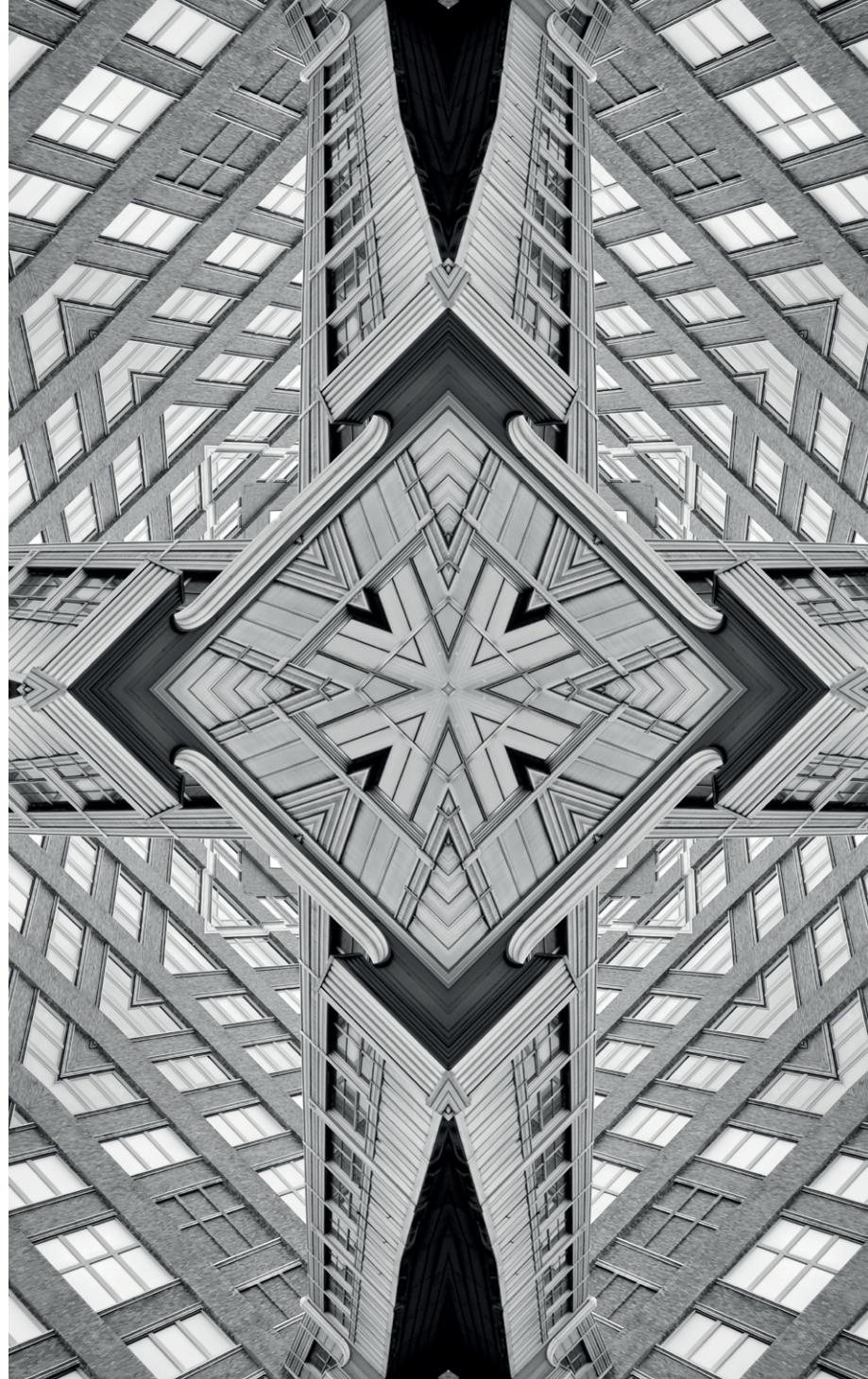




Issue Brief

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Building Rainwater Resilience in India's Cities

Rumi Aijaz

Abstract

Extreme water events are affecting cities in various parts of the world. During rainy seasons or in the event of typhoons or cyclones, the sudden inflows of large volumes of rainwater into cities, combined with inadequate preparedness of administrative agencies, result in injuries, loss of lives, and damage to property. This brief examines excess-rainwater-related incidents in select global cities, reviews innovative practices for managing flooding and related calamities, and offers recommendations for better management of rainwater in India. It emphasises the need for strengthening rainwater resilience in cities.

