Sponge City Practices in China

Subjects: Engineering, Environmental
Contributor: Haifeng Jia, Dingkun Yin, Changqing Xu

In recent years, China has been committed to strengthening environmental governance and trying to build a sustainable society in which humans and nature develop in harmony. As a new urban construction concept, sponge city uses natural and ecological methods to retain rainwater, alleviate flooding problems, reduce the damage to the water environment, and gradually restore the hydrological balance of the construction area.

Keywords: sponge city ; low-impact development ; pilot exploration ; systemic demonstration

1. Introduction

The rapid urbanization process in China has effectively driven the development of the national economy [1]. However, it has also exposed the risk of urban water issues due to the increase in impervious underlying surface and a decrease in green space and water areas [2][3][4][5]. This led to a significant reduction in the amount of rainfall runoff absorbed in the processes of plant interception, infiltration, depression detention, and evapotranspiration [6][7][8], and then increased the flooding risk [9][10][11]. When the rainfall runoff is large enough and exceeds the capacity of the drainage networks, it will bring more serious urban water safety and water environment issues [12][13]. Many cities in China have suffered a variety of water related problems such as frequent flooding, water environment pollution, water resources shortage and water ecology deterioration, which have seriously impacted the quality of people's life [14][15][16].

In order to improve the status quo, on the basis of learning from the stormwater management experiences in developed countries, China initiated the development of sponge city in 2013. This became a new solution for urban stormwater management. Whereafter, the government issued a series of related policies and guidelines for the sponge city development in an effort to improve the sponge city construction [17][18]. In addition, China central government selected 30 pilot cities considering their different natural and social conditions (with the average construction area of 31.3 km^2 for each city) for the sponge city construction exploration in 2015 and 2016, and all of them have completed performance assessment in the end of 2019 [19]. Furthermore, in 2021, based on the experiences of pilot cities, China began to systematically promote the sponge city demonstration on a national scale.

The construction of sponge city emphasis the full utilization of the natural absorption and infiltration capacity of pervious areas to effectively control stormwater runoff, thereby minimizing water system problems caused by the damage of urbanization-induced hydrological effects. The philosophy of sponge city is to transform the traditional "fast drainage" principle to a systematic implementation of "infiltration, detention, retention, purification, utilization and discharge" [13]. It aims to achieve stormwater runoff control from source reduction and process control to systematic remediation through planning, design, construction, operation, and management, which would lead to a sustainable approach for urban development.

2. Inception of Sponge city

2.1. Foreign Advanced Experiences

The urban drainage concept can be traced back to the 3000 BC, with the most important goal being to quickly discharge the rainfall runoff from the urban area to the downstream channel or other receiving water bodies [20]. However, with the complexity of urban development and the frequent occurrence of extreme stormwater events, a series of relatively 'novel' concepts have appeared in the different developed countries. These concepts mainly include the Low Impact Development (LID), Green Infrastructure (GI) and Best Management Practices (BMPs) [21] in US, the Sustainable Urban Drainage System (SUDS) in UK [22], the Water Sensitive Urban Design (WSUD) in Australia [23] and Nature-Based Solution (NBS) [24]. These concepts attempted to combine urban drainage with natural processes to reduce rainfall runoff through various nature-based solutions and therefore, achieved a benign urban water cycle. All of these concepts are closely related, but different terms represent different technical systems, which also have certain differences in the field of application scale, technical measures and control objectives [25]. This section describes the concepts related to drainage proposed by the US, the UK and Australia, and explores the relationship and connection between these concepts and sponge city construction.

2.1.1. LID-BMP and GI for Source Control in US

BMP first appeared in the “Clean Water Act”, enacted by the US Congress in 1972 and was first applied mainly in the field of sewage discharges or point sources [26]. After 15 years, the BMP for stormwater runoff or nonpoint pollution control was implemented. The main technical measures included different low-cost engineering measures. Besides, it also emphasized the non-engineering measures, such as facility maintenance rules. Since then, the concept of LID has been used in the reports related to urban stormwater management issued by the US EPA and in the related design manuals of various states. The application of source runoff control facilities has been promoted by taking a “nature design approach”, such as green roofs and rain gardens. Moreover, the US also promoted urban drainage design by using LID-BMPs, which represented all of the BMPs for urban stormwater runoff control using the LID strategy, and the frequency of this concept rapidly increased in international literature in recent years [27]. Subsequently, green infrastructure or GI, which covers traditional BMP and typical LID measures, was evolved as the term represented source control infrastructure for urban runoff. GI can bring multiple ecological benefits, such as alleviating the urban heat island (UHI) effect, increasing biological habitat, and improving biodiversity [20]. In the sponge city construction, source runoff control is also a top priority since it can effectively reduce the total amount of runoff and absorb part of the runoff on-site. However, the source control of sponge city includes not only small, decentralized infiltration and retention facilities (green roofs, grass swales and bioretention), but also large-scale storage facilities, such as stormwater ponds and wetlands. It is important to select appropriate facilities according to the scale and characteristics of runoff quantity and quality of the specific region.

2.1.2. SUDS for Multifunctional Drainage System Design in UK

In UK, a sustainable drainage concept was proposed in 2007, which not only includes the concepts of LID-BMPs and GI in the US, it also diversifies the design of the drainage system to avoid the traditional sewer network being the only drainage outlet [28][29]. Meanwhile, the filtering effect of drainage facilities was taken into account to reduce the discharge of pollutants into the receiving water body. In addition, rainfall collection and utilization were also emphasized [30][31][32]. Thus, strategies for the urban stormwater management became more functional rather than focusing solely on rapid runoff discharge. Besides, various corresponding environment, social and economic benefits were also obtained [33][34]. These benefits were reflected not only in the overall reduction of urban runoff, the improvement of air quality, and the CO_2 storage, but also in the burden reduction of the stormwater fees and the energy consumption [33][35][36][37]. It is not difficult to see that SUDS rose from a traditional “rapid drainage” system to a more sustainable and multifunctional drainage system that maintains a high level of benign water circulation. Meanwhile, it began to optimize the entire water system including urban drainage, sewage, and reclaimed water system rather than that of only urban drainage facilities. This also coincided with the concept of sponge city construction. In the sponge city design, the water quantity and quality, potential landscape and ecological value of runoff are all comprehensively considered.

