Research on key fundamentals and technical systems of Sponge City development in China

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Abstract. The Chinese government has promoted Sponge City construction in the last five years. The premise for a “Sponge City” was based on the problem of accumulation and rapid discharge of various stormwater and water-environment issues during the urbanization process in China. With reference to the expansion of stormwater management in other developed countries, this study summarizes related research results in China. Unlike other stormwater management systems put forward by other countries, such as low impact development, water sensitive urban design, etc., this study investigates stormwater issues at the current developmental stage in China and comprehensively considers the integrated objectives, including water ecology, water security, water resources, water environment, and water culture. Aimed at transforming the traditional extensive urbanization model, it builds on the existing integrated system at the core of stormwater management, which connects with the sewage and / or water supply, and other related systems. This study describes and summarizes the Sponge City’s key fundamentals, targets, technical systems, and extensional relations to guide the further construction of Sponge City and provide important references for other countries.

1. Introduction
The urbanization rate of China was about 19.4% in 1980 and will rise to 60% in 2020, taking into account an increased rate of nearly 1% per year in the past 40 years[1]. Urban issues gradually emerged during the rapid extensive development process, with particular problems in the urban environment, resources and ecology. In the past two or three decades, although China had carried out long-term research and practical work in the fields of urban drainage and stormwater management, many urban stormwater issues, such as flooding, stormwater pollution and combined sewer overflow (CSO) pollution have still been common in Chinese urban development. According to statistics, by the end of 2016, nearly 2000 urban water body were identified as “black and malodorous water” across the country[2]. Since urban sewage treatment rate had over 90% in 2018[3], the issues of urban stormwater and combined sewer system have been becoming more and more highlighted.
The Chinese government first proposed the concept of “Sponge City” in 2013 and launched the pilot construction programs in 16 cities in 2015 and 14 cities in 2016[4]. Because this field requires extensive involvement and systematic complexity, there is a shortage of knowledge and experience in most Chinese cities, so at the same time, demands for rapid development of skills must be addressed. Although Sponge City construction is gaining greater understanding and coverage in government, academia and engineering fields, there are still many different interpretations and a lack of consensuses in the promoting process. This directly affects the standards setting, planning compilation, governance build, effects evaluation, markets guide and many other aspects of Sponge City development.

This research focused on the key fundamentals, objectives, technical systems and extensional relations of “Sponge City”, and compared them with the progress of stormwater management in other countries of the world, in order to exploit the wisdom and experience of integrated solutions for urban water issues, notably the developing countries who are suffering from the same issues.

2. Urban stormwater and water environment issues in China

2.1. Issues of accumulation and rapid discharge

In the process of Chinese urbanization, urban stormwater systems didn’t get enough attention compared with sewage and water supply systems. For instance, the “Code for design of outdoor drainage engineering” (GB50014) is the primary Chinese national standard to guide urban stormwater and wastewater system design. From the code’s first edition (1987) until to the third revision (2011), the main requirements for stormwater systems concerned only drainage pipes, pumping stations and ancillary facilities. Most Chinese cities just considered 0.5-3/year storm frequency adequate for the storm drains design in general urban areas, according to the code, which is far below that in developed countries. The traditional design method also could’t meet the urban development requests.

Urban water environment issues are also increasingly highlighted. Because separate stormwater drains often mixed with wastewater drains in many Chinese urban areas, especially in old towns, there still exist the serious issues in separate stormwater systems, with mixed wastewater discharging, and separate sewer overflows (SSO) [5]. There are also a lot of Chinese urban areas with combined sewer system, so the pollution control of combined sewer overflow (CSO) is also at the forefront of urban water environment management in China[6]. Serious pipe network deterioration, such as sediment deposition, pipe damage and so on requires long-overdue maintenance. According to statistics of national environmental supervision in 2017, for above issues of sewer system, the differences between statistical categories and real data of urban sewage treatment rate could reach to 20%[5]. Historically, there has been an absence of urban stormwater runoff and CSO pollution control requirements in China national laws and policies. In “Action Plan for Prevention and Control of Water Pollution” and other related policies issued in recent years, stormwater runoff pollution control began to be mentioned, but referred to as initial runoff control[7]. Because natural hydrologic functions have been broken after urbanization, some ecological issues, like soil erosion and biological habitat degradation are gradually emerging.