The natural occurrence of rains causes the accumulation of abundant rainwater or storm water. In India, cities are generally not designed nor adequately prepared to absorb the water and channel it properly, especially during extreme weather events that cause excessive inflows. This can often lead to a disaster. The challenge has intensified in the recent years, as a result of worsening climate change.

The water received from rains, and other sources such as breaches in river or canal embankments, can inundate large areas of a city and disrupt daily life. Due to the resultant flooding and waterlogging, mobility is restricted and civic activities could come to a standstill for prolonged periods. It also leads to overflowing drains, power outages, damage to property, roads, infrastructure, and vegetation; physical injuries, and loss of lives. Although every city has a drainage system to channel water to treatment plants and surface water bodies, there is evidence that existing systems are failing to cope with the large inflows.

This brief seeks to provide a strategy for India for mitigating the adverse impacts of extreme rainfall. It is based on a review of recent rainfall-related incidents in cities of India and Spain, as well as the United Arab Emirates (the UAE).^a It outlines lessons from the innovative methods applied in Shanghai and Rotterdam to manage the excessive inflow of rainwater in congested cities.

^a The cities chosen as cases in this brief have all experienced serious problems due to the mismanagement of rainwater.

A study of recent rainfall-related incidents in various regions of the world can help create an understanding of the causes and consequences of large inflows of rainwater.

India

Wayanad, a district in the state of Kerala, experienced a massive water-related disaster in July 2024 as heavy rains caused landslides at various locations in the district. The foothill settlements of Chooralmala, Mundakkai, and Punjirimattom were damaged by the collapse of hillsides and the downward flow of water, rocks, mud, and debris. Over 400 people died, 397 were injured, and 129 were reported missing.¹ Houses and shops, and essential infrastructure such as schools, were badly damaged. It is estimated that property worth US\$140 million was damaged.² National, state, and local government agencies and volunteers undertook the rescue and rehabilitation activities. The measures included the setting up of a command and control centre, deployment of medical teams, use of radar equipment and search canines, and allocation of funds for rehabilitation and reconstruction. The rescued people were initially taken to relief camps and then shifted to relief housing.

The Cochin University of Science and Technology conducted a study to investigate the causes of the extreme rainfall and the resulting disaster in Wayanad.³ It indicated that the heavy downpour resulted from atmospheric warming. In some areas, the forests on hill slopes had been cleared for tea plantations, which made the soil unstable and susceptible to landslides. Furthermore, many buildings, constructed using sub-standard materials and not meeting safety norms, collapsed. Some of the buildings were constructed illegally in landslide-prone areas.

In past years, various Indian cities have experienced rainwater-related problems too. Srinagar (Jammu and Kashmir) suffered during the September 2014 floods in the Kashmir Valley. Large areas of the city were submerged, and infrastructure such as bridges were damaged. Torrential rainfall was the primary cause of the disaster, with the severity of the problem heightened by the landslides, mismanagement of flood spill channel, blockage of natural drainage channels by unplanned construction activities, and encroachment of wetlands and lands adjoining river banks.⁴

Rainfall-Related Disasters

In November–December 2015, Chennai was flooded during the north-east monsoon rains due to unplanned constructions and encroachment of wetlands on the city outskirts. The disaster affected more than four million people, resulting in over 470 deaths and the displacement of a large population. The flooding also damaged many structures and disrupted people's livelihoods across various sectors.⁵

In July 2023, torrential rain in upstream areas caused the Yamuna to overflow, inundating many habitable areas of Delhi situated along the river.⁶ The subsequent flooding displaced people, seriously affected their livelihoods, and caused massive traffic jams and water shortages.

