China's Sponge City Construction: Ambition and challenges

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Summary

China's Sponge City Construction (SCC) initiated by the central government, represents an enormous efforts and unprecedented undertaking by the government for achieving urban sustainability, which presents also a global challenge and demand for urban planners united with implementation of natural based solutions to reduce urban flooding, water shortage and serious pollution of water courses and water bodies during urbanization and climate change. Sponge city construction aims to achieve an integrated and sustainable management of urban stormwater through its 6-step approaches, i.e. Infiltration, Detention, Storage, Cleaning, Reuse and Discharge. 30 Chinese cities were selected as pilot cities, received financial support from the central government to implement of different LID solutions. This paper introduced the SCC concept, bringing together the political objectives, technical approach, guidelines, financial scheme, pilot projects, successful expereince, and challenges during the China's SCC. It highlighted the added value and demand for international collaboration during the ambitious evolution.

Sammendrag

Kinas «blå-grønne» byutvikling: Ambisjoner og utfordringer Kinas «Blå-grønne» byutvikling ble initiert av den nasjonale sentralregeringen. Det representerer en betydelige innsats og enestående satsing fra regjeringen for å oppnå målet av bærekraftig utvikling i byer. Det som henvender seg til en verdens utfordring og etterspørsel om innvirkning av lokal overvannshåndtering som LOD-løsninger for å handtering overvanns utfordringer, for eksempel flom i byer, vannmangel og alvorlig forurensning av vannkilder, elver og resipienter. Målet av «blå-grønne byutvikling er å gjennomføre en 6-fase tiltak som infiltrasjon, forsinkelse og fordrøyning, rensning, samtidig å øker muligheten for gjenbruk av overvannressuser og forbedring av bymiljø og urbanøkosystemtjenester. 30 kinesiske byer har blitt utvalgt som pilotbyer med finansiering støtte fra staten for å teste og gjennomføre de ulike LOD-løsninger. Denne artikkelen samler de politiske målet, tekniske metoder og veiledning, finansiel midler, pilotprosjekter og utfordringer nåværende og i framtiden, samt behov for internasjonale samarbeid.

Background and challenges

Rapid urbanisation and climate change have caused significant water related consequences and challenges in cities all over the world. Since 1970es, the development of low impact development measures (LIDs), sustainable urban drainage systems (SUDS), best management practices (BPMs), green infrastructure (GI),

water sensitive urban design (WSUD) etc have been implemented in different countries (Fletcher et al., 2014; Nie et al., 2015). The past 50 years brought about a remarkable progress in the development of management of urban stormwater (Marsalek, 2013).

For the past 40 years, rapid economic development and population migration to Chinese cities have intensified urbanization, and exacerbated the stress of water resource in cities, resulting in ubiquitous urban water crises (Cheng and Hu et al., 2011; CPC, 2014). During 1978 to 2014, urbanization expanding from 18% to 55% and socio-economic development represented by GDP increasing 174 times, which have put significant pressure on the traditional urban water system in most of Chinese cities. During this progress, urban domestic water consumption has increased several times, while the continuously growing demand and limited availability of freshwater resources is getting seriously unbalanced, and becomes one of the bottlenecks that restricts the development in cities (Cheng and Zhao, 2009). Moreover, during the rapid urban development, so much porous living landscape was changed to impervious surface. Yet, as urban surfaces calcified into a waterproof shell, other problems appeared worse. The existing urban drainage systems were designed according to static assumption, based on past averages of hydrological records; planners did not anticipate or cope with the high-density extreme storm events. Consequently, rapid urbanisation and climate change have resulted in significant impacts on the urban environment and brought about significant challenges on urban stormwater management, such as waterlogging and urban flooding caused by extreme events and limited capacity of surface absorption, detention and existing drainage systems. During 2008-2010, 237 of 351 investigated cities experienced flooding, and 137 citied encountered 3 flood disasters, according to a survey made by the Ministry of Housing and Urban-Rural Development in 2010 (Jia et al, 2013). According to another survey of flood disasters, 641 cities in China experienced floods during 2000-2014, resulted in economic damage about RMB 2 Trillian (equivalent about NOK 2.5 Trillion) (Xu, 2016).

