

A Review Paper on Smart Sponge City: Integrating Innovative Urban Infrastructure for Storm Water Management, Flood Control and Water Conservation

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Abstract

A Sponge City is an urban development approach that manages rainwater through infiltration, storage, detention, treatment, drainage, and reuse. It helps reduce urban flooding, water pollution, and pressure on natural ecosystems while improving groundwater recharge and water security. The concept was first widely implemented in China to address the effects of rapid *urbanization* and climate change. For India, increasing urbanization and extreme rainfall events, such as the severe flooding experienced in Hyderabad, highlight the need for improved storm water management. However, successful implementation requires proper planning, site-specific research, regular maintenance, technical knowledge, and suitable infrastructure. Overall, Sponge City development has significant potential to support sustainable and climate-resilient cities in India.

Keywords: Sponge City, Storm Water Management, Flood Control, Water Conservation.

1. INTRODUCTION

Water sustainability has become a major concern because of rapid population growth, urbanization, and climate change. Traditional urban water management systems often work separately and are not sufficient to handle problems such as urban flooding, storm water runoff, water pollution, and water shortages. A Sponge City is an urban area designed to absorb, store, clean, and reuse rainwater, similar to how a sponge absorbs water. It uses green infrastructure such as rain gardens, permeable pavements, wetlands, green roofs, and detention ponds.

The Sponge city has the same function as a sponge, which can effectively adapt to environmental changes and handle natural disasters. Water can be absorbed in the event of heavy rainfall, and when necessary, the stored water can be released in time of drought. Therefore, Sponge City projects can contribute to controlling floods and can effectively collect rainwater for future use, thereby satisfying the requirements of green infrastructure and sustainable development.

Sponge City is a Chinese approach that uses natural processes to absorb, store, infiltrate, purify, and reuse rainwater, similar to a natural sponge or wetland. It focuses not only on storm water but also on flood control, water restoration, water purification, and ecological improvement. Overall, Sponge City aims to create water-efficient, flood-resilient, environmentally friendly, and sustainable cities by restoring natural water processes and using low-impact development techniques.

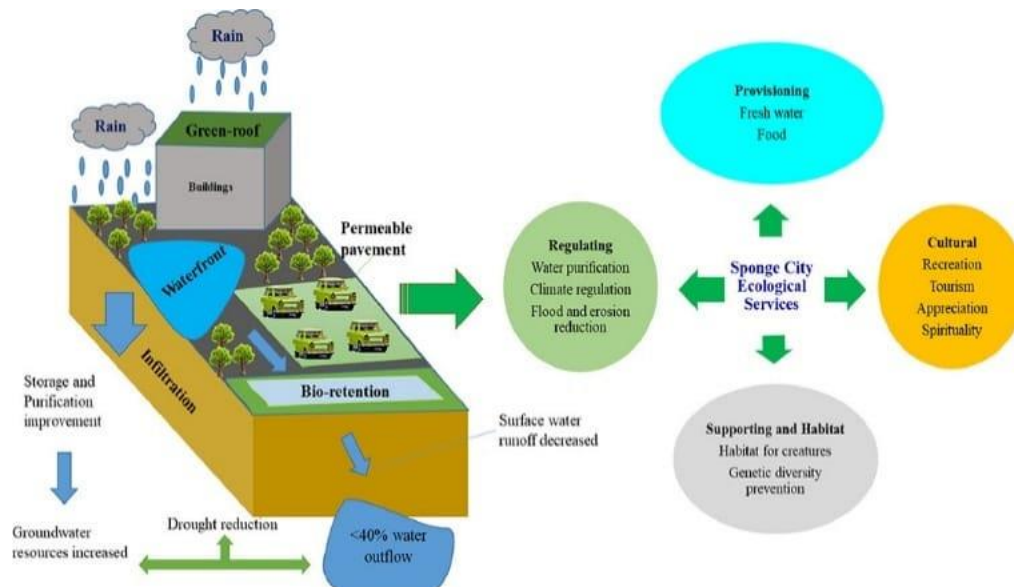


Fig.1. smart sponge city

2. OBJECTIVES

1. To study the concept of Smart Sponge City.
2. To review innovative urban infrastructure.
3. To study effective storm water management techniques.
4. To examine flood control measures.
5. To explore water conservation methods.
6. To study the role of smart technologies.

