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Sponge City Policy and Sustainable City Development: The Case of Shenzhen

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The massive construction of buildings has changed the city's aquatic ecological environment. The aquatic ecological condition of the city has been deteriorated with serious water issues. To coordinate various departments to jointly build the sponge city and improve the water environment, the Shenzhen government formulated the policy note on "Interim Measures for the Construction Management of Shenzhen Sponge City". This article discusses the impact of the policy note on Shenzhen's construction of sponge cities. The result shows that the policy is effective from the perspective of the environment. However, in the face of a complex water ecological environment, there are still some deficiencies in the policy. We therefore put forward policy suggestions for the Shenzhen municipal government to better manage its construction of sponge city in the future.

Keywords: sponge city, policy note, sustainable development, Shenzhen, urban planning

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1 INTRODUCTION

Sponge city is a method that takes full advantage of the rainwater, which is absorbed, stored, and slowly released by the city facilities, such as waterways, sunken rain garden, green spaces, permeable pavement and floor tiles, and green roof buildings to control stormwater runoff and to accumulate, infiltrate, and purify naturally (Li et al., 2017; Xia et al., 2017; Chan et al., 2018). Sponge city can absorb and utilize the rainfall on the spot through enhancing the permeability of the road surface, the capacity of water storage, water purification and water use of Sunken Green Areas, and rain gardens, as well as the drainage of surface channels, to improve the urban water environment and save urban water resources (Liu et al., 2017; Wang et al., 2018). The concept is closely related to strategies and practices of the Western world such as the "Sustainable Drainage System" of the United Kingdom, "Best Management Practice", and "Low Impact Development" (LID) from the United States and New Zealand, as well as the "Water Sensitive City" from Australia (Fletcher et al., 2015; Chui et al., 2016; Mao et al., 2017).

Urban construction in China has made remarkable achievements, but there also exist some problems. Most of the rainfall is discharged as runoff, which has led to waterlogging during heavy rain in the city (Lyu et al., 2018). It results in water ecological deterioration and water environment pollution, and seriously affects citizens' lives and the orderly operation of the city. This requires us to seek innovative solutions for drainage and waterlogging prevention.

The main objective of the sponge city is to ensure that there is no water accumulation in the city when the rain is light, and to minimize the possibility of waterlogging when the rain is heavy. It enables the city to take full advantage of the rainwater by controlling stormwater runoff, and to

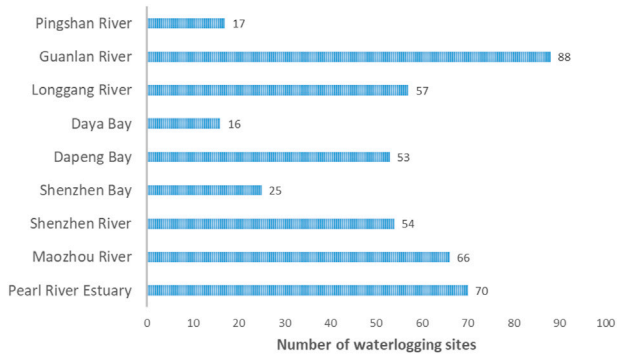

FIGURE 1 | Number of waterlogging sites across various watersheds in Shenzhen.

improve the urban water environment and save urban water resources by absorbing and utilizing the rainfall on the spot (Nguyen et al., 2019).

Shenzhen is a mega-city in southern China with a population of over 17 million in 2020. It is a major high-tech and financial center in China with a vibrant and booming economy. In the decades following China's reform and opening up, the city has transformed from a small peasant village into a modern metropolis. Since its establishment, Shenzhen has experienced high-speed development. However, the municipal planning of Shenzhen lags behind the rapid growth of the city, and there are a large number of illegal constructions lacking supportive drainage facilities. The waterlogging control standards of the waterlogging prevention facilities in Shenzhen and the construction standards of the rainwater pipe network are lower than the current national standards.