2.1.3. WSUD for Urban Water System Optimization in Australia

Around the technical core of urban stormwater management, Australia put forward the concept of WSUD in 1994 through a whole understanding of the water cycle in the local physical and environmental context [38][39]. It was also the first time that stormwater, groundwater, drinking water, sewage and reclaimed water system were comprehensively considered together. WSUD was described as “a philosophical approach to urban planning and design aimed at reducing the hydrological impact of urban development on the surrounding environment” [23]. It emphasized the consideration of stormwater management issues within an integrated framework of the entire urban water cycle [40]. Different with LID-BMPs, WSUD used integrated method to achieve stormwater management rather than only micro-scale landscape stormwater control [41]. All of these had a higher overlap with sponge city construction [42]. For example, the fragmentation of management and the discretization of related departments might hinder the evolution of WSUD. Thus, WSUD promoted urban water management through institutional construction and administrative measures to build a long-term mechanism for sustainable urban design [41]. As far as the sponge city construction is concerned, it is still necessary to learn from WSUD and conduct various studies to provide scientific construction guidance, including the runoff regulation capacity of different GIs, long-term tracking monitoring, and comprehensive performance evaluation [31][43][44][45]. All of these actions play a vital role in the development of sponge city construction and its promotion in the future.

2.2. Chinese Historical Inheritance

The idea of “natural storage, natural infiltration, and natural purification” in sponge city is derived from the wisdom of the ancient Chinese people using nature approaches to discharge and collect stormwater. As early as the Qin and Han dynasties (221 BC–220 CE), China began to build strip-shaped or wave-shaped terraced fields along the contour lines on the hills for farming [46]. This was also an effective measure for controlling soil erosion on sloping farmland. The terraced fields has been listed as a United Nations Educational, Scientific and Cultural Organization (UNSCEO) heritage since 2013 [47]. Researchers can see that people in ancient times have been able to combine the living environment with the natural environment to realize the recycling of stormwater. In the settlement development, Chinese ancients also took advantage of natural power to harvest stormwater for utilization, to drainage stormwater for safety.

2.2.1. Ancient Stormwater System of Courtyards and Villages

The domestic studies on ancient Chinese drainage system are mostly including structure, composition, and operation mode. In China, the quadrangle is one of the most common buildings in ancient times, but the styles are slightly different to adapt local climate. The ancient wisdom and concepts contained in the ancient courtyard drainage system also can be a valuable reference for the current sponge city construction. In northern China, the rainfall depth is much less than that in the southern region. However, the rainfall is more turbulent, and the instantaneous rainfall intensity is stronger, which requires the drainage system to have a good drainage capacity. The quadrangles are all built with walls. Along these walls, flowers and trees are planted (**Figure 1**a), so that people can enjoy the natural scenery while utilizing rainwater. Usually, as the rain falling down the eaves, part of the runoff is absorbed on the permeable surface in the courtyard, and the rest is discharged out of the courtyard along the ditches into the drainage system.

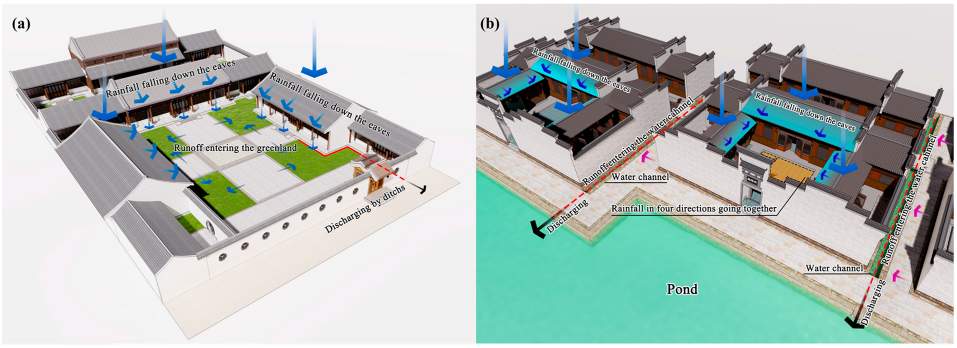

Figure 1. Drainage systems in ancient southern and northern China: (**a**) Typical courtyard buildings in northern China; (**b**) Ancient villages in southern China.

In the southern China, courtyard is more restrained and smaller compared with northern region due to the scarce land resources. Therefore, patios are often used as a substitute for courtyards. The average annual rainfall in the southern region exceeds 800 mm, which is generally higher than that in northern area.

Taking Hongcun which located at the south of Huangshan City, Anhui Province, as an example, it was built in the Southern Song Dynasty (1127–1279 CE) and was also selected as an UNESCO heritage. Based on historical records, Hongcun was unscathed and unaffected by heavy rainfall events in history [48][49]. The reason is that Hongcun includes a smart drainage system that combines storage and drainage facilities together, so that it can retain stormwater runoff on-site first and drain the extra stormwater to downstream water bodies safely. As can be seen in **Figure 1**b, when rainfall events occur, the stormwater is flowing down the eaves, entering the courtyard, and then drains into the river from the trenches around the patio. Thus, stormwater runoff in Hongcun can be merged into the channel and spread throughout the village. The runoff from the channel then flows into the pond for midway regulation and storage along the terrain, and finally flows into the receiving water body. Hongcun solves the problem of water shortage in the dry season and can reduce flood peaks and runoff flow volume through the rational use of channel, pond and receiving water body at the raining time. The villagers use part of the collected stormwater for production and living. In addition, the management system in Hongcun clearly states that domestic sewage water cannot be directly discharged into the channel and needs to be infiltrated through the soil. This measure ensures the water environment of the stormwater system is not affected by domestic sewage water.

There are also examples for larger areas to deal stemwater rationally, such as Ganzhou in Jiangxi province, China [48]. The urban drainage system of Ganzhou also make reasonable use of ditches, ponds and city walls to achieve source reduction and resource utilization of a large amount of runoff generated by rainfall events, and quickly discharge excess runoff into downstream receiving water bodies [50]. All of the above are good references for sponge city construction and modern stormwater management.