3. LITERATURE REVIEW

Yang, S. & DeLoyde, C. N. M. (2026)

Studied "Sponge City for flood control: implementation, challenges and opportunities." The study examined the development of Sponge City as an approach for improving urban flood management and resilience. It discussed how sponge-city measures can reduce the impact of storm water by retaining, infiltrating, storing and managing rainfall within urban areas. The authors also highlighted that successful implementation cannot depend only on individual infrastructure elements; it requires consideration of local climate, urban form, drainage systems, governance, financing and institutional coordination. The study is relevant to the present project because it supports the idea of combining several infrastructure measures rather than depending only on conventional drainage.

Pinto, H., Elston, J., Sunday, O. S. & Nogueira, C. (2026)

Investigated Sponge City implementation in Shenzhen, China, focusing on the transition from the Sponge City concept to practical implementation. The study examined how sponge-city principles are applied in a rapidly urbanizing and densely developed city. It considered the challenges associated with translating sustainability and resilience objectives into actual urban infrastructure and planning practices. The research is particularly useful for understanding why a Sponge City model needs to consider existing urban conditions, available land, infrastructure limitations and institutional coordination.

Montezuma, M. A., Zevenbergen, C., van de Ven, F., Ding, Z., Veerbeek, W., Corzo Perez, G. & Liu, J. (2026)

Applied the Three-Point Sponge Policy Approach (3PSPa) to the 2021 Zhengzhou flood. The study integrated blue, green and grey infrastructure and considered different strategies for newly developed and densely built areas. It showed that new areas may provide opportunities for larger-scale interventions, whereas older dense areas may require smaller, incremental retrofits. The study emphasized moving from a drainage-conveyance approach toward diversified systems that work with natural hydrological processes. This provides a strong conceptual basis for the proposed integrated Smart Sponge City model.

Lu, Y., Huang, M., Xiao, H., Lu, Z., Xie, M. & Chen, K. (2025)

Conducted a systematic review of China's Sponge City policy and flood-management research. From a larger collection of literature, the authors selected 61 closely related studies and used bibliometric and keyword-analysis techniques to identify major research themes. The study found that Sponge City research has gradually moved from conventional engineering-based flood control toward multi-objective and interdisciplinary approaches involving flood-risk assessment, green infrastructure, policy implementation, economic feasibility and public participation. The authors identified smart management and cross-scale coordination as areas requiring further research.

Ali, L., Gato-Trinidad, S. & Imteaz, M. (2025)

Reviewed the application of green infrastructure for urban flood management. The research considered measures such as green roofs, permeable surfaces, rain gardens and bio retention systems. These facilities can reduce runoff by increasing infiltration, temporary storage and evapotranspiration. The study also highlighted practical challenges including maintenance requirements, financial limitations, technical knowledge and community participation. The findings support the use of multiple green-infrastructure components in the proposed Sponge City model.

Soni, L., Iqbal, A., Waheed, F., Shah, A. A. & Akbar, N. (2025)

Investigated nature-based solutions for future megacities, with implications for Karachi and Sponge City development. The study connected rapid urbanization and increasing impervious surfaces with higher storm water runoff and flood risk. It discussed how nature-based infrastructure can restore natural water processes while providing urban environmental benefits. The study is useful for Indian cities because many rapidly growing cities face similar problems of increasing built-up areas, inadequate drainage and reduced infiltration.

Ding, Z., Veerbeek, W., Corzo Perez, G. (2025/2026 publication cycle)

Developed the Three-Point Sponge Policy Approach for integrating blue-green-grey infrastructure. The framework builds upon the Three-Point Approach and Sponge City principles and considers everyday rainfall, design events and extreme events. It promotes multifunctional infrastructure that can simultaneously provide flood protection, ecological benefits, water management and urban-quality improvements. Its application to Zhengzhou demonstrated that interventions need to be adapted to the characteristics of individual urban areas.

