The drainage systems of India's cities

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As India's cities have expanded, their drainage systems have not kept pace with building growth nor with the provision of water supply. Encroachment on floodplains as well as inadequate sewerage systems flowing into storm drains mean that these drains cannot cope with monsoon runoff. This article looks at attempts to tackle these problems.

India has been undergoing rapid urbanization since independence. While the total population of India in 1947 was about 270 million, the total population is now 1027 million, with the urban population now standing at 285 million.

In almost all of India's cities, developments in the water supply sector have outpaced those in the drainage sector. With increasing water supply to cities, drainage managers are faced with additional wastewater from the highly populated areas for which the existing drains are totally inadequate.

Urban development and rainfall patterns

There are now 108 million people living in 35 metropolitan cities (or 'metros', defined as having a population of one million or more) and some of these metros are listed in order of size in Table 1, which also gives the average annual rainfall. There is a wide variation of rainfall; for example Santa Cruz, Mumbai, which is on the coast, receives over 2000 mm during the monsoon from the Arabian Sea, while some other cities receive only 600 mm of rainfall, depending on their location and geographical features.

What is significant, however, is that over 75 per cent of the rainfall occurs during the four months from June to September (with the exception of Chennai, which also receives rainfall from the north-east monsoon from October to January). Mumbai receives almost all of its 2300 mm rainfall during June to September and several catchments in Mumbai experience severe flooding, usually when high tide is preceded by heavy rainfall for three hours. This period of heavy rainfall causes severe disruption to the transportation system and paralyses commercial activities at least twice a year; the losses are estimated at US$5 million per flooding event. Figure 1 is a rainfall hyetograph for the rain event of 4 August 2004, which caused severe flooding and brought the city of Mumbai to a standstill.

Effect of urbanization on drainage

With increasing urbanization and the pressures of population, the impervious surfaces in the metros are increasing, thereby increasing the volume of stormwater runoff. The former holding basins and detention ponds have been levelled and new housing estates have been built on these sites. While the new areas have been receiving increased water supply through pipelines or tankers, these localities do not even have a well-defined sewerage system and it is a common sight in most cities to see raw sewage flowing into the open storm drains.

Although major cities like Mumbai and Chennai have implemented plans for augmenting the existing sewerage systems, drainage has lagged behind water supply development and has neither been planned nor implemented fully in a majority of the cases. For example, in Chennai, the capacity of the existing sewerage systems is grossly inadequate and the open drains essentially function as flood carriers during the monsoon. During the remaining part of the year, the flow is due to the discharge of treated, partially treated and untreated sewage through the outfalls meant for stormwater discharge, resulting in an accumulation of large volumes of sludge and the formation of sand bars in the mouth of the rivers. These overflows have created significant problems for flood protection systems, storm-water drainage and public health.

Table 1 The rainfall of India's top 10 cities (by population)[1]

Rank	City	Population	Av. annual rainfall (mm)	% rainfall (June–Sept)
1	Mumbai (Bombay)	16 368 084		
	(a) Colaba		1793	–
	(b) Santa Cruz		2401	96
2	Kolkata (Calcutta)	13 216 546	1614	75
3	Delhi	12 791 458	797	84
4	Chennai (Madras)	6 424 624	1267	32
5	Bangalore	5 686 844	970	54
6	Hyderabad	5 533 640	805	76
7	Ahmedabad	4 519 278	800	96
8	Pune	3 755 525	722	76
9	Surat	2 811 466	1207	–
10	Kanpur	2 690 486	792	–

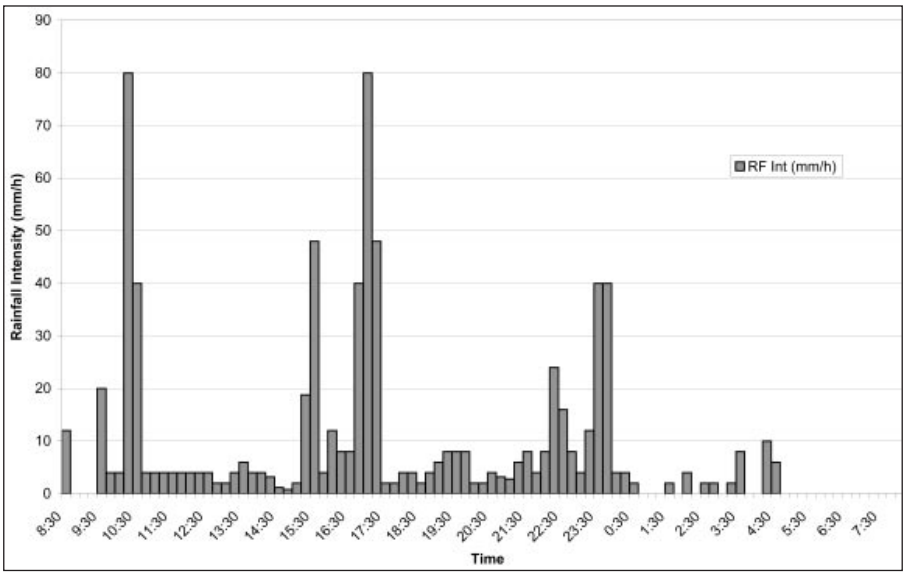


Figure 1 Rainfall Hyetograph for 4th August 2004, Santa Cruz, Mumbai (India).