2.2.2. Ancient Drainage System of Architectural Complex

In addition to the smart stormwater management in courtyard and village, the stormwater system in architectural complex was also well designed in ancient China. Taking Tuancheng (**Figure 2**), Beijing, which was constructed during the Ming Dynasty (1368–1644 CE), as an example, its area is about 0.5 hectares with an average annual rainfall depth of 560 mm [48]. On 21 July 2012, Beijing suffered the extraordinary stormwater event in the past 60 years, with an average rainfall depth of 210.7 mm. According to data, approximately 1.602 million people were affected, and the economic loss was about 11.64 billion Yuan. However, the drainage system in Tuancheng was still in service, and there was no report of flooding there. In Tuancheng, there are no open ditches. The ground of Tuancheng is paved by bricks with good water permeability, and the shape of these bricks is an inverted trapezoid. When rainfall occurs, the stormwater runoff infiltrates into the ground through the gaps between adjacent bricks (**Figure 2**). When the runoff quantity is large enough that cannot be absorbed locally, it will flow into the surrounding water holes from north to south according to the terrain. The vertical shafts are directly below the water holes, and connected by culverts with a height of 80–150 cm. Therefore, the runoff flows into the water holes can be stored among the culverts, this design cleverly solves the local drainage problem, which can be used for reference when dealing with urban flooding issues.

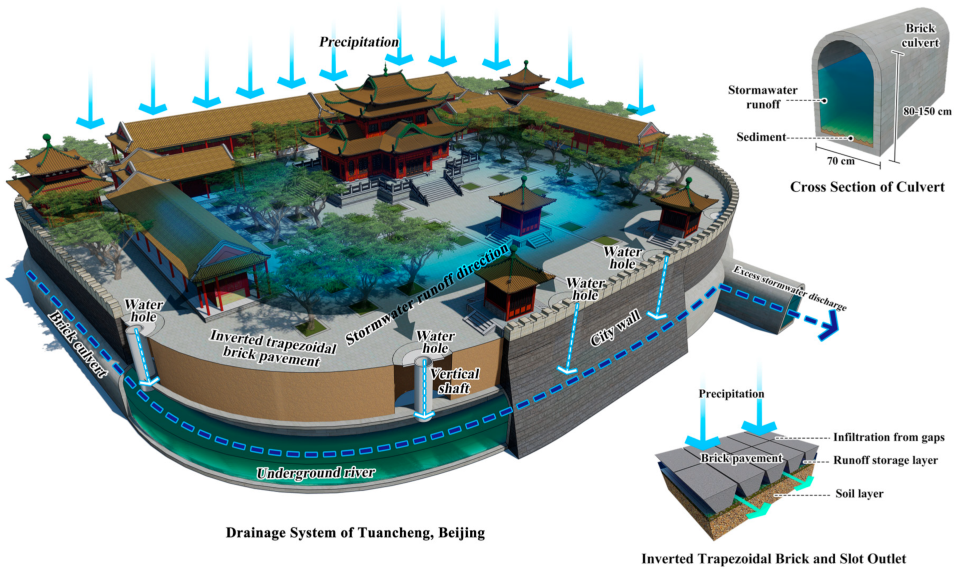

Figure 2. Typical ancient drainage system of Tuancheng, Beijing in northern region.

There are countless historical sites similar to Tuancheng scattered in China, which contain extremely rich scientific and technological value. They are the concrete reflection of ancient scientific thinking, water culture, and technological progress. Besides, these architectures also embody the ingenuity of ancient people and demonstrate historical process of social science and technology development. Traditional culture is the source of modern culture. In order to better understand the modern urban stormwater management system, traditional culture must be learned. The historical site faithfully records the traditional way of stormwater utilization with high cohesion of traditional culture and is also a window for scholars to explore the symbiosis of human and water. At the same time, it provides the possibility for people to experience the broad, profound, and splendid traditional culture.

However, with the onset of rapid urbanization, some ancient drainage systems have been gradually replaced by a large number of engineering pipe systems in urban area which led to urban water quantity and quality issues. In order to avoid the aggravation of such problems, it is urgent to carry out sponge city constructions in urban area to reverse these kinds of situations.

3. Sponge city Pilot Exploration

3.1. Sponge city Construction Implementation Mode in China

Based on the several years' exploration of sponge city construction, the Chinese implementation mode was formed (**Figure 3**). In the implantation mode, the government carries the main responsibility. Central government acts as the promoter and local municipal governments are organizers of sponge city construction and management. Usually, a sponge city construction office or committee would be setup, which includes the officers from the related municipal bureau or agencies of urban planning, construction, landscaping, transportation, environment protection, water resources, and so on. The sponge city construction office or committee organizes all of the related issues on sponge city construction and management.