Ahmed, H. G. et al. (2024)

Reviewed Sponge City facilities for controlling surface-runoff pollution. The study classified Sponge City facilities according to functions such as infiltration, retention, storage, purification, utilization and drainage. This classification demonstrates that Sponge City infrastructure can address both flood quantity and water-quality problems. The research is

important for the proposed project because storm water should not simply be collected and discharged; it can be temporarily stored, treated and reused.

van de Ven, F. H. M., Zevenbergen, C., Avellar Montezuma, M., Ding, Z., Veerbeek, W. & Chen, S. (2024)

Introduced the Three-Points Sponge Policy approach for enhanced multi-level resilience. The approach combines blue-green infrastructure with conventional grey infrastructure and considers flood and drought risks across different spatial scales. The authors emphasized multi functionality , ecosystem-based adaptation, asset management, data handling and communication between stakeholders. A proof-of-concept was developed for Zhengzhou, showing how interventions can be planned at local, city and river-basin scales.

Research on integrated urban runoff control and Sponge City construction (2024): - examined how different sponge facilities can work together to reduce runoff and improve urban ecological conditions. Instead of using a single measure, the research emphasized combinations of infiltration, storage, detention, purification and drainage. This supports the concept of the present project, where permeable pavement, rain gardens, green roofs, storage and recharge are integrated into one system.

Chikhi, F., Li, C., Ji, Q. & Zhou, X. (2023)

Reviewed Sponge City implementation in China from both performance and policy perspectives. The study examined whether Sponge City measures were achieving their intended flood-management objectives. It highlighted that some areas continued to experience flooding despite implementation, indicating that infrastructure alone cannot guarantee complete flood protection. Better planning, performance assessment, monitoring and adaptation are required. This provides an important lesson for designing a Smart Sponge City model with measurable performance.

Femin, M. I. & George, E. H. (2023)

Reviewed Sponge City construction for urban flood management, with particular relevance to the Indian context. The study discussed the ability of Sponge City approaches to support rainwater harvesting, flood reduction, ecological restoration, water-quality improvement and water security. It highlighted the potential for adapting the Sponge City concept to Indian cities rather than directly copying systems developed in other countries. This is relevant to the present project because the proposed model can be designed according to Indian rainfall, urbanization and drainage conditions.

Fu et al. (2023)

Examined the ability of Sponge City approaches to address increasing urban flooding. The research emphasized the role of nature-based measures in reducing runoff and improving urban water management. However, the effectiveness of these measures depends on rainfall characteristics, soil conditions, land use, drainage capacity and local hydrological conditions. Therefore, Sponge City measures should be selected based on site-specific studies rather than applied uniformly.

Lu et al. (2023)

Reviewed roadside green swales in Sponge City development. Green swales can intercept runoff from roads and surrounding impervious surfaces, slow the movement of water, promote infiltration and help remove pollutants. The study demonstrated that roadside green

infrastructure can be incorporated into conventional drainage networks. This is particularly useful for the proposed model because bioswales can be represented as one of the major components.

Jiang et al. (2022)

Examined the water–soil–plant system in Sponge City construction. The study emphasized that storm water management depends on interactions between rainfall, soil characteristics, vegetation and infiltration. Vegetation can increase interception and evapotranspiration, while suitable soil conditions can improve infiltration and groundwater recharge. The findings indicate that Sponge City design should consider the entire soil-water-vegetation system rather than treating green infrastructure as simple landscaping.

Cheng et al. (2022)

Investigated the flood-reduction performance of green and grey Sponge City measures. The study emphasized that green infrastructure and conventional drainage infrastructure should not be considered completely separate systems. Green facilities can reduce and delay runoff, while grey infrastructure can provide conveyance and additional protection during larger events. Their combined use can improve the overall resilience of an urban drainage system.