In August 2023, torrential rain in various parts of Himachal Pradesh (including Shimla) triggered landslides, flash floods, and cloudbursts. The disaster claimed over 400 lives, left many families homeless, damaged buildings, and disrupted rail connectivity.⁷

The cyclonic storm Remal struck Kolkata and the Northeast region in May 2024. The off-season rainfall, strong winds, and landslides led to loss of lives, collapse of boundary walls, uprooted trees and electric poles, traffic congestion, waterlogging, and cancellation of flights.⁸

In Sikkim, continuous rainfall in early October 2023 resulted in a landslide that breached the natural boundary of South Lhonak Lake. The resulting surge increased the water levels of Teesta river, damaged the Chungthang dam, and flooded downstream areas. As a result, some 46 people died, more than 70 were reported missing, and 88,400 were affected.⁹ Many houses, bridges, highways, and essential utilities were also damaged by the sudden inflow of water.

A similar rainwater-related incident occurred in Bengaluru in October 2024. Several areas of the city, including roads and basements of apartment buildings, were inundated after heavy rains. The conditions created difficulties for travellers.¹⁰

Spain

The southern and southeastern regions of Spain received torrential rains in late October 2024. In the province of Valencia, several municipalities (including Chiva, Turis, and Utiel) were flooded due to the high precipitation. Chiva received 500 millimetres of rainfall on a day when it rained continuously for at least eight hours. Overflowing water from ravines and rivers in the region exacerbated the flooding. In some areas, landslides covered large areas with mud. During the calamity, a number of people were trapped in different

locations while many others were reported missing and dead. Educational, cultural, and sports activities were suspended. Vehicles, roads, rail lines, bridges, and buildings were damaged. Telephone, electricity, and gas services collapsed, offices were closed, and flights were diverted or cancelled. According to available information, over 200 people in various areas of Spain died due to the disaster.¹¹ The total damage was estimated to be US\$11 billion.¹²

Many citizens and civil society organisations were unhappy with the government's actions before the disaster and its response in the aftermath. They believed that the advancing storm was not given due attention, leading to delays in sending out weather alerts to people and the distribution of aid in affected areas. The communities took it upon themselves to deliver essential items to those in need, and clear debris and mud wherever they collected as a result of the storm.

The development of a high-altitude isolated depression, the location of Valencia near a riverbed and mountains, and construction activities along the coastal area are some of the factors responsible for the disaster in Spain.

The United Arab Emirates (UAE)

In April 2024, continuous rainfall over three days caused flooding across many areas in the UAE. Some parts of Dubai recorded about 164 mm of rain. The adverse weather conditions affected life in the city. Flooding brought metro rail, bus, and airline services to a standstill, leaving citizens stranded across various locations. Educational institutions and offices remained closed. As per available information, the disaster claimed five lives and caused property damage estimated at about US\$3 billion.¹³ The national government took several measures, including allocation of aid for relief, provision of equipment for cleaning streets, and relocation of stranded people and vehicles to safer locations.

A review of climatic conditions revealed the formation of a strong low-pressure system that triggered multiple rounds of high winds and heavy rains.¹⁴

Rainwater Management Solutions

Various factors are responsible for disasters caused by the mismanagement of rainwater. The case studies presented in the preceding section offer insights into certain common variables: the concretisation of cities; unplanned construction and development in flood-prone areas; and lack of adequate sewerage and drainage infrastructure. For example, the massive scale of concretisation in cities prevents the absorption of water into the ground. Furthermore, the discharge of untreated sewage into surface water bodies by residential, commercial, and industrial establishments raises water levels and pollutes water sources. Therefore, when there is surplus rain, overall water volumes increase, with polluted water posing health risks for the population. While damage can be minimised in several ways, proper management of rainwater can be a sustainable solution. Cities should be equipped to manage large volumes of water efficiently.

Use of ‘Water Sponges’

The present-day methods of city planning and development fail to incorporate water resilience requirements correctly.¹⁵ Furthermore, conventional drainage systems are not sufficient for managing the problem. Therefore, harnessing nature’s power to drain water is gaining traction,¹⁶ emphasising the creation of natural and artificial sponges to mitigate rainwater-related challenges.