Moreover, according to a survey of the ecological status of the natural lakes in China, 75% of the lakes are eutrophic (Wu, 2017). The big Lakes such as Tai-, Chao- and Dian Lake suffering from algae blooms. The number of polluted lakes has increased from 135 small urban lakes to 5000 in 2000, including large and medium lakes. And this number has increased to 8700 in 2007. Further, over 90% domestic urban rivers being polluted in different extents and more than half of urban rivers were heavily polluted. A recent investigation showed that as much as 3/4 of the lakes in China are classified as eutrophic, according to Wu (2017). These issues impose heavier pressures on the existing urban water and ecosystems, and the situation continues to deteriorate without taking effective mitigation measures.

The observed challenges have enforced decision makers, urban planners, engineers, ecologists, hydrologists, as well as economists and sociologists to re-think current practices in managing urban water resources, exploring holistic and sustainable management approach.

About the Sponge City

Policy initiatives

In the recent decades, China has carried out numerous engineering measures, such as implementation of the South- to-North long-distance water transportation projects, construct new and enlarge the capacity of the wastewater treatment plants to cope with the serious urban water shortage crisis and reduce pollution of rivers and various water bodies. However, these actions would not sufficiently alleviate much of the consequences in regard to drinking water safety, pollution of water bodies and subsequent pollution in air, soil and impacts on food safety, as well as degradation of urban ecosystem services and biodiversity. Because of the existing problem and foresee challenges in the future, China's President Xi Jinping indorsed the concept of Sponge City and launched Sponge City

Figure 1. Illustration of the Sponge city concept (updated from Chinese version by authors)

Construction (Figure 1) at the end of 2014 all over China.

What is Sponge City?

A sponge city refers to a city where its surface and underground systems act like a sponge to absorb, infiltrate, store, and purify the rainwater for different types of reuse, before it is discharged (Figure 1).

It is a concept similar as SUDS, LID, BG solution, BMP, WSUD in many other countries in the world (Marsalek, 2013; Fletcher 2014; Nie et al., 2015), while it was initiated in a new way targeting to solve or mitigate the severe problems of urban flooding, water shortage and pollution of urban rivers and other water bodies in China. Because of the diversity of practices, initiation in implementation of the SUDS and adoration of the terminology in different regions and countries, the abbreviation of SCC and LIDs are applied in the following sections in regard to the expereince in China.

Changes of the concept for sustainable urban development and stormwater management

In order to achieve the goals of the SCC, it is essential to change our thinking from the conventional-oriented concept and approach to a sustainable concept and approach by introducing and implementation of LIDs during urban planning, rehabilitation or reconstruction phases. The transition of concept and approach includes the following main points:

1). Change from demanding-oriented approach to resources-oriented approach, i.e. according to the available resources to decide the scale and dimension of cities, in terms of total population, types of land use, city and economic development model.
2). Change from development dominated approach to take into account the impact to the environment and sustainability, and balancing impacts of the environment and development.
3). Change from downstream remediation to a systematic and comprehensive approach of sources control, pollution control in upstream, process control, downstream reduction and remediation.
4). Change from drainage-driven approach to a holistic approach, including infiltration, detention, storage, purification, reuse and finally discharge.

Objectives

Main objective of the sponge city is to achieve an overall planning goal of control the total volume of annual runoff, the peak value of runoff, pollution control and reuse of stormwater resources. The goal will be achieved through implementation of various LID solutions (Figure 2).

The Sponge City Construction (SCC) announced a new paradigm that calls for the use of natural systems, such as soil and vegetation will be applied as part of the urban runoff control strategy, which represents an enormous and unprecedented effort by any government in the world for achieving urban sustainability and minimizing the adverse impacts of urbanization and adaptation to climate change.