Yin et al. (2022)

Examined the transition of Sponge City practices from pilot projects toward more systematic implementation. The study emphasized integrated planning, performance assessment and long-term operation and maintenance. It indicated that constructing facilities is only one stage of a Sponge City project. Continuous inspection, cleaning, monitoring and performance evaluation are necessary to maintain their effectiveness.

Yin et al. (2021)

Reviewed Sponge City construction, assessment, operation and maintenance. The research emphasized the importance of combining green and grey infrastructure with hydrological modelling and monitoring. It also identified problems such as clogging, deterioration and inadequate maintenance, which can reduce facility performance over time. This is particularly relevant to a practical civil engineering model because the model should demonstrate not only construction but also maintenance requirements.

Kumar, N., Liu, X., Narayanasamy damodaram, S. & Pandey, K. K. (2021)

Compared urban flood-management practices in India and China's Sponge City programme. The study provided useful lessons regarding the transfer of Sponge City concepts to Indian conditions. It highlighted differences in urban development, governance and water-management practices. The research suggests that India can learn from international Sponge City experience while adapting infrastructure to local rainfall, soil, land-use and institutional conditions.

Jiang, A. Z. & McBean, E. A. (2021)

Studied the Sponge City concept using a “One Water” approach. The research connected storm water, wastewater, water supply and other components of the urban water cycle. A major principle was that storm water can be considered a resource instead of simply waste that must be rapidly discharged. This supports the water-conservation objective of the present project, particularly through rainwater storage and reuse.

Liu et al. (2021)

Reviewed modelling approaches for Sponge City construction. The research considered modelling of retention, infiltration, storage, purification, discharge and water reuse. Modelling can help engineers predict how infrastructure will perform under different rainfall conditions. This supports the future development of the proposed physical model into a data-based or computer-simulated Sponge City system.

Yang, M., Sang, Y.-F., Sivakumar, B., Chan, F. K. S. & Pan, X. (2020)

Examined challenges in urban storm water management in Chinese cities from a hydrological perspective. The study emphasized the influence of rainfall characteristics, urbanization, impervious surfaces and drainage conditions on urban flooding. The findings demonstrate that effective storm water management requires understanding the local hydrological system. This supports the need for area-specific analysis before implementing Sponge City infrastructure.

Yin et al. (2020)

Reviewed Sponge City practices from construction to assessment, operation and maintenance. The study highlighted that Sponge City infrastructure should be continuously monitored after construction. Performance can change due to sediment accumulation, clogging, vegetation growth and other maintenance-related issues. Therefore, long-term management should be included in Sponge City planning.

Ma, Z., Jiang, Y. & Swallow (2020)

Examined Sponge City development from an ecosystem-services perspective. The study emphasized that Sponge City infrastructure can provide multiple benefits simultaneously, including flood reduction, ecological improvement, water management and improvement of urban environments. The research supports multifunctional infrastructure instead of designing each facility for only one purpose.

Nguyen et al. (2019)

Investigated urban water management through the Sponge City concept. The research identified principles including urban water resourcing, ecological water management, green infrastructure and permeable pavement. It also emphasized intelligent decision-making and cooperation between different agencies. These findings are closely related to the proposed Smart Sponge City because the project combines physical infrastructure with monitoring and management.

Zhang, He & Zhang (2019)

Analyzed 71 Sponge City cases in China and investigated their relationship with sustainable urban development. The study demonstrated that Sponge City planning must consider local environmental, physical and socioeconomic conditions. Different locations may require different combinations of infrastructure. The study therefore supports a site-specific approach for developing a Sponge City model for an Indian urban area.

Xie et al. (2019)

Examined professional perspectives regarding China's Sponge City initiative. The study highlighted the importance of technical knowledge, professional cooperation and urban planning. It indicated that successful Sponge City implementation requires coordination between civil engineers, planners, environmental professionals, government agencies and communities. This provides an important management perspective for the proposed project.