The ‘sponge cities’ approach involves the creation of green spaces, such as forests, gardens, parks, and wetlands, that can act as sponges, absorbing and managing excess water efficiently. It also emphasises preserving a city’s natural areas and water bodies, undertaking development activities in harmony with nature, creating sponge buildings, infrastructure, and permeable surfaces, and installing rainwater harvesting structures. This approach aims to slow down the flow and distribution of water to minimise the flooding risk.

In early 2000, researchers in China first put forth the idea of creating sponge cities.¹⁷ It was accepted by the government in 2014, when the drainage infrastructure failed to control the flood and stormwater.¹⁸ Under the initiative, 30 cities were identified for implementing sponge city designs. The initiative is executed by sub-provincial or municipal governments, with about 80 percent of the costs covered by local governments and the private sector while the national government provides the remaining support.

Rainwater Management Solutions

Chinese scholar Yu Kongjian states, “Conventional flood water management involves building pipes or drains to carry away water as swiftly as possible, or reinforcing river banks with concrete to ensure that they do not overflow.”¹⁹ He is of the view that a sponge city does the opposite. It soaks up rainfall and slows down surface run-off. At the source, the water is contained in ponds; during the flow, meandering rivers with vegetation or wetlands slow down water. He discourages construction in low-lying areas (or sinks), where the flood water finally empties out into a river, lake, or sea.

In 2016, the Shanghai government issued directives for incorporating sponge city designs into all urban planning activities.²⁰ This provision led to the creation of a large sponge park with permeable pavements, a wetland, and rainwater storage facilities. Elsewhere in the city, projects that were implemented included wide streets with permeable pavements, green spaces, green rooftops, and water tanks. Replacing all paved surfaces in the city with porous material was also an objective.

Similar initiatives for creating ‘sponge cities’ are being undertaken in various parts of the world. In India, the national government offers financial support to state governments for building climate resilience.²¹ Like many other nations, India is experiencing unusual weather conditions due to the climate change phenomenon, and the frequent occurrence of cyclonic activities, rainfall and the rising temperatures are affecting living conditions. For rainwater management, the government is investing in the development of water sponges and is strengthening natural ecosystems. This is noted in Andhra Pradesh, where plans are being prepared for rejuvenating water bodies in 15 cities.²² The work is based on an appraisal of existing water bodies. Many of these receive untreated effluents and solid waste. There are also reports of silt accumulation and encroachment by builders.²³ It is expected that the initiative will help increase the rainwater retention capacity of water bodies and build resilience against floods.

Hyderabad in Telangana, too, is drawing up plans to create sponge zones.²⁴ In this regard, the city corporation has highlighted the need for having more parks, trees, and natural drainage systems, which will help in increasing water absorbency. In Tamil Nadu, the government has allocated INR 880 million for the development of sponge parks in Chennai.²⁵ In March 2025, a wetland sponge park was inaugurated.

The term ‘sponge cities’ is not commonly used in Indian literature. However, many ongoing urban development and reform initiatives address some of the requirements. Some projects implemented in different cities under the Smart

Cities Mission include eco-friendly parks, rejuvenation of water bodies like lakes and rivers, city forests, tree plantations, sewage treatment plants, rainwater harvesting systems, drainage networks, and solid waste management systems.²⁶ These initiatives are already addressing some of the rainwater management-related issues.

Water Squares

Some cities have built ‘water squares’ in public areas to manage stormwater. A water square is an urban planning concept that creates a “floodable” public area when needed. In Rotterdam (the Netherlands), a water square was designed in 2012 after obtaining inputs from citizens living and working in areas near the project site. Surrounded by buildings and centrally located in a neighbourhood, the water/public square project was implemented in December 2013. It comprises three basins at different ground levels (two shallow and one deep), along with supporting infrastructure for collecting rainwater. During normal rainfall, the water that has accumulated on rooftops and the ground enters the stainless steel gutters and flows into the two shallow basins. During heavy downpour, the water reaches the deep basin. During the dry seasons, the surface area of the water square is used for recreational purposes, such as for sunbathing, sports, and theatre. Thus, the square is a multifunctional public space that manages rainwater and enhances citizens’ quality of life.²⁷