The problem has been exacerbated by informal settlements on the banks of the storm drains in many of the cities, such as Delhi, Kolkata and Mumbai. There has been a gradual encroachment on the banks of the open storm drains and some drains have had their widths reduced to only 20 per cent of their original width. What were once natural drainage channels now have buildings on their flood plains discharging raw sewage into storm drainage channels. In a few extreme cases, even multi-storey buildings have been built on the top of the storm drains. The capacity of the drains to carry storm flows has therefore been reduced. This has resulted in increased incidences of urban flooding during the monsoons. There are problems acquiring land for drainage, since most drainage banks are occupied by informal settlements with the blessing of local leaders.

Drainage systems in major cities

Perhaps the oldest combined sewerage system in India is in the city of Kolkata (Calcutta), which was the capital of the British Empire in India till 1911. The first brick sewer in Kolkata was commissioned in 1876, and it was designed to cope with 6.35 mm/h of rainfall with 100 per cent of runoff. Attempts were made in the 1970s to increase the capacity to cater for 12.7 mm/hr rainfall. However, Kolkata received 54 mm in one hour in the year 2003, which caused severe flooding.

Ad hoc measures, such as installing additional pumps to pump out water from the low-lying areas, are quite expensive in the short term and often ineffective, since the power supply is not dependable, particularly during heavy rainfall when power lines are sometimes dislodged. Sustainable infrastructure development is a more promising solution and efforts are now being made in this direction. For example, various pilot projects are now being carried out for using constructed wetlands for treating domestic wastewater in small urban settlements.

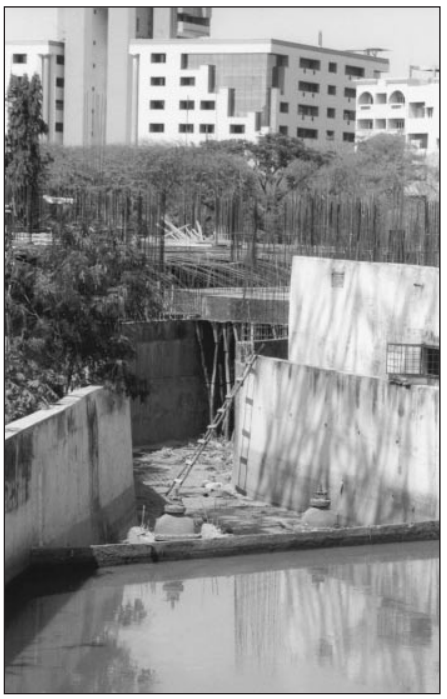
In Bhubaneshwar, a number of urban environmental improvement projects are under way, such as the conservation of urban lakes and water bodies, slum improvement projects, revision of master plans, the development of water sports and even the use of information technology to develop drainage projects. Legally, no construction is allowed in the portion earmarked for drains, so as to facilitate the free flow of rainwater.

Bangalore receives an average annual rainfall of around 900 mm. As with other cities, the existing stormwater drains were constructed many years ago when the catchment area included more open space, so that water was absorbed into the soil during rains. Recent growth of the city resulted in more water flowing into the stormwater drains during rains, and flash floods in the low-lying area adjacent to the drains due to backflow into the roadside drains. Recent studies have been commissioned to check the adequacy of the major existing drains. Simple measures were recommended, like cleaning the existing drains, modifying the cross section wherever inadequate, strengthening the damaged side walls, reconstruction of inadequate culverts, deep excavation of the existing drain beds and the diversion of sewer lines leading to stormwater drains. Subsequent studies focused on checking the adequacy of these drains for storm intensity and the frequency of storm occurrence. It was also recommended that new reinforced cement concrete drains be constructed for all primary and major secondary drains. However, these involved substantial costs and considerable safety measures.

Smaller cities that do not have international funding assistance are finding it difficult to implement improvement measures. For example, some cities such as Pondicherry still use septic tanks and no underground drainage system has yet been implemented. In Ludhiana, Punjab, in the absence of a proper drainage system, a large amount of water during the monsoon pours into big potholes in the road, which are more than 50 cm deep and wide enough to create problems even for four-wheelers. Apart from the poor drainage system, the other major reason for