Jiang, Y., Zevenbergen, C. & Ma, Y. (2018)

Reviewed urban pluvial flooding and storm water management in China. The study connected rapid urbanization and increasing impervious surfaces with increased runoff and flood risk. Sponge City was discussed as an alternative approach for managing urban storm water by restoring some natural hydrological processes. The study provides theoretical support for using infiltration and retention measures in urban areas.

Chan, F. K. S. et al. (2018)

Examined Sponge City as an approach to urban planning and flood-risk management. The research highlighted the importance of blue and green infrastructure for retaining, infiltrating and managing storm water. It also connected flood management with wider urban resilience. This indicates that Sponge City should be considered as an urban planning strategy rather than simply a drainage technology.

Wang et al. (2018)

Examined Sponge City as a strategy for integrated urban water management. The study emphasized retention, infiltration, storage, treatment and reuse of rainwater. Instead of rapidly conveying rainfall away from the city, the Sponge City approach attempts to manage water at multiple stages. This directly supports the water-conservation component of the proposed model.

Hu et al. (2018)

Investigated permeable pavement in Sponge City construction. The research demonstrated the potential of permeable pavement to reduce surface runoff and promote infiltration. Permeable pavement is particularly useful in areas such as footpaths, parking spaces and low-traffic surfaces where conventional impervious pavement can be replaced or supplemented. It is therefore an important component for inclusion in a physical Sponge City model.

Zhang, Zevenbergen, Rabé & Jiang (2018)

Investigated the influence of Sponge City development on property values in Wuhan. The study indicated that Sponge City projects may produce benefits beyond direct flood control, including environmental improvement and better urban quality. This illustrates the broader economic and social implications of sustainable urban-water infrastructure.

Jiang, Y., Zevenbergen, C. & Fu, D. (2017)

Examined governance challenges associated with China's Sponge City initiative. The study emphasized that technical infrastructure alone cannot ensure successful implementation. Financing, institutional cooperation, planning and governance are equally important. The findings indicate that a successful Sponge City system requires coordination between multiple stakeholders.

Li et al. (2017)

Reviewed the challenges and opportunities of Sponge City construction in China. The research identified technical, financial, regulatory and institutional challenges. It emphasized the need to integrate Sponge City measures into urban planning rather than treating them as independent projects. This provides an important basis for identifying challenges in the proposed study area.

Jia et al. (2017)

Discussed technical approaches for Sponge City construction and emphasized combinations of Low Impact Development (LID) and storm water-management facilities. Rather than depending on a single facility, different measures can be distributed throughout an urban catchment. This approach forms an important technical foundation for integrating permeable pavement, rain gardens, swales and storage systems in the proposed model.

Liu (2016)

Discussed China's emerging Sponge City initiative and its potential for urban rainwater management. The work helped establish the concept of treating urban areas as systems capable of absorbing, storing, infiltrating and reusing rainfall. This represented a shift from conventional drainage approaches that primarily focus on rapidly conveying storm water away from developed areas. The concept provides the basic theoretical foundation for modern Sponge City research.

Li et al. (2016)

Presented case studies of China's Sponge City programme and demonstrated how different urban areas can use combinations of green infrastructure and storm water-management measures. The research showed the importance of adapting measures according to local urban conditions. These early case studies provide useful background for understanding how Sponge City principles developed into more integrated approaches involving flood control, water conservation and ecological improvement.

4. CONCLUSION

The Smart Sponge City Model provides an integrated approach to urban water management by combining innovative infrastructure, natural processes and smart technologies. Permeable pavements, green roofs, rain gardens, bio swales, wetlands, recharge structures, rainwater harvesting and storage facilities can work together to manage storm water closer to where rainfall occurs. The literature shows that Sponge City approaches can support flood mitigation, storm water management, water conservation and environmental improvement, but their performance depends strongly on local conditions and appropriate planning. For Indian cities, the concept can be adapted according to local rainfall, soil, groundwater, topography, land use and existing drainage infrastructure. The integration of sensors, GIS and other smart technologies can further improve monitoring and management. Therefore, the proposed model demonstrates a shift from the traditional approach of “drain water away” toward “capture, absorb, store, treat, reuse and intelligently manage water.”

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