Shenzhen's water management is not well coordinated with the river basins. The insufficient connection between urban development and the construction of drainage facilities have led to the overflow of sewage into the rainwater system. Drainage management of municipal construction projects such as rail transit is not in place, and the original drainage system has been destroyed, resulting in a large number of new waterlogging points. In addition, the rain and sewage mixed flow are common in Shenzhen. The sewage treatment system is designed and constructed according to pure sewage, which makes it less effective during the rainy seasons. Moreover, reservoirs have been constructed to alleviate the freshwater shortage, which has led to a smaller runoff in the middle and lower reaches of the rivers, and water exchange capacity in Shenzhen rivers is poor (Li et al., 2016). These heavily affected Shenzhen's water environment for a long time. Accordingly, local waterlogging occurs frequently in the city. **Figure 1** shows the number of waterlogging sites across the watersheds of the city.

Sponge city construction is a significant way to transform the urban development model, as it solves urban water problems and builds a city in a green and sustainable way. During the development of Shenzhen, a series of water problems were encountered including the potential risks of water security, the need to improve the water environment, the lack of local water resources, and the need to restore water ecology. All of these demand the sponge city construction initiative.

We chose Shenzhen as the case study of sponge city in China for the following reasons: First, in the 2019 National Sponge City Project Evaluation organized jointly by the Ministry of Finance, Ministry of Housing and Urban-Rural Development, and Ministry of Water Resources of the Chinese government, Shenzhen ranked first among 14 sponge city initiatives. It is important to uncover the advantages of Shenzhen's initiative. Second, as Shenzhen is quickly emerging as the major city in the Greater Bay Area of China, it is helpful to clarify the focus and direction of sponge city construction in the post-sponge pilot period by reviewing the relevant work of sponge city construction in Shenzhen in recent years.

2 MEASURES FOR THE CONSTRUCTION OF SPONGE CITY IN SHENZHEN

The "Interim Measures for the construction and management of Shenzhen sponge City" ("Measures" afterward) was issued on December 7, 2018, and will be valid for 3 years. "Measures" contain seven parts including general rules, planning management, construction management, operation and maintenance, capacity building, legal responsibilities, and the supplementary rules, with a total of 36 articles. The policy applies to the sponge city planning, design, construction, operation, maintenance, and management activities of various construction projects in Shenzhen.

Sponge city construction involves all aspects of city construction and requires multi-sector cooperation and multi-disciplinary integration (Jia et al., 2017). However, from the perspective of institutional mechanism, there is still no systematic top-level document to coordinate and lead the construction and management of the sponge city.

According to the assessment standard of the Ministry of Housing and Urban-Rural Development, building sponge cities should establish a legalized mechanism that can last a long time to ensure the implementation of the sponge city construction concept in all aspects of urban planning, construction, and management, and to improve the systemic nature of urban construction. The Measures help integrate the requirements of sponge city construction into the current city construction system and the daily administrative work of the city construction management.

In April 2016, after being selected as the second batch of sponge city national pilots, Shenzhen has set the sponge framework through a spatial integration of water management and urban re-construction. First, it completes a comprehensive city-district-key area 3-layer sponge plan, which has realized a full coverage of the city from both the spatial and administrative level. Second, it has formulated a standardized framework for the city construction with the coordination sponge city requirement. Third, it enhances sponge city construction through ecological protection and forms a sustainable base for the city's grand ecosytem.

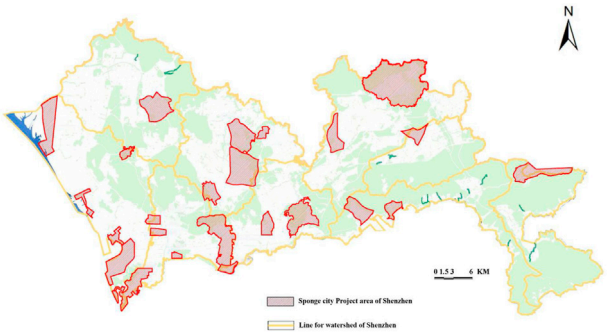

FIGURE 2 | Sponge city project areas within Shenzhen watersheds.