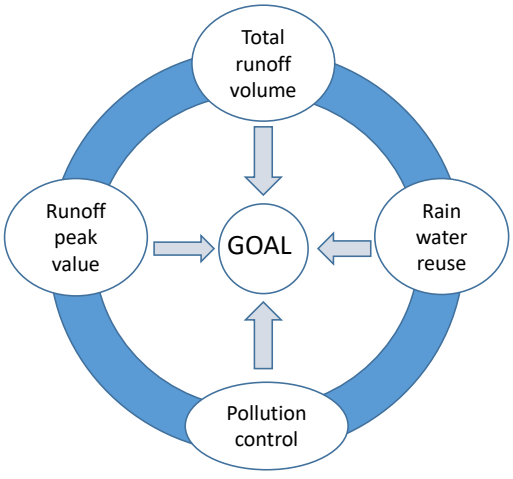

Figure 2. Goals of Sponge city construction plan

Technical guideline

In order to guide the implementation of Sponge city construction, the Ministry of Housing and Urban-Rural Construction (MHURC) mandated a trial version of the Technical Guideline for Sponge City Construction (SCC) - Development of LID stormwater systems in October 2014 (MHURC, 2014). The guideline covers issues of general principle, definition of the Sponge city construction, development of sustainable urban drainage systems/LIDs, and guides for planning, design, construction and maintenance of different solutions. The guideline provides also specifications and information of the precipitation and runoff relationship, cost estimation of some of the LID measures in Beijing region, examples of demonstration projects and other supplementary materials.

Recognizing the limitation of Low Impact Development (LID) in coping with large and less frequent storm events, the General Office of the State Council of China mandates guiding opinions to the integration of Green and Grey Infrastructure (GGI) (GOSCC, 2015). Green infrastructure (GI) is the "strategic use of networks of natural lands, working landscapes, and other open spaces to conserve ecosystem values and functions and provide associated benefits to human populations". Grey infrastructure refers to the human-engineered infrastructure for water resources such as water and wastewater treatment plants, pipelines, and reservoirs. Grey infrastructure typically refers to components of a centralized approach to water management (Gartner et al., 2013). Green infrastructure is not a replacement for grey infrastructure and vice versa.

The expanded SCC Plan aims to achieve multiple benefits of urban flood control, rainwater harvesting, water quality improvement

and rehabilitation of urban ecosystems. The use of LID and GGI measures are required for all new development and retrofit sites, including science and commercial parks, building roofs, open spaces, non-mechanical vehicle roads, pedestrian walkways, etc.

Management approach

Since the successful implementation of the SCC will require a combined and coordinated efforts by many government agencies at different levels, public and private sectors, such as landscape, architecture, urban planning, urban drainage, road, transportation, project owners and other parties and stakeholders. The SCC guideline mandates a Top-Down management framework, assigning the city Mayor or municipal governor as the main responsibility body to ensure good collaboration and successful implementation of SCC (Figure 3).

Implementation plan and pilot cities

As shown in Figure 4, 16 cities were selected pilot cities in 2015. The State Council of China announced a major expansion of the SCC in October 2015, which means the SCC is being implemented nationwide. Another 14 cities were selected the pilot cities for the second batch in 2016. In total, 30 cities in China have been selected pilot cities for the implementation of the SCC pan (Figure 4).

Of the pilot cities, Baicheng, allocated in the most northeast, has the cold continental climate, long winter covered by snow, with similar climate as Norway.

Financial support for Implementation of the SCC

Sponge City construction is a public endeavour, therefore would require public financing. During 2015 and 2016, Chinese government