Thus the issues in Chinese urban stormwater and water environment systems are complex and mixed, it’s a big challenge, but also an important opportunity for further improvement of Chinese urban water systems.

2.2. Comparison with developed countries

“Stormwater Management” is an important field for improvement in water systems in developed countries[8], whilst upgrading urban sewage and water supply systems. Different stages of development in the field of stormwater management in the USA, Australia, and other countries were looked at.

In the USA, the concept of Best Management Practice (BMP) for stormwater was put forward in the 1970s. Since then, a lot of centralized stormwater storage facilities like stormwater detention or retention ponds and wetlands were applied with stormwater drains for stormwater quality and quantity control. Then in the 1990s, the concept of Low Impact Development (LID) was proposed. It focused more on
stormwater runoff volume control to mimic the natural hydrologic functions, and was characterized by
decentralized and small scale facilities such as bioretention systems located at or near the source of
runoff. In recent years[9][10], “Green Stormwater Infrastructure (GSI)” came to be widely used to
become an “umbrella word”, involving different scales of green stormwater management measures[8].
Since the 1970s’-’80s, combined sewer overflow (CSO) pollution control was initiated in the USA,
including nine basic control measures, the long term control plan, promoting green and grey
infrastructure combination and so on[6].

In Australia, the development of urban water systems was divided into different stages with
urbanization, including water supply city (basic state of modern water management), sewered city
development of sewerage systems), drained city (protect city from flooding), waterways city (clean
waterways, point and diffuse source pollution management, put forward water sensitive urban design,
WSUD), water cycle city (waterway health restoration, WSUD widely promoted), and water sensitive
city (urban design reinforcing water sensitive values) were presented[11]. The connotation of WSUD is
that water is integrated as an important consideration from the perspective of urban planning and urban
design., and encompasses all aspects of integrated urban water cycle management, with stormwater
management the most highlighted subset[12]. In Germany and other European countries, WSUD was
also proposed in some stormwater management research reports, and bring forward WSUD as the
combination of water management, urban plan and design, and landscape design[13].

In China, a number of research teams have investigated urban rainwater harvest, urban drainage and
flood control, and urban diffuse pollution control in the past 20 years[14]. The concept of “stormwater
synthetic utilization” contained stormwater harvest and infiltration was put forward in the late of
1990s[15]. PAN put forward the design rainfall and corresponding annual volume capture ratio of
different Chinese cities[16]. In 2011, “Low Impact Development” was incorporated into China “12th
five-year period” national water special research programs. These provided an important foundation for
the Sponge City proposition. In a general sense, however, a relatively complete stormwater management
system wasn’t established in China step by step, as in the USA and Australia, and the characteristics and
critical issues of urban stormwater system and urban development level are extremely diverse and
complex in different Chinese cities, even in different regions of a city. There is still no common and
clear understanding of stormwater management in China.

2.3. Sponge City proposition

Because stormwater management in China has remained in its infancy for a long time, a lot of
accumulated stormwater issues have evolved progressively. Referencing the developmental course of
this field in developed countries, and on the basis of the previous Chinese research and practice, in all
the above context, the concept of Sponge City was proposed. Thus the “Sponge City” concept was not
created out of nothing: it is built on long-term development logic, and important expert foundations.

The aims of “water ecology, water security, water resources, water environment, water culture” were
set out for Sponge City construction, giving consideration to the integrated stormwater and other water
issues now emerging in China, but the above “Five Water” aims basically involve all aspects of urban
water systems, and there are several ongoing works in different fields of expertise. Since the Sponge
City was proposed, there have always been different interpretations from different perspectives.