Shenzhen carried out a series of projects to promote the project of sponge city since 2016. In terms of top-level design, 26 sponge city plans have been accomplished (Lancia et al., 2020). The first sponge city Public Private Partnership (PPP) project was initiated in Guangming district of Shenzhen, with a total investment of over 1.5 billion Chinese Yuan. Shenzhen has also been actively creating a sponge technology standard system concerning all aspects of project planning, design, construction, acceptance, operation and maintenance, and performance evaluation. At present, 38 sponge cities supporting policies and standards have been issued. A large number of high-quality projects have also emerged in Shenzhen, for example, the Baishida Elementary School project in Luohu District. The project built a permeable playground, which could solve water accumulation at the entrance of the campus. The control rate of total annual runoff in Futian Mangrove Ecological Park has reached 92%; that is, the rainwater in the ecological park has been effectively used, 92% of the total annual rainfall has been infiltrated into the green space, stored in the freshwater lake, or evaporated, and the remaining 8% is discharged outside the park. Another example is the demonstration building community project—Vanke Cloud City Project, which designs and uses abandoned quarry pits to achieve a win–win situation between construction and ecological restoration. These projects provide successful experiences for the transformation and construction in Shenzhen's sponge city.

Overall, 1,361 projects have been completed in Shenzhen, and the newly built-up sponge city area is 276 km^2, accounting for 28.3% of the urban area, exceeding the national target of 20% for sponge city, as shown in **Figure 2**. Meanwhile, 220 historical waterlogging points have been basically eliminated (Liu et al., 2020).

3 ACTIONABLE RECOMMENDATIONS

China's urbanization rate has been greatly improved from the level of 17.9% in 1978 to 58.52% in 2017. Rapid urbanization has led to relatively backward urban construction, and Shenzhen is no exception. Climate risks related to typhoons, rainwater, and waterlogging have seriously disrupted the daily life and travel safety of Shenzhen residents.

As a new type of urbanization model, the sponge city can enrich the way of harmonious development between the use of water resources and urban development and provide a feasible idea to solve the water problem. It can also contribute to the protection and maintenance of water resources. Therefore, sponge city is of pivotal significance for systematically solving the water problem in urban development and promoting sustainable urban development in order to control possible urban diseases caused by floods and the increasing concerns on surface water pollution (Liang, 2018). In areas with abundant rainfall like Shenzhen, it is necessary to control the stored water through the construction of sponge cities.

Therefore, it is very necessary to enhance the sponge city policy, as evidenced from the fact that it has played a positive role during its implementation. However, in the face of a complex aquatic ecological environment, there are still deficiencies within this policy.

Firstly, the construction of Shenzhen's sponge city is still in its infancy. At present, most of the documents issued have provided effective guidance in many aspects, and some supporting laws and regulations have imposed institutional constraints on the construction of the sponge city. However, at present, Shenzhen's sponge city construction seldom involves the participation of citizens. The higher the degree of citizen participation and the more high-level construction talents in a region, the more likely it is to formulate policies and plans that meet the needs of the region under the influence of efficiency constraints (Wagle, 2000). Therefore, local governments should pay more attention to public participation, including citizens and private corporations. The government needs to dredge the channels of public participation and understand the public opinions in a more comprehensive way. Meanwhile, it requires that the government needs to protect the legitimate rights and the enthusiasm of citizens to take part in the planning stage.

Secondly, sponge city construction involves many fields, such as architecture, green space, urban water system, and road traffic, and covers many aspects, such as urban planning, engineering design, construction implementation, management, and maintenance (Sun et al., 2020). It is, therefore, necessary to formulate corresponding guidelines for different fields to form a more systematic and mature sponge city construction standard policy system. As presented in **Figure 3**, in each stage of the sponge city construction project, different governmental departments need to carry out comprehensive coordination and joint management. Additionally, in terms of technical support, local governments should support various engineering technology centers and industry promotion platforms related to sponge cities to provide all-around technical and industrial support for the construction of sponge cities. A comprehensive sponge city database including hydrology, meteorology, land, and transportation should also be set up, and the data should be updated in time to provide data support for sponge city policy according to local conditions.