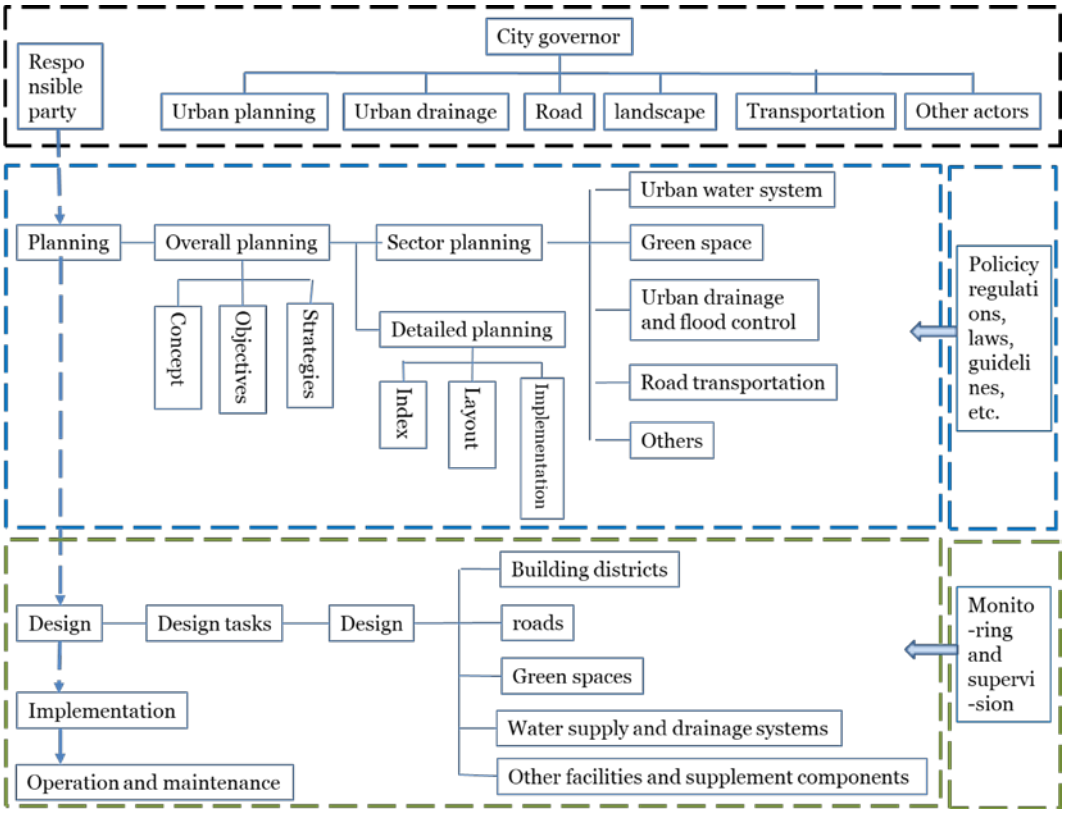

*Figure 3. A collaborative SCC Management Framework (*Original Chinese version of the MF in (MHURC, 2014), translated into English by the authors).*

Figure 4. Map of location of the pilot cities of the SCC in China

selected 30 cities as pilot cities (Figure 4). Each city is to receive 400 to 600 million RMB (500 – 750 million Norwegian Krone) annually for the three years, with the total investment estimated to be about 42.3 billion RMB, or 53 billion NOK (1 RMB ~ 1.25 NOK).

To finance the overall implementation of all the sponge city projects is a real challenge. In addition to the financial support from central government to the pilot cities, the government has also proposed other strategic options for raising co-fund, which includes, e.g. a financial scheme of the Public-Private Partnerships (PPP) is introduced to financing the implementation of Sponge city construction in other cities. Local matching is required and public-private partnerships (PPP) are encouraged. Cities will receive a 10% bonus from the central government if the PPP contribution exceeds a certain percentage of the overall budget. Moreover, the government also encourages participation of financial agencies, and will allow qualified entities to issue construction bonds to finance the SCC projects.

However, there are several factors which influence the invest interest of social capitals, such as the perceived high costs of design, construction and maintenance; inadequate public investment and return estimates; no clear economic incentive for using LID, although other social and environmental benefits are obvious.

Challenges and barriers

It has been three years since the SCC was launched at the end of 2014. The following challenges and barriers have been observed during the process (Jia et al, 2016; Jia et al, 2017; Hou et al, 2017; Li et al., 2017).