Montreal in Canada is another city with a water square, completed in 2024 following a four-year participatory process. The site of a former gas station, measuring about 1,000 square metres, was utilised for the purpose.²⁸ In addition to collecting and managing on-site stormwater, the square handles stormwater received in neighbouring areas. This has been made possible by reshaping the streets that facilitate the flow of water to the square. During the dry season, citizens enjoy spending time in the area, which features facilities such as a programmed rain fountain, lighting, a shallow pool, seating spaces, gardens, and walkways. The place also hosts an annual art and design competition.²⁹

Recommendations for Building Rainwater Resilience in Indian Cities

A study on a number of cities in different parts of the world, conducted from a rainwater management perspective, reveals that their governments have not made adequate arrangements to manage large inflows. It shows the deficiency in urban planning, management, and infrastructure provision. Inadequate attention to the issue causes numerous problems, as people suffer the consequences of flooding and the governments are spending huge sums on relief, rehabilitation, and reconstruction. The prevailing conditions are affecting social and economic progress, necessitating appropriate response measures.

At the same time, city governments in other parts of the world, as discussed in an earlier section of this brief, are actively working to improve rainwater management in their jurisdictions. In addition to maintaining effective drainage systems, new solutions are being developed and applied by these cities. Two examples are the development of natural areas, permeable buildings, and infrastructure for absorbing water (i.e. the ‘sponge cities’ approach) in China and the construction of water storage basins in central areas of cities (i.e. water squares) in the Netherlands. To be sure, such initiatives are still scarce and limited to certain parts of the city. The occasional flooding of areas in Australia, China, Germany, Italy, Russia, the United Kingdom, and the United States indicates the inadequate preparedness of countries—sitting in varied stages of economic development—to address the issue of rainwater-related calamities.

A primary concern is the insufficient attention nations give to changing climatic conditions. In this respect, the United Nations (UN) has stated that “climate change is affecting the hydrological cycle and increasing the frequency and intensity of storms.”³⁰ Therefore, it is suggested that rainwater systems be redesigned on the basis of emerging climate patterns.

This present brief observes that cities are insufficiently prepared for mitigating the adverse impacts caused by excess inflows of rainwater. Therefore, a combination of measures needs to be applied for creating better living conditions in urban areas (see Figure 1).

Recommendations for Building Rainwater Resilience in Indian Cities

Figure 1: Strategy for Strengthening Rainwater Resilience

1	2	3	4	5	6
Weather Information Systems	Early Warning Systems	Disaster Preparedness and Management Plans	Community Resilience	Rainwater Management	Planned Urbanisation and Good Governance
• Radars • Observation equipment	• Sirens • Loudspeakers • Mobile phone SMSes • TV, radio services	• Infrastructure • Contact persons • Relocation sites • Emergency medical services	• Survival techniques – swimming, protection from electrocution • Survival kits	• Water sponges • Water squares • Water passages • Drainage lines • Rainwater harvesting • Artificial intelligence	• Master plans • Regulated development • Municipal capacity-building and equipment

Source: Author's own

1. **Weather Information Systems:** In many disaster-prone regions, local administrations and citizens do not receive reliable information on weather forecasts for their areas. In this situation, it becomes impossible for them to prepare in advance for the sudden changes in weather conditions. This deficiency needs to be addressed by strengthening weather prediction infrastructure, including the deployment of advanced radars and observation equipment, and ensuring proper dissemination of data to the affected populations.
2. **Early Warning Systems:** Often, people do not receive timely warnings about an approaching storm from the local administration or other sources, and are thus caught unawares and suffer greatly the consequences of extreme and unmanaged rainfall. The impact of an unexpected weather event needs to be minimised by providing timely information to the public through various communication modes, such as sirens, loudspeakers, mobile phone SMSes, and TV and radio services. This will allow them to take timely actions for their safety.