Thirdly, with the progress of construction of sponge city and release of self-assessment notice, the focus of sponge city

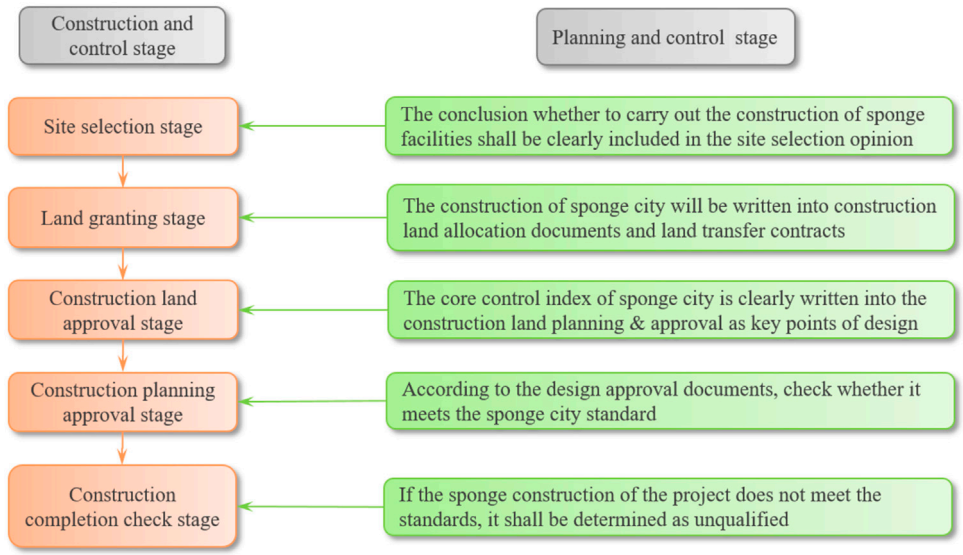

FIGURE 3 | Procedures of Sponge city construction project in Shenzhen.

construction should be gradually shifted from development and construction to monitoring and information platform construction. However, the current sponge city monitoring data are insufficient, so it is difficult to build a sponge city information integrated management and control platform. In terms of monitoring data, no systematic rainwater management database has been formed, resulting in insufficient comprehensive monitoring data of rainwater collection, flow, and water quality. Therefore, in addition to the improvement of the policy itself, we should also vigorously develop relevant scientific data record processing technology to provide a solid foundation to operate the policy in a better way.

4 CONCLUSION

Since its high-speed development process, Shenzhen's backward municipal planning has been unable to meet the facility requirements for the rapid development of the city, and thus have caused Shenzhen's water environment to be seriously polluted for a long time. Waterlogging in the city occurs frequently. To solve the above issue, the Shenzhen government formulated the "Interim Measures for the Construction Management of the Shenzhen Sponge City". The sponge city is able to protect the ecosystem of the city and hydrological characteristics, thereby achieving better self-regulation and sustainable development of the city's water ecological environment.

Even though the implementation of this policy is meaningful and has contributed a lot to the construction of Shenzhen's sponge city, the policy needs continuous improvement. For instance, the monitoring data of the sponge city is insufficient at present, and a systematic rainwater management database has not been formed. So, we put forward related suggestions, such as developing relevant data record processing technology to provide a solid foundation to enhance the effectiveness of the policy.

AUTHOR CONTRIBUTIONS

YW and LZ conceived of the idea and outlined the brief. LZ wrote the first draft of the article. ZJ provided data support. All authors contributed to article revision and have both read and approved of the submitted version.