Inertia of traditional approaches versus the concept of the sponge city

First, in contrast to the traditional urban construction philosophy in China, e.g. following Chairman Mao's belief that man can conquer nature, the basic concept of the SC approach is living with nature, preservation, rehabilitation and making use of nature's properties in most sustainable ways. Although the Central Govern-

ment has mandated the SCC, issued technical guidelines, some provincial and local government officials are slow to take action due to inertia of traditions, and insufficient guide for urban planning, in particular short-term action versus long term planning, new development or rehabilitation of the existing ones. So far, the financial assistance from central government does provide incentives for cities and different parties to take into quick action into the SCC.

Lack of assessment criteria for measuring success in implementation of the SCC for local officials
The current criteria for the evaluation of the local administrators' performance does not include SC implementation. If the promotional evaluation process could be modified to include implementation results of SCC, local officials would be much more committed to success.

Lack of site-specific technical guidance and certification of products
Stormwater management by nature is highly site-specific due to spatial rainfall variability, land use and other pertinent local environmental, social economy and other factors. For example, the Guiding Opinions on Advancing the Construction of Sponge Cities issued by the China State Council sets a goal of total runoff volume control from 20% of the built-up areas in 2015 to 70% by 2020 (GOSCC, 2015). In order to achieve this goal, cities in different climate regions will need different hydrological design parameter for the design of their control practices. Also, the quality and effectiveness of some of the control measures, in particular the underground stormwater treatment systems. An evaluation certification and validation of different technologies, materials and products would be highly desirable before such products are used for public projects. Furthermore, the design, construction and maintenance of LID/GI systems require professionals with appropriate background and training. Therefore, continuing efforts of Research and Development in SC technology and training are essential in order to achieve successes for the SCC in China.

Lack of long term urban planning and effectiveness of individual and combined measures
Before the design and construction started, a consolidated long term urban planning should be well-prepared in place. However, this is not true in many of the Chinese cities. Urban planning is a fundamental process for implementation of the SCC in regard to rehabilitation of the existing urban infrastructure and planning for the new development areas. Therefore, the assessment of the effectiveness of individual and combined LID measures is indispensable inputs for urban planning and budget allocation for design and construction of the different measures.

Summary and Outlook

Sponge city construction is the national initiative and strategic action in China. However, it represents a universal challenges of sustainable management of urban water systems during urbanization and in changing climate in most of the cities in the world. To tackle these challenges, it is essential to develop a holistic approach and make efforts on establishing integrated actions of multi-functional and best-practice approaches. Learning experience from Europe, North America, Australia and other countries are essential to achieve the goals of the Sponge City Construction Plan.

Can China's model go global? Workman (2017) highlighted in his paper that the Chinese Sponge city construction addressed and exemplified a universal struggle of urban planners united with water professionals against a volatile climate. Sponge city construction, similar measures as WSUD, LID or SUDS and BMPs in many other countries and regions in the world, aims to achieve an integrated and sustainable management of urban stormwater through its 6-step approaches, i.e. Infiltration, Detention, Storage, Cleaning, Reuse and Discharge. China had higher ambitions and took sustainable measures that would transform its metropolitan areas into the proclaimed as 'sponge cities'.

It is a universal challenge to enhance ecosystem resilience and adaptive capacity to cope

with the changes in climate and society, and enable ecosystems to deliver their services for more liveable, healthier and resilient cities. Following the EU-China Sustainable Urbanization Flagship Initiative 2016-2017, H2020 work programme 2018-2020 on Climate change, Environment, Resource efficiency and Raw Materials issued one topic for International collaboration on sustainable urbanization through implementation of natural based solutions for restoration and rehabilitation of urban systems, tackling the universal challenges of unsustainable, non-resilient urbanisation patterns (EC, 2017). It is expected that international collaboration on natural based solution with Chinese SCC could bring synergy and mutual benefits for Europe and China, and other countries in the world (e.g. Knollmann and Peng, 2018; EU-China Sustainable Urbanization Flagship Initiative 2016-2017).