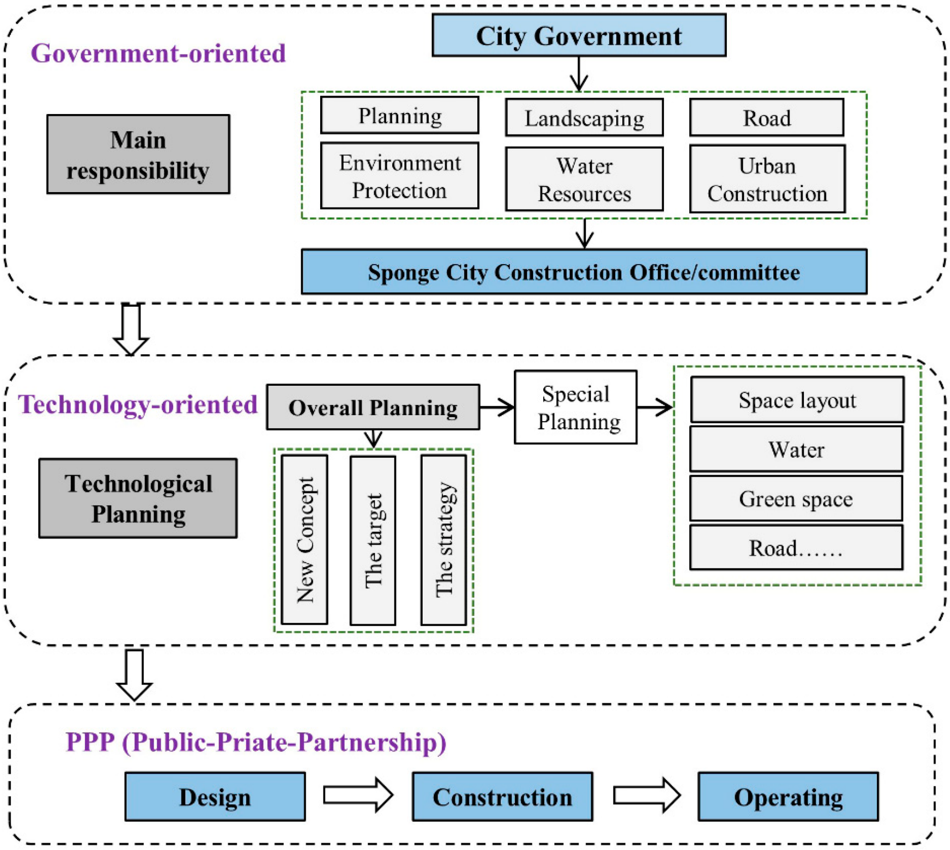

Figure 3. Chinese implementation mode of sponge city pilot construction.

During the planning stage, all of the different levels of planning are oriented by technology. For overall city planning level, the concept and the target of sponge city construction should be included, and the implementation strategy should be proposed. For special planning level, the main principles focus on "flooding control, water environment improvement, water resources conservation and water ecology rehabilitation". The objectives are "no ponding in light rain, no flooding in heavy rain, no black and odorous urban water, and mitigating the heat island effect". The schemes which can meet the above objectives should be proposed related with infrastructure space layout, water system, green space and road system.

As of the design, construction and operation stage, the role of different stakeholders in sponge city construction are emphasized. The Public-Private Partnership (PPP) mode is encouraged. Typically, it involves private capital financing government projects and services up-front, and then drawing profits from taxpayers and/or users over the course of the PPP contract. In sponge city construction, usually the related projects are bundled up by municipal government and sign PPP contract with the qualified enterprises. The enterprise will have responsibility for design, construction, and operations.

3.2. National and Local Pilot Sponge Cities

To explore the specific development model of sponge cities construction in different regions of China, the Ministry of Finance (MF), the Ministry of housing and urban-rural development (MHURD) and the Ministry of water resources (MW) of China coordinately promoted the national pilot sponge cities construction. According to the characteristics of China's geographical climate, average annual rainfall, and urban development intensity, 30 cities were selected as national pilot sponge cities with different annual rainfall volume capture ratio targets in 2015 and 2016 (**Figure 4**). Each pilot city constructed a pilot region with no less than 15 km^2 in 3 years. The main task of pilot cities was to explore a development model which is suitable for the construction of sponge cities in the specific region, and to form a set of practices, experiences, policies, and systems which can be promoted in similar cities. In addition to the national pilot construction, provinces and cities have also carried out their own sponge city pilot construction. According to statistics, 13 provinces have carried out local pilot programs in 90 cities, 28 provinces have issued requirements of sponge city construction, and two-thirds of the cities in China have formulated special plans for sponge city construction [51].

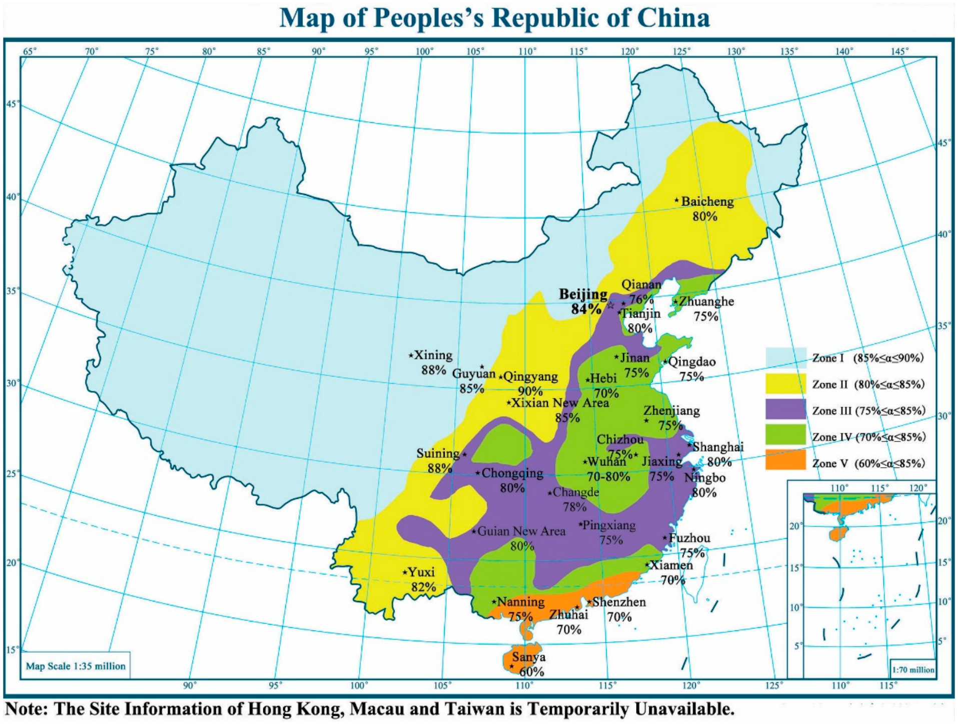

Figure 4. Location of 30 national pilot sponge cities in China (reprinted with permission from Ref. [13]. 2020, Haifeng Jia).

3.3. Achievements

The 30 national pilot sponge cities have passed the joint acceptance check of MHURD, MF, and MW in 2019. After summarizing the national pilot experiences and practices, it was found that many impressive achievements have been obtained.