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REFERENCES

Chan, F. K. S., Griffiths, J. A., Higgitt, D., Xu, S., Zhu, F., Tang, Y.-T., et al. (2018). "Sponge City" in China-A Breakthrough of Planning and Flood Risk Management in the Urban Context. *Land use policy* 76, 772–778. doi:10.1016/j.landusepol.2018.03.005

Chui, T. F. M., Liu, X., and Zhan, W. (2016). Assessing Cost-Effectiveness of Specific LID Practice Designs in Response to Large Storm Events. *J. Hydrol.* 533, 353–364. doi:10.1016/j.jhydrol.2015.12.011

Fletcher, T. D., Shuster, W., Hunt, W. F., Ashley, R., Butler, D., Arthur, S., et al. (2015). SUDS, LID, BMPs, WSUD and More - the Evolution and Application of Terminology Surrounding Urban Drainage. *Urban Water J.* 12 (7), 525–542. doi:10.1080/1573062x.2014.916314

Jia, H., Wang, Z., Zhen, X., Clar, M., and Shaw, L. Y. (2017). China's Sponge City Construction: A Discussion on Technical Approaches. *Front. Environ. Sci. Eng.* 11 (4), 1–11. doi:10.1007/s11783-017-0984-9

Lancia, M., Zheng, C., He, X., Lerner, D. N., Andrews, C., and Tian, Y. (2020). Hydrogeological Constraints and Opportunities for "Sponge City" Development: Shenzhen, Southern China. *J. Hydrol. Reg. Stud.* 28, 100679. doi:10.1016/j.ejrh.2020.100679

Li, H., Ding, L., Ren, M., Li, C., and Wang, H. (2017). Sponge City Construction in China: A Survey of the Challenges and Opportunities. *Water* 9 (9), 594. doi:10.3390/w9090594

Li, X., Li, J., Fang, X., Gong, Y., and Wang, W. (2016). Case Studies of the Sponge City Program in China. *World Environ. Water Resour. Congress* 2016, 295–308. doi:10.1061/9780784479858.031

Liang, X. (2018). Integrated Economic and Financial Analysis of China's Sponge City Program for Water-Resilient Urban Development. *Sustainability* 10 (3), 669. doi:10.3390/su10030669

Liu, H., Jia, Y., and Niu, C. (2017). "Sponge City" Concept Helps Solve China's Urban Water Problems. *Environ. Earth Sci.* 76 (14), 1–5. doi:10.1007/s12665-017-6652-3

Liu, J., Gong, X., Ren, X., Liu, C., Wu, L., and Wu, Y. (2020). Sponge City Construction and Innovation in Shenzhen. *J. Shenzhen Univ. Sci. Eng.* 37 (4), 331–440. doi:10.3724/sp.j.1249.2020.04334

Lyu, H.-M., Xu, Y.-S., Cheng, W.-C., and Arulrajah, A. (2018). Flooding Hazards across Southern China and Prospective Sustainability Measures. *Sustainability* 10 (5), 1682. doi:10.3390/su10051682

Mao, X., Jia, H., and Yu, S. L. (2017). Assessing the Ecological Benefits of Aggregate LID-BMPs through Modelling. *Ecol. Model.* 353, 139–149. doi:10.1016/j.ecolmodel.2016.10.018

Nguyen, T. T., Ngo, H. H., Guo, W., Wang, X. C., Ren, N., Li, G., et al. (2019). Implementation of a Specific Urban Water Management - Sponge City. *Sci. Total Environ.* 652, 147–162. doi:10.1016/j.scitotenv.2018.10.168

Sun, Y., Deng, L., Pan, S.-Y., Chiang, P.-C., Sable, S. S., and Shah, K. J. (2020). Integration of green and gray Infrastructures for Sponge City: Water and Energy Nexus. *Water-Energy Nexus* 3, 29–40. doi:10.1016/j.wen.2020.03.003

Wagle, U. (2000). The Policy Science of Democracy: The Issues of Methodology and Citizen Participation. *Pol. Sci.* 33 (2), 207–223. doi:10.1023/a:1026500906034

Wang, H., Mei, C., Liu, J., and Shao, W. (2018). A New Strategy for Integrated Urban Water Management in China: Sponge City. *Sci. China Technol. Sci.* 61 (3), 317–329. doi:10.1007/s11431-017-9170-5

Xia, J., Zhang, Y., Xiong, L., He, S., Wang, L., and Yu, Z. (2017). Opportunities and Challenges of the Sponge City Construction Related to Urban Water Issues in China. *Sci. China Earth Sci.* 60 (4), 652–658. doi:10.1007/s11430-016-0111-8

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