References

Cheng H., Hu Y., Zhao J. (2009). Meeting China's water shortage crisis: Current practices and challenges Environ. Sci. Technol. 2009, 43 (2) 240– 244.

Cheng H, Hu Y. (2011). Economic transformation, technological innovation, and policy and institutional reforms hold keys to relieving China's water shortages. Environmental Science & Technology, 45(2): 360–361.

EU-China Sustainable Urbanization Flagship Initiative 2016-2017: https://eeas.europa.eu/sites/eeas/files/eu_china_research_in_urbanisation.pdf.

European Commission (EC) (2017). H2020 Work Programme 2018-2020 for Environment, Resources Efficiency and Raw Materials.

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., Mikkelsen P. S., Rivard Q., Uhl M., Dagenais D. & Viklander M. (2014). SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. Urban Water Journal, pp.1-18.

Gartner G., Mulligan G., Schmidt R. and Gunn J. (2013). Natural Infrastructure - Investing in Forested Landscapes for Source Water Protection in the United States. World Resources Institute (https://www.wri.org/sites/default/files/wri13_report_4c_naturalinfrastructure_v2.pdf (P.10/total 16), last access 16 May 2018).

Hou, L.A. (2017). Improvement of Water Environment through Sponge City Construction in China. Presentation on high-level technical forum of Sponge City and, 10-12. October 2017, Yiwu, China.

Jia H.F., Yao, H., Yu Shaw L. (2013). Advances in LID BMPs research and practice for urban runoff control in China. *Frontiers of Environmental Science & Engineering*, 7(5): 709–720. DOI: 10.1007/s11783-013-0557-5.

Jia H, Wang Z, Yu S L. (2016) Opportunity and Challenge: China's Sponge City Plan. Hydrolink, 2016, 4: 100–102.

Knollmann J. and Peng, C. (2018). Sponge City, the Chinese interpretation about Storm Water Management in Cities – Example of Wasser Hannover Association. Presentation given on the World Water Day, March 22, 2018. Oslo, Norway.

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* 2017, 9, 594; doi: 10.3390/w9090594.

Ministry of Housing and Urban-Rural Construction (MHURC) of China (2014). Technical guidelines for Sponge City construction – Development of Low impact development (LID) stormwater systems (in Chinese). October 2014.

Marsalek J., 2013. Fifty years of innovation in urban stormwater management: Past achievements and current challenges. In Proceeding of the Int. Conf. of NOVATECH 2013, 23-27 June, Lyon, France.

Nie, L., Ma, J.M., Zheng, S.L., Chang, T. (2015). Integrated Urban Stormwater Management in Norway- Transition from a traditional underground drainage system towards a sustainable system on surface. In H. Liu Chief Editor Int. Urban Stormwater Management and Landscape Hydrology Research: A Multidimensional Interpretation towards strategies, pp. 223-235, Tsinghua University Publish House, Beijing. ISBN 978-7-302-41838-2.

Ren N., Wang Q., Huang H. and Wang X. (2017). Upgrading to urban water system 3.0 through sponge city construction. Front. Environ. Sci. Eng. 2017, 11(4):9. DOI 10.1007/s11783-017-0960-4.

The CPC Central Committee (2014). The State Council. The National New Urbanization Plan (2014-2020).

The General Office of State Council of China (GOSCC) (2015). Guiding Opinions of the General Office of the State Council on Advancing the Construction of Sponge Cities (in Effective) (in Chinese), October 11, 2015.

Workman J. Sponge cities: Can China's model go global? The Source, pp. . August 2017. Available: https://www.thesourcemagazine.org/sponge-cities-can-chinas-model-go-global/. Last access, 11 November 2017.

Wu, Z.B. (2017). Development and application of technologies on remediation of ecosystem of polluted water bodies in China. Presentation on high-level technical forum of Sponge City and, 10-12. October 2017, Yiwu, China.

Xu Y.C. (2016). Sponge cities – An Answer to Floods. China Water Risk Review. www.chinawaterrisk.org/resources/analysis-reviews/sponge-cities-an-answer-to-floods/. Last Access 08. January 2018.