Ren consider Sponge City belongs to the fields of integrated water resource and water environment
management, which involves three key units that are stormwater management, “black and odorous”
water control, and sewage treatment[17]. Wang consider Sponge City mainly focus on three issues of
urban flood, water pollution, and water shortage[18]. Zhang put forward the key of Sponge City is
stormwater management[14]. Yu proposed the major work of Sponge City is to establish different scales
of ecological infrastructure (EI)[19]. Different opinions emerging resulted in the boundary of Sponge
City construction being blurred, and created confusion and doubts for those working on Sponge City
construction. Identifying the Sponge City’s key fundamentals, key objectives, key technical systems,
and extensional relations needs to be the prime focus in order to guide the further construction
scientifically.
3. The Fundamentals and Objectives of Sponge City Construction

3.1. Fundamental analysis of sponge city construction

Some research has revealed that the natural hydrologic regime in urban areas is changing with the development of impervious surface and geography characteristics, and this is the quintessential reason for multiple urban water issues[20]. In Wuhan, for example, the main urban area was 189.3 km² in 1990, then increased to 497.36 km² in 2010, and the imperious surface rate was up to 90% in core urban areas. At the same time, many natural depressions for stormwater storage have disappeared with development. There were 127 lakes and ponds in downtown Wuhan in 2005, and 38 of them remaining in 2016[21], an important cause of more frequent urban flooding, more serious pollution, more severely ecological degradation issues.

In ancient China, there were ecological concept of “Taoism follows nature” and “human-water harmony”. Back in the Qin Dynasty (200 BC), the Chinese ancients created terrace, many separate stormwater storage spaces were created through building terraces[22]. When the rainfall volume exceeds the capacity of terraces, stormwater runoff overflow to next layer, the runoff velocity was reduced and runoff concentration time was extended, so it can storage regional water resources and prevent soil erosion, maintain local natural hydrologic regime, which were highly consistent with “Sponge City”.

The key concept of Sponge City is changing traditional extensive urban development model, maintaining the natural hydrologic functions after urbanization. Natural hydrologic processes mainly involve rainfall, evapotranspiration, infiltration and runoff. The fundamental principal of Sponge City construction is to control urban stormwater runoff comprehensively using integrated measures of “infiltration, detention, retention, purification, harvest, and drainage” to mimic the natural hydrologic regime.

Stormwater management is the key intent of Sponge City, in accordance with LID and WSUD, but as mentioned previously, China is currently at a different stage of stormwater management to the USA and Australia. On the one hand, China needs to catch up with international levels to build the urban stormwater management systems - an important replenishment of Chinese urban water management. On the other hand, the interrelationships of urban stormwater, sewage, water supply, reclaimed water and other related systems must be synthetically considered, and connected with the ongoing related work of “black and odorous” water management and sewage system quality and efficiency improvement in China. Because of the transformation of urban development models, there is also a need to manage the interactive relationships of urban planning, landscape architecture, municipal engineering and many different fields, so Sponge City is a comprehensive and systematic work, and an overstepping development of urban water systems in China.

3.2. Key objectives and extensional relations

Identifying the key objectives and extensional relations with other objectives first, the construction contents and expected effects of Sponge City construction will become clear. Corresponding with the key fundamental of maintaining hydrologic functions before and after urbanization, the key objectives of Sponge City construction can be evaluated through consideration of runoff volume, peak flow rates, storm frequency, and water quality management.

Through continuous rainfall record analysis, the results show that the majority of stormwater runoff volume comes from small and frequent events (less than 1/year storm frequency). Under the natural condition, this portion of runoff volume is mainly managed by infiltration, interception, evapotranspiration and depression losses[23], so small storm events are controlled through natural and artificial measures in the core of stormwater runoff volume control, which is now an international consensus. Because of the features of randomness and complexity for stormwater runoff pollution, increased runoff volume is the cause of water quality issues, so the objective of runoff pollution control always needs to be achieved through runoff volume control. Based on this, runoff volume control targets are always called water quality volume (WQV) in the USA. As an example, in the state of Connecticut, there is a runoff pollution requirement in the MS4 permit that is reducing the average annual TSS loading.
by 80%. This target is assumed to be achieved by the water quality volume control standard (corresponding design rainfall depth is 25 mm). Besides, the objectives of groundwater recharge, rainwater harvest and others aspects are always involved in stormwater runoff volume control; the detailed targets should be subdivided according to different conditions of different projects and cities. In Sponge City construction, the control requirement of annual runoff volume capture ratio in different Chinese regions was put forward to be implemented in Sponge City planning[24].