Recommendations for Building Rainwater Resilience in Indian Cities

3. **Disaster Preparedness and Management Plans:** For all areas prone to disasters, a plan should be available to inform local administrations and communities about the measures to be taken before, during, and after an emergency situation. It should be prepared by the local administration on the basis of inputs from the community and experts. It must provide information on water and sewage infrastructure needed for rainwater management, the persons to be contacted during an emergency, survival kits, relocation sites, and emergency medical facilities. Its non-availability results in confusion, incorrect actions on the part of communities and the administration, loss of lives and assets, and injuries. Also, disaster plans should be integrated with city plans for better coordination of development activities.
4. **Community Resilience:** Communities have limited ability to protect themselves from floodwater. Children and adults who cannot swim risk being swept away by strong currents. Many get electrocuted in buildings and public areas. Local administrations must take steps to make communities flood-ready.
5. **Rainwater Management:** It may be impossible to prevent a sudden inflow of excess rainwater into an area due to its force and volume. Therefore, one option can be developing wide overground and/or underground passages for diverting the flow of water into areas without habitation. Sewerage and drainage lines, water squares, forests, surface water bodies, wetlands, permeable buildings and surfaces, and rainwater harvesting systems are the other available facilities and resources to be maintained for reducing the negative impacts of excessive rainfall. Tanks and ponds built in sponge parks and water squares for storing rainwater can also help meet the urban population's drinking water and non-potable water needs. Successful implementation of the above-mentioned measures requires cooperation of the city departments concerned, such as water, environment, and land and buildings. Furthermore, for better forecasting and management of extreme rainfall events, adoption of artificial intelligence (AI) and internet of things (IoT)-based methods can be highly beneficial. This has been observed in Jakarta (Indonesia), which faces the problem of recurrent flooding.³¹ The issue is being addressed with the help of a system developed by the government that analyses real-time data from sensors on rainfall, water levels, and river flow. This information forms the basis for predicting, managing, and mitigating flooding. It allows city officials to prepare the city about six hours in advance of dangerous flooding. This includes sending notifications to citizens via an app, closing floodgates, activating water pumps, and alerting response teams.

Recommendations for Building Rainwater Resilience in Indian Cities

6. **Planned Urbanisation and Good Governance:** It is important to ensure that the expansion, growth, and development of urban areas align with city (or master) plan proposals. This facilitates proper land utilisation and protects natural areas, such as vacant lands, ridges, mountain slopes, forests, green areas, surface water bodies, and wetlands. Violations of city plans—such as building/infrastructure construction and unauthorised construction in unsuitable locations—disrupt the natural flow of rainwater. Additionally, illegal encroachments and the dumping of construction and demolition waste in natural areas hinder rainwater percolation into the soil. Understanding local administrations' capacity to deal with such challenges is crucial. Conducting capacity-building programmes on best practices in disaster management and equipping officials with the necessary tools are critical steps towards resilience.

Conclusion

The Indian subcontinent receives monsoon rains during two time periods in a year—June to September and October to December. During these periods, large volumes of water are received from the rains. The water helps in meeting the requirements of the country's population, i.e. for drinking, sowing crops, and generating electricity. However, the mismanagement of rainwater by authorities is resulting in disasters.

This brief described the adverse impact of rainwater in select cities of the world. The experiences of cities in India, Spain, and the UAE have been documented to build wider understanding of the issues. It is learnt that adequate arrangements for rainwater management are not being made by the city governments. This deficiency has created problems for the citizens, as the sudden inflow of excess water in cities affects people's lives. It also damages civic properties and infrastructure.

Accordingly, for Indian cities, this brief calls for better management of rainwater. It recommends that resilience to rainwater needs to be built by applying a combination of measures, including: strengthening the weather forecasting infrastructure; establishing early warning systems; formulation and implementation of disaster preparedness and management plans; development of floodwater management infrastructure; and ensuring planned urbanisation and good governance. 

Rumi Aijaz is Senior Fellow, ORF.

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20, Rouse Avenue Institutional Area,
New Delhi - 110 002, INDIA

Ph. : +91-11-35332000. Fax : +91-11-35332005

E-mail: contactus@orfonline.org

Website: www.orfonline.org