3.3.1. Worldwide Influence

Sponge city has gained worldwide attention due to its innovative concepts, huge implementation plan and strong performance in improving water quality and controlling flooding situation. To strengthen the academic communication, there are many books, journal papers, international conferences, workshops, and other academic activities on sponge city. The most attractive international conferences are the 2016 International LID Conference held in Beijing and the 2018 International sponge city conference held in Xi'an. Statistical results showed that more than 1200 attendants from more than 20 countries and regions attended the 2016 International LID Conference, and more than 2000 attendants (more than 800 thousand persons online) attended the 2018 International sponge city conference. The internationally renowned journal, *Nature* and *Science*, also reported that sponge city is crucial for many cities which suffer severe flooding and water shortage [52][53]. These studies pointed out that the green sponge infrastructure should be combined with conventional drainage systems, particularly in areas of medium- and high intensity urbanization.

In recent years, related literatures have been rapidly growing. The literature of China National Knowledge Network (CNKI) from 1995 to 2021 showed that sponge city related (for example, sponge city, permeable pavement, low impact development, rain garden, LID, sunken green space, green roof) has reached more than 2000 papers. These papers cover engineering cases, reviews, experimental studies, planning schemes, efficiency evaluation, and so on. Moreover, many books, such as typical cases of sponge city construction, sponge city construction and operation technology system, theory and practice of urban sponge green space planning and design, etc. have been published to help people further understand sponge city [54][55][56].

The International Water Association (IWA) published many articles (for example, getting to Climate Resilient and Low Carbon Urban Water) about the performance of sponge city in controlling urban runoff and avoiding water scarcity. Major international journals, such as Water Research, Resources, Conservation & Recycling, Journal of Cleaner Production, Science of the Total Environment, Journal of Hydrology, Journal of Environmental Management, and etc. published a large number of papers which are related to sponge city [13][57][58][59][60].

3.3.2. Sponge city Performance

In recent years, a large amount of data on sponge city performance has been accumulated. However, these data have various sources, diverse formats, and uneven quality, making it difficult to fulfill relevant research and design needs directly. Thus, Xu et al. establishes a China sponge city database with a clear structure and convenient management schemes [61]. It includes facility size and cost information under various environmental conditions. At present, 1066 urban runoff source control facilities parameters from 30 pilot sponge cities are included in the database. The database can provide useful guidance information to other countries with similar environmental and fiscal conditions for the construction of urban runoff source control facilities.

Sponge city urban runoff source control facilities can achieve good water quality control performance. The average pollutant removal rates of urban runoff source control facilities are presented in **Table 1**. Results showed that these facilities have good removal performance in COD, SS, NH_3-N, TP, TN, Pb, and Zn.

Table 1. Pollutants average removal rate of urban runoff source control facilities (reprinted with permission from Ref. [51]. 2020, Changqing Xu).

Urban Runoff Source Control Facilities	Pollutants Average Removal Rate (%)						
	COD	SS	NH_3-N	TP	TN	Pb	Zn
Concaved green space	**51.65**	**-**	**60.39**	**54.88**	**33**	**-**	**-**
Constructed wetland	**86.23**	**71.18**	**67.07**	**70.56**	**85.33**	**62.71**	**-**
Bioretention	**59.10**	**79.15**	**65.45**	**72**	**73.90**	**-**	**-**
Permeable pavement	**62**	**34.93**	**39**	**57**	**53**	**60**	**60**
Detention pond	**41.88**	**59.32**	**21.62**	**20.05**	**15**	**-**	**-**
Buffer strip	**77.97**	**90**	**-**	**85.11**	**69.93**	**-**	**-**
Grassed swale	**26.70**	**46.25**	**44.70**	**51.40**	**-**	**98**	**97**

As mentioned before, the 30 national pilot sponge cities have passed the joint acceptance check by MHURD, MF, and MW. The 30 cities all achieved the pilot objectives of water environment, water ecology, water resources, and water security. For example, performance evaluation of sponge city construction in Qian'an city is good [62]. The scores of water resources, water security, water ecology and economic benefits are high, indicating Qian'an has made positive progress in rational utilization of water resources, water security, and economic benefits after sponge city implementation. Similar to Qian'an, Jiaxing's sponge city construction performance is at a "relatively high" level [63]. From the performance evaluation results, the sponge city construction in Jiaxing has achieved remarkable results, indicating the rationality and feasibility of its overall implementation plan and related policies. Specifically, the environmental performance, which includes water ecology, water environment and water resources indicators (for example, volume capture ratio of annual rainfall, groundwater level, water resource utilization rate, water environmental quality), has higher index weight coefficient than social performance and management performance. Therefore, Jiaxing should focus on the control of the above factors in the future construction of sponge city. The Science and Education Channel of China Central Television (CCTV-10) reported that Nanning City implemented permeable pavement, rain garden, green roof and other practices in sponge city pilot areas, these made Nakao River change from a gutter to an ecological wetland park. The citizens living in Nanning have experienced the significant positive changes in the urban water environment around them.

3.3.3. Education and Talent Training

To further promote the sponge city construction sustainably, strengthening professional expertise and social publicity are necessary. Apart from building information promotion platforms and implementing community demonstration projects, letting sponge city enter the campus and training sponge city talented people are key strategies. At present, there are some teaching materials (for example, Designing Our Sponge Community, Sponge Castle Adventure (primary school version), Sponge city Exploration (middle school version) and activities have been promoted in schools [64][65][66].

The comprehensive practice series instruction book "Designing Our Sponge Community" was based on the Primary Science Curriculum Standards for Compulsory Education issued by the Ministry of Education. This textbook becomes the "China's first STEAM (Science, Technology, Engineering, Arts, and Mathematics) project teaching guide for primary and secondary schools". Besides the textbooks, many schools launched activities to help students have a comprehensive understanding of sponge city and feel the great changes sponge city has brought to the city. In Suzhou, sponge city course taught on campus has aroused the students' interest in knowing the theory of sponge city. Field trips were organized to guide students to understand the design of bioretention, a permeable pavement, and a green roof etc. In Jinan, the students carry out some experiments in campus by themselves to help them better understand the principle and function of SPONGE CITY. In fact, the active promotion of sponge city construction allows everyone to develop an environmental protection and sustainable thinking mode.