Stormwater runoff peak flow rates control applies mainly for large storm events. In the USA, the stormwater detention ponds have been widely used to control runoff peak rates since the 1970s to mitigate the urban flood risk. Based on the concept of the establishment of minor and major drainage systems, overland flow paths and centralized storage measures were built with storm drains to meet the peak rates discharge requirements of all storm frequency events from 1-100/year. In Denver and other regions of the United States, the urban drainage master plan is required to make to establish the runoff peak flow control system based on “site-catchment-watershed” [23]. In China, the “Technical code for urban flooding prevention and control” (GB51222) was issued in 2017, the runoff peak flow control requirements for urban drainage and flood control were put forward for 2-10/year storm frequency and 20-100/year storm frequency respectively, and needed to be connected with river flood control requirements.

![Figure 1](image-url)  
**Figure 1.** Key objectives and extensional relations of Sponge City.

CSO control is one of the key subsets of stormwater management. The objectives of CSO control usually involve CSO events control, CSO volume control, CSO effluent volume or concentration reduction rate of TSS (total suspended solid) or BOD (biochemical oxygen demand), and effluent concentration limits of fecal coliform, pH, SS (suspended solid), BOD, DO (dissolved oxygen) and other indices. In the USA, the requirements of the annual CSO events control requirements range form 1 to 4, the annual CSO volume reduction rate requirements range from 80% – 90%, and the total TSS effluent concentration limit is 35 mg/L or 30 mg/L[25]. In China, there has been an ongoing lack of CSO control requirements, and CSO pollution has been the unavoidable result, with water environment improvement now essential in China. The CSO control standard needs to be applied comprehensively, according to different conditions of rainfall characteristic, drainage pipe condition, receiving water quality, sewage
treatment plant condition and so on. In “Assessment standard for Sponge City construction effect” (GB/T51345), which was issued in 2019, the requirement of CSO control was first proposed, for runoff that was not causing water “black and odorous”, where the CSO reduction rate was not less than 50% and the average monthly effluent concentration of SS was not less than 50 mg/L[25].

From the broader perspective of urban water systems, as well as the key objectives of stormwater management above, other related objectives, including sewage, water supply, reclaimed water systems, and urban ecology also need to be connected with each other, to achieve the integrated objectives of “water ecology, water security, water resource, water environment, water culture” and support the new urbanization development of China. The key objectives and extensional relations with other systems of Sponge City are shown in Figure 1.

In order to further guide Sponge City construction, and standardize Sponge City construction effect evaluation, the “Assessment standard for Sponge City construction effect” was issued in 2019, and thus established an assessment system for the effects of Sponge City construction effect. As shown in the evaluation contents, the key objectives of stormwater management were collected from different scales of projects and catchments respectively, involving runoff volume, peak flow rates, frequency, pollution control. And connection requirements with other related systems were also put forward to accomplish the integrated objectives involving natural ecological pattern control, urban water environment improvement, groundwater recharge, and urban heat effect mitigation (Figure 2).

![Figure 2. Main contents of Sponge City construction effects evaluation.](image)

4. Key technical systems and interactive relations of Sponge City

4.1. Establishment of key technical systems

The core of Sponge City construction is urban stormwater management, the integrated stormwater management system should involve three subsets that are source control system, urban minor drainage system, and major drainage system. Because urban stormwater drainage and river flood control are managed separately by the Ministry of Housing and Urban-Rural Development and the Ministry of Water Resources in China; and their work are closely in many stormwater issues control like urban flooding. So the key technical systems should involve three subsets of stormwater management with the addition of the river flood control system, it’s “3+1” systems. The CSO control system is distinguished from urban drainage systems in terms of targets, design methods, technical measures, and it’s also an important part now in Sponge City construction, so the CSO control system can be seen as an individual sub-system separate from the four sub-systems mentioned above. At a holistic level of engineering techniques, the key integrated technical systems of Sponge City construction should consist of “4+1” sub-systems. In different projects and city areas, the actual technical systems composition should be
analyzed according to the issues and conditions involved. On the basis of identifying key technical systems of Sponge City Construction, the integrated urban water issues and related systems like water supply system, sewage system and others also should be considered from a perspective of the whole watershed/catchment.

