expenditures associated with a green roof include installation, upkeep, and irrigation. Nonetheless, the cost-benefit analysis reveals that the high cost typically comes before the benefit, which is difficult to measure.

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Finally, we have permeable asphalt. This technology is partially universal and straightforward to deploy. Permeable pavement comprises permeable brick pavement, permeable concrete pavement and permeable asphalt concrete pavement. Compared to conventional pavement, this material is porous and includes cementing material, admixture, and water as filler and auxiliary. Its purposes include minimizing impervious areas on urban surfaces, lowering noise levels, preventing slipping, cooling, and mitigating the urban heat island effect. This does not imply that the technology is fully developed. Existing studies have shown us that the majority of researchers have hypothesized that permeable surfaces could lower noise, temperature, and pollution, but have not yet tested their effectiveness. It also offers a suggestion for future investigation. Moreover, rain and snow in extreme weather conditions will also cause damage to permeable materials, thus the application area of permeable pavement must also be evaluated.

3.2. Drainage Systems in Other Countries

The sponge city concept in China is derived from the theories and practices of "low-impact development" and "green infrastructure" in the United States, "sustainable drainage system" in the United Kingdom, and "water-sensitive urban design" in Australia. China should learn from the successful experiences of some industrialized nations, notwithstanding the fact that different cities have unique traits and benefits. Throughout the process of urbanization, developed nations have also endured severe water contamination, frequent flooding disasters, environmental degradation, and other comparable occurrences. By implementing comprehensive rainwater management and adequate control of rainwater runoff, these nations have effectively solved or mitigated the aforementioned issues. In the 1990s, the United States introduced the concept of low-impact development, whose fundamental objective is to reduce the influence and destruction of natural ecosystems during the development and construction of artificial systems. The concept of a sustainable drainage system in the United Kingdom, whose fundamental principle is to imitate the natural process, store rainwater and release it slowly, encourage the infiltration of rainwater, apply design technology to filter pollutants, control flow rate, and create an aesthetically pleasing environment. Since 1990, Australia has utilized the concept of water-sensitive urban design (WSUD), making it a world leader in stormwater management. WSUD is a strategy that tries to minimize the hydrological impact of urban growth on the surrounding environment [10].

4. Discussion

Sponge city development is not a short-term endeavor, and the Chinese government must be prepared to invest years or perhaps decades. The absence of reliable profits and the requirement for cash are the two greatest obstacles to the development of sponge cities. According to statistics, one square kilometer of land requires 100 million or even 150 million yuan to develop. The present national sponge city construction plan requires trillions of yuan by 2030. Currently, public-private partnerships (PPP) are being advocated actively. However, some argue that the PPP model cannot quantify benefits such as sewage treatment and that there is no ideal model for sponge cities. This paper argues that sponge cities should be constructed from multiple perspectives. The government should actively plan and investigate development strategies and provide enterprises with development guidance. Individuals should be made more conscious of sustainable development and environmental conservation. A progressive city cannot exist without the support of the masses.

5. Conclusion

Unlike the majority of publications on sponge city, this paper examines sponge city from both good and negative perspectives. Initially, sponge city is thoroughly elucidated, and then Ningbo, Zhejiang

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Province, is used to illustrate the good impact sponge city has had. The report then evaluates the current limitations and development challenges of sponge city based on three types of green facilities, and compares them to the modern drainage systems of other nations. In addition, this paper arrives to the following conclusions:

First, there are apparent issues with the conventional drainage systems employed in the majority of cities today. Even when rainfall sewage is separated and collected, in extreme circumstances it might cause overflow and damage to the environment.

Second, "Blue and green cities" under the concept of sponge city can improve the ecological environment of cities, minimize the urban heat island effect, and lower the risk of flooding.

Finally, the three future research directions for green infrastructure are outlined as follows: 1) Create site-specific guidelines for rain gardens to form a network of multiple rain gardens in the city; 2) install green roofs on high-rise buildings; 3) investigate the mechanism of temperature and noise reduction of permeable pavements and identify protection measures during extreme weather.

Fourth, sponge cities today face two significant challenges: a high demand for capital and an absence of dependable returns.

This paper's deficiency is the absence of data analysis on specific sponge city measurements. The reason behind this is because the sought literature is insufficient to provide adequate facts to assist the building of sponge city. Sponge city construction is a long-term endeavor requiring cooperation from multiple perspectives.

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