Sponge city construction is a multi- and cross-disciplinary project that involve the majors of water supply and drainage engineering, environmental engineering, water conservancy engineering, urban planning, land use, landscape, transportation and ecology [67]. In the process of sponge city construction, close cooperation across all these disciplines is very important. Wide academic discussion and collaboration are needed. The summary of achievements, such as books, handouts, papers, atlas, manuals, and etc. are significant in education and talent training.

3.3.4. Public Awareness

As a national scale public project to address environmental issues, sponge city project is subject to public financial support and perception. Willingness to pay (WTP) is an effective tool to explore public behavioral intention and evaluate integrated benefits of a project. Wang et al. examined public perceptions of sponge city construction, as well as the public's willingness to support sponge cities in Zibo and Dongying City, Shandong Province [68]. A total of 1800 questionnaires were distributed with 900 each in Zibo and Dongying City, finally 1443 were valid returns. Results indicated that most respondents knew about sponge city projects and supported sponge city construction in residential areas. Respondents also accepted 17% of the domestic water price as a surcharge to be used for sponge city construction. Results also showed that educational level, income, and occupation were main factors affecting respondents' WTP to support sponge city initiatives. Wang et al. made a questionnaire survey in the flood affected communities with 656 respondents in Guyuan City [69]. Survey results showed that most respondents accepted an 8.3% surcharge of domestic water tariff for sponge city development. The results provide practical implications for government and developers to optimize financing and operation of sponge city developments and thus can improve the sustainable performance of sponge city.

During the process of sponge city construction, public dissent has arisen over the effectiveness of sponge cities, the most common dissent is "Omnipotence" and "Uselessness" of sponge city [70]. This is mainly because the public holds unrealistic expectations to the effect of sponge city construction, hoping to solve all water problems in one way, once and for all. In addition, some sponge city construction projects exaggerate the implementation effect in the early publicity, undoubtedly contributing to the public misjudgment. Besides, the public has a partial understanding of the nature of sponge city construction, thinking only source reduction LID facilities represent sponge city construction. Another reason is that the public only cares about sponge city construction projects when flooding occurs, and they are more concerned about the quality of outdoor built environment. Whether sponge facilities are effective depends largely on construction quality, which is consistent with the public's perception of built environment quality. For some sponge facilities, the poor engineering quality has been criticized for a long time. sponge city construction should focus on improving residents' well-being. Only when residents feel the urban water problem is alleviated and observe the improvement of living environment quality, can they support the continuation of more such work, and sponge city construction can be promoted systematically.

References

1. Jiang, C.; Li, J.; Liu, J. Does urbanization affect the gap between urban and rural areas? Evidence from China. Socio-Economic Plan. Sci. 2022, 101271. in process.
2. Yin, D.; Evans, B.; Wang, Q.; Chen, Z.; Jia, H.; Chen, A.S.; Fu, G.; Ahmad, S.; Leng, L. Integrated 1D and 2D model for better assessing runoff quantity control of low impact development facilities on community scale. Sci. Total Environ. 2020, 720, 137630.
3. Wu, J.; Cheng, D.; Xu, Y.; Huang, Q.; Feng, Z. Spatial-temporal change of ecosystem health across China: Urbanization impact perspective. J. Clean. Prod. 2021, 326, 129393.
4. Xu, C.; Jia, M.; Xu, M.; Long, Y.; Jia, H. Progress on environmental and economic evaluation of low-impact development type of best management practices through a life cycle perspective. J. Clean. Prod. 2018, 213, 1103–1114.
5. Cheng, M.; Qin, H.; Fu, G.; He, K. Performance evaluation of time-sharing utilization of multi-function sponge space to reduce waterlogging in a highly urbanizing area. J. Environ. Manag. 2020, 269, 110760.
6. Pumo, D.; Arnone, E.; Francipane, A.; Caracciolo, D.; Noto, L.V. Potential implications of climate change and urbanization on watershed hydrology. J. Hydrol. 2017, 554, 80–99.