Based on different professional responsibilities, the directly related disciplines of Sponge City construction corresponding with key technical systems are water supply and drainage engineering, environmental engineering, and water resources engineering. Indirectly related disciplines are urban plan, landscape architecture, street engineering and so on. There is a need, in Sponge City construction, to identify the specialization of different disciplines and enhance effective communication, understanding, cooperation, and eventually integration, and to preserve mutual respect. This is the important part for the efficient implementation of Sponge City construction.

Sponge City construction engineering covers both new development and redevelopment with measures that include both green and grey infrastructure. Engineering categories involve of urban drainage and flood control engineering, low impact development engineering, CSO control engineering, landscape engineering, water quality improvement engineering and so on. Identifying the role of different types of engineering in Sponge City construction and the correspondent relations between engineering and objectives is a guarantee of promoting the Sponge City construction systematically (Figure 3).

4.2. Analysis on interactive relationships of technical systems
In the core technical systems of Sponge City, the source control system is designed mainly for small storm events where storm frequency is less than 1/year with the intent of achieving stormwater runoff

![Figure 3. Key technical systems, disciplines and engineering systems of Sponge City.](image-url)
volume control at source, in projects in communities, streets, parks, squares and others[26]. Urban minor drainage system is designed to control the flow rates of greater than 2 year frequency and up 10-year frequency storm events, consisting of underground stormwater pipe networks, natural channels, and detention basins and so on. CSO control system is for CSO events control, CSO volume control and other related targets through runoff source reduction, drainage pipe improvement, mains intercepting sewer construction, CSO storage measures implementation, and sewage treatment upgrade and so on. During major storm events (up to 100/year), major drainage system would play a role in exceedance flows control when the capacity of the minor drainage system is exceeded. This includes streets, public open space, natural waterways and so on. It also needs to be connected with the river flood control system. Stormwater runoff pollution control measures can be combined with source control system, minor and major drainage system to ensure flows are afforded water quality protection, wherever possible. The sub-systems of Sponge City construction are designed for different objectives and in respective roles, while at the same time, there are close connections and interactive effects in these sub-systems. So the integrated stormwater management system must be able to coordinate different objectives through the establishment of the cascading sub-systems, to adequately manage small, minor and major rainfall events (Figure 4).

Figure 4. Interactive relations of sub-systems and objectives.

It also should be noted that “source control” is relative based on the scale of projects in Sponge City construction. It can be referred to a site or a measure, and also can be referred to the catchment management from the perspective of the watershed. With the implementation of stormwater runoff volume control in source control systems, there is also a need to consider the connected requirements with minor and major drainage systems.

Therefore, considering urban stormwater management, although sewage system, water supply system, and other related water systems are connected with each other, each system also has a relative defined boundary, so it is important to follow specifications and characteristics for each system while maintaining all links correctly.
5. Conclusions
The proposed concept of “Sponge City” was proposed based on the accumulation and rapid discharge of a lot of stormwater and other urban water issues during Chinese urbanization process. Fully referencing the developmental course of stormwater management in developed countries, this study also summarizes the Chinese related research experience, on the core of stormwater management and aimed at transforming the urban development model. Different to other stormwater management systems, like LID, WSUD, put forward by other countries, this study is inherited and developed from international stormwater management systems and takes a new path.

There is a need to build the integrated systems (“4+1”) which must be considered from the perspective of urban planning, involved in grey and green infrastructure, structural and non-structural measures, and connected with different fields and professional disciplines. Considering the development stage and complex issues emerging now in China, the integrated systems of Sponge City “cannot be built overnight” and must take account of Chinese governance, professional division, design code systems and so on to identify the fundamentals, objectives, technical and engineering systems, and the emphasis and direction in different development phases. This will be a continuous long-term process.