7. Mei, C.; Liu, J.; Wang, H.; Yang, Z.; Ding, X.; Shao, W. Integrated assessments of green infrastructure for flood mitigation to support robust decision-making for sponge city construction in an urbanized watershed. Sci. Total Environ. 2018, 639, 1394–1407.
8. Guan, X.; Wang, J.; Xiao, F. Sponge city strategy and application of pavement materials in sponge city. J. Clean. Prod. 2021, 303, 127022.
9. Liu, K.; Li, X.; Wang, S. Characterizing the spatiotemporal response of runoff to impervious surface dynamics across three highly urbanized cities in southern China from 2000 to 2017. Int. J. Appl. Earth Obs. Geoinf. ITC J. 2021, 100, 102331.
10. Mahmoud, S.; Gan, T.Y. Urbanization and climate change implications in flood risk management: Developing an efficient decision support system for flood susceptibility mapping. Sci. Total Environ. 2018, 636, 152–167.
11. Chan, F.K.S.; Griffiths, J.A.; Higgitt, D.; Xu, S.; Zhu, F.; Tang, Y.-T.; Xu, Y.; Thorne, C.R. “Sponge city” in China—A breakthrough of planning and flood risk management in the urban context. Land Use Policy 2018, 76, 772–778.
12. Qi, Y.; Chan, F.K.S.; Griffiths, J.; Feng, M.; Sang, Y.; O’Donnell, E.; Hutchins, M.; Thadani, D.R.; Li, G.; Shao, M.; et al. Sponge city Program (SCP) and Urban Flood Management (UFM)—The Case of Guiyang, SW China. Water 2021, 13, 2784.
13. Yin, D.; Chen, Y.; Jia, H.; Wang, Q.; Chen, Z.; Xu, C.; Li, Q.; Wang, W.; Yang, Y.; Fu, G.; et al. Sponge city practice in China: A review of construction, assessment, operational and maintenance. J. Clean. Prod. 2020, 280, 124963.
14. Wang, C.; Hou, J.; Miller, D.; Brown, I.; Jiang, Y. Flood risk management in sponge cities: The role of integrated simulation and 3D visualization. Int. J. Disaster Risk Reduct. 2019, 39, 101139.
15. Hasan, H.H.; Razali, S.F.M.; Zaki, A.Z.I.A.; Hamzah, F.M. Integrated Hydrological-Hydraulic Model for Flood Simulation in Tropical Urban Catchment. Sustainability 2019, 11, 6700.
16. Li, J.; Zhang, B.; Mu, C.; Chen, L. Simulation of the hydrological and environmental effects of a sponge city based on MIKE FLOOD. Environ. Earth Sci. 2018, 77, 32.
17. MHURD. Technical Guide for Sponge Cities-Construction of Low Impact Development; China Architecture Publishing & Media Co., Ltd.: Beijing, China, 2014.
18. MHURD. Assessment Standard for Sponge city Effect; China Architecture Publishing & Media Co., Ltd.: Beijing, China, 2019.
19. Jia, H.; Yin, D. Green Infrastructure for Stormwater Runoff Control in China. In Oxford Research Encyclopedia of Environmental Science; Oxford University Press: Oxford, UK, 2021.
20. Fletcher, T.D.; Shuster, W.; Hunt, W.F.; Ashley, R.; Butler, D.; Arthur, S.; Trowsdale, S.; Barraud, S.; Semadeni-Davies, A.; Bertrand-Krajewski, J.-L.; et al. SUDS, LID, BMPs, WSUD and more—The evolution and application of terminology surrounding urban drainage. Urban Water J. 2015, 12, 525–542.
21. DoER. Low Impact Development Design Strategies: An Integrated Design Approach; U.S. Environmental Protection Agency: Washington, DC, USA, 1999.
22. Woods-Ballard, B.; Kellagher, K.; Martin, P.; Jefferies, C.; Bray, R.; Shaffer, P. The SUDS Manual; CIRIA: London, UK, 2007.
23. Lloyd, S.D.; Tony, H.F.W.; Chesterfield, C.J. Water Sensitive Urban—A Stormwater Management Perspective; Cooperative Research Centre for Catchment Hydrology: Melbourne, Australia, 2002.
24. European Commission. Policy Topics: Nature-Based Solutions. Available online: https://ec.europa.eu/research/environment/index.cfm?Pg=nbs (accessed on 21 April 2017).
25. Yang, Z.; Li, J.; Wang, W.; Che, W.; Ju, C.; Zhao, Y. The advanced recognition of low impact development and sponge city construction. Environ. Eng. 2020, 38, 10–15. (In Chinese)
26. Keller, B.D. Griffin, Georgia’s Stormwater Utility “A Non Structural Best Management Practice (BMP)”. In Proceedings of the 1999 Georgia Water Resources Conference, the University of Georgia, Athens, Georgia, 30–31 March 1999.
27. Jia, H.; Yao, H.; Yu, S.L. Advances in LID BMPs research and practice for urban runoff control in China. Front. Environ. Sci. Eng. 2013, 7, 709–720.
28. Riechel, M.; Matzinger, A.; Pallasch, M.; Joswig, K.; Pawlowsky-Reusing, E.; Hinkelmann, R.; Rouault, P. Sustainable urban drainage systems in established city developments: Modelling the potential for CSO reduction and river impact mitigation. J. Environ. Manag. 2020, 274, 111207.
29. Eckart, K.; McPhee, Z.; Bolisetti, T. Performance and implementation of low impact development—A review. Sci. Total Environ. 2017, 607–608, 413–432.

30. Lim, H.S.; Lim, W.; Hu, J.Y.; Ziegler, A.; Ong, S.L. Comparison of filter media materials for heavy metal removal from urban stormwater runoff using biofiltration systems. J. Environ. Manag. 2015, 147, 24–33.

31. Gong, Y.; Yin, D.; Li, J.; Zhang, X.; Wang, W.; Fang, X.; Shi, H.; Wang, Q. Performance assessment of extensive green roof runoff flow and quality control capacity based on pilot experiments. Sci. Total Environ. 2019, 687, 505–515.

32. Zubelzu, S.; Rodríguez-Sinobas, L.; Andrés-Domenech, I.; Castillo-Rodríguez, J.; Perales-Momparler, S. Design of water reuse storage facilities in Sustainable Urban Drainage Systems from a volumetric water balance perspective. Sci. Total Environ. 2019, 663, 133–143.

33. Johnson, D.; Geisendorf, S. Are Neighborhood-level SUDS Worth it? An Assessment of the Economic Value of Sustainable Urban Drainage System Scenarios Using Cost-Benefit Analyses. Ecol. Econ. 2019, 158, 194–205.

34. Joshi, P.; Leitão, J.P.; Maurer, M.; Bach, P.M. Not all SuDS are created equal: Impact of different approaches on combined sewer overflows. Water Res. 2020, 191, 116780.

35. Li, J.; Gong, Y.; Li, X.; Yin, D.; Shi, H. Urban stormwater runoff thermal characteristics and mitigation effect of low impact development measures. J. Water Clim. Chang. 2018, 10, 53–62.

36. Guptha, G.C.; Swain, S.; Al-Ansari, N.; Taloor, A.K.; Dayal, D. Assessing the role of SuDS in resilience enhancement of urban drainage system: A case study of Gurugram City, India. Urban Clim. 2022, 41, 101075.

37. Maqbool, R.; Wood, H. Containing a sustainable urbanized environment through SuDS devices in management trains. Sci. Total Environ. 2021, 807, 150812.

38. Sharma, A.K.; Cook, S.; Tjandraatmadja, G.; Gregory, A. Impediments and constraints in the uptake of water sensitive urban design measures in greenfield and infill developments. Water Sci. Technol. 2012, 65, 340–352.

39. Tjandraatmadja, G. Chapter 5—The Role of Policy and Regulation in WSUD Implementation. In Approaches to Water Sensitive Urban Design; Sharma, A.K., Gardner, T., Begbie, D., Eds.; Woodhead Publishing: Cambridge, UK, 2019; pp. 87–117.