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References
[1] Xia J, Zhang Y Y, Xiong L H, He S, Wang L F and Yu Z B et al 2017 Opportunities and challenges of the Sponge City construction related to urban water issues in China Science China (Earth Sciences) 60 652-58
[2] Liang Z W, Siegert M, Fang W W, Sun Y, Jiang F, Lu H, Chen G H and Wang S Q 2018 Blackening and odorization of urban rivers: a bio-geochemical process FEMS Microbiology Ecology 94(3) 180
[3] Qu J H et al 2019 Municipal wastewater treatment in China: Development history and future perspectives Front. Env. Sci. Eng. 13(6) 88
[4] Li X N, Li J Q, Fang X, Gong Y W and Wang W L 2016 Case studies of sponge city program in China In: 2016 World Environmental and Water Resources Congress (West Palm Beach: ASCE) ed C S Pathak and D Reinhart pp 1-14
[5] Bai Y, Liu G Q, Zhang Z G and Xu H W 2018 Evaluation method research of municipal wastewater treatment system efficiency based on pollutant load Water and Wastewater Engineering 11 20-5
[6] Zhao Z K, Che W, Zhao Y and Zhang W 2018 Summary comparison of combined sewer overflow control between China and the United States Water and Wastewater Engineering 11 128-34
[7] Zhang K , Che W, Zhang W and Zhao Y 2016 Discussion about initial runoff and volume capture ratio of annual rainfall Water Sci. Technol. 74(8) 1764-72
[8] Fletcher T D et al 2015 SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage Urban Water J. 12(7) 525-42
[9] Larry C 1999 Low-Impact Development Design Strategies: An Integrated Design Approach (Prince George's County Maryland: Department of Environmental Resources, Programs and Planning Division) p 150
[10] Larry C 1999 Low-Impact Development Hydrologic Analysis (Prince George's County, Maryland: Department of Environmental Resources, Programs and Planning Division) p 45
[11] Brown R, Rogers B and Werbeloff L 2016 Moving toward Water Sensitive Cities: A guidance manual for strategists and policy makers (Melbourne, Australia: Cooperative Research Centre for Water Sensitive Cities) p 8
[12] Che W, Yan P, Zhao Y and Tian F 2014 Development and Analysis of International Updated Stormwater Management Systems China Water & Wastewater 18 45-50
[13] SWITCH 2014 Managing water for the city of the future http://www.switchurbanwater.eu/about.
php (2020-03-20)

[14] Zhang W and Che W 2016 Connotation and multi-angle analysis of sponge city construction Water Resources Protection 6 2-9
[15] Che W, Li J Q, Liu H and Meng G H 2003 Modern Stormwater Harvest Technology System. Beijing Water Resources 3 22-4
[16] Pan G Q, Che W, Li J Q and Li H Y 2008 Urban runoff pollution control control quantity and its design rainfall in China China Water and Wastewater 22 25-9
[17] Ren N Q, Wang Q, Wang Q R, Huang H and Wang X H 2017 Upgrading to urban water system 3.0 through sponge city, construction Frontiers Environ. Sci. Eng. 11 1-9
[18] Wang H, Mei C, Liu J H and Shao W W 2018 A new strategy for integrated urban water management in China: Sponge city Science China (Technological Sciences) 3 317-29
[19] Yu K J, Li D H, Yuan H, Fu W, Qiao Q and Wang S S 2015 “Sponge City”: Theory and Practice City Planning Review 6 26-36
[20] Jeff H 2010 Low Impact Development a design manual for urban areas (Arkansas: University of Arkansas Community Design Center) p 2
[21] Jiang H 2017 Research on urban problem in Wu Han Water & Wastewater Engineering S1 118-20
[22] Che W, Qiao M X and Wang S S 2013 Enlightenment from Ancient Chinese Urban and Rural Stormwater Management Practices Water Science & Technology 7 1474
[23] Guo J C Y 2017 Urban Flood Mitigation and Stormwater Management (Boca Raton: CRC Press) p 9
[24] Wang W L, Li J Q and Che W 2016 Analysis on the Determination and Implementation of Stormwater Annual Runoff Volume Capture Ratio Water & Wastewater Engineering 10 pp 61-9
[25] Jia N, Wang W L and Che W 2019 Analysis of Combined Sewer Overflow Control Standards of the United States and Its Enlightenment to China China Water & Wastewater 7 1-7
[26] Guo J C Y, Li J Q, Urbonas B and Wang W L 2019 Runoff Capture Methods Developed for Stormwater Low-Impact Development Designs J. Hydrol. Eng. 24(4) 04019005