40. Wong, T.H.F. Water sensitive urban design−The journey thus far. Australas. J. Water Resour. 2006, 10, 213–222.

41. Liu, D. A Comparative Research on LID and WSUD from the Perspective of Rainwater Management. Archit. Cult. 2021, 93–96. (In Chinese)

42. Sun, X.; Qin, H.; Lu, W. Evolution of Water Sensitive Urban Design in Australia and Its Enlightenment to Sponge city. Chin. Landsc. Archit. 2019, 35, 67–71. (In Chinese)

43. Mitchell, V.; Deletic, A.; Fletcher, T.; Hatt, B.; McCarthy, D. Achieving multiple benefits from stormwater harvesting. Water Sci. Technol. 2007, 55, 135–144.

44. Leng, L.; Mao, X.; Jia, H.; Xu, T.; Chen, A.S.; Yin, D.; Fu, G. Performance assessment of coupled green-grey-blue systems for Sponge city construction. Sci. Total Environ. 2020, 728, 138608.

45. Yin, D.; Chen, Z.; Yang, M.; Jia, H.; Xu, K.; Wang, T. Evaluation of runoff control effect in sponge city construction based on online monitoring + simulation modeling. Environ. Eng. 2020, 38, 151–157. (In Chinese)

46. Zhang, Y. Inspiration from Traditional Wisdom of Rainwater Utilization to Contemporary Urban Landscape Design; Nanchang University: Nanchang, China, 2018. (In Chinese)

47. UNSCEO. Honghe Hani Rice Terraces Inscribed on UNESCO's World Heritage alongside an Extension to the uKhahlamba Drakensberg Park. Available online: https://www.unesco.org/en/articles/honghe-hani-rice-terraces-inscribed-unescos-world-heritage-alongside-extension-ukhahlamba (accessed on 22 June 2013).

48. Cun, C.; Zhang, W.; Che, W.; Sun, H. Review of urban drainage and stormwater management in ancient China. Landsc. Urban Plan. 2019, 190, 103600.

49. UNSCEO. Ancient Villages in Southern Anhui-Xidi and Hongcun. Available online: https://whc.unesco.org/en/list/1002 (accessed on 30 November 2020).

50. Xu, Y.-S.; Shen, S.-L.; Lai, Y.; Zhou, A.-N. Design of sponge city: Lessons learnt from an ancient drainage system in Ganzhou, China. J. Hydrol. 2018, 563, 900–908.

51. Xu, C. Research on Life-Cycle Environmental and Economic Benefits Assessment of Sponge city Source Control Facilities; Tsinghua University: Beijing, China, 2020.

52. Liu, D. China's sponge cities to soak up rainwater. Nature 2016, 537, 307.

53. Larsen, T.A.; Hoffmann, S.; Lüthi, C.; Truffer, B.; Maurer, M. Emerging solutions to the water challenges of an urbanizing world. Science 2016, 352, 928–933.

54. Zhang, L. Typical Cases of Sponge city Construction; China Architecture Publishing: Beijing, China, 2017.

55. Huang, M.; Shen, R.; Yan, D.; Huo, D. Sponge City Construction and Operation Technology System; China Architecture Publishing: Beijing, China, 2019.

56. Xu, H. Theory and Practice of Urban Sponge Green Space Planning and Design; Southeast University Press: Nanjing, Jiangsu, 2021.

57. Jia, H.; Liu, Z.; Xu, C.; Chen, Z.; Zhang, X.; Xia, J.; Yu, S.L. Adaptive pressure-driven multi-criteria spatial decision-making for a targeted placement of green and grey runoff control infrastructures. Water Res. 2022, 212, 118126.

58. Liu, Z.; Xu, C.; Xu, T.; Jia, H.; Zhang, X.; Chen, Z.; Yin, D. Integrating socioecological indexes in multiobjective intelligent optimization of green-grey coupled infrastructures. Resour. Conserv. Recycl. 2021, 174, 105801.

59. Xu, C.; Tang, T.; Jia, H.; Xu, M.; Xu, T.; Liu, Z.; Long, Y.; Zhang, R. Benefits of coupled green and grey infrastructure systems: Evidence based on analytic hierarchy process and life cycle costing. Resour. Conserv. Recycl. 2019, 151, 104478.

60. Zhu, Y.; Xu, C.; Yin, D.; Xu, J.; Wu, Y.; Jia, H. Environmental and economic cost-benefit comparison of sponge city construction in different urban functional regions. J. Environ. Manag. 2021, 304, 114230.

61. Xu, C.; Shi, X.; Jia, M.; Han, Y.; Zhang, R.; Ahmad, S.; Jia, H. China Sponge city database development and urban runoff source control facility configuration comparison between China and the US. J. Environ. Manag. 2021, 304, 114241.

62. Chen, Z.; Tang, Q.; Liang, C. Performance Evaluation of Sponge city Construction in Qian’an City. Hebei Province Water Conservancy 2021, 33–37. (In Chinese)

63. Cao, D.; Wei, Y.; Xu, R.; Chen, Q. Performance Evaluation of sponge city Construction—A case study of Jiaxing City. Spatial Governance for High-quality Development. In Proceedings of the 2021 China Urban Planning Annual Conference (08 Urban Ecological Planning), Chengdu, China, 25–30 September 2021.

64. Cheng, J.; Wang, Y.; Guo, X. Sponge Castle Adventure; Jinan Publishing Press: Jinan, Shandong, 2017.

65. Cheng, J. Sponge city Exploration; Jinan Publishing Press: Jinan, China, 2017.

66. Lu, H.; Chen, Y.W. Design Our Sponge Community; Shanghai Education Press: Jinan, China, 2018.

67. Zhang, W.; Che, W. Connotation and multi-angle analysis of sponge city construction. Water Resour. Prot. 2016, 32, 19–26. (In Chinese)

68. Wang, Y.; Sun, M.; Song, B. Public perceptions of and willingness to pay for sponge city initiatives in China. Resour. Conserv. Recycl. 2017, 122, 11–20.

69. Wang, Y.; Liu, X.; Huang, M.; Zuo, J.; Rameezdeen, R. Received vs. given: Willingness to pay for sponge city program from a perceived value perspective. J. Clean. Prod. 2020, 256, 120479.

70. She, N.; Xie, Y.; Li, D. Reflections and Suggestions on China’s Sponge city Construction. Landsc. Archit. Front. 2021, 9, 82–91. (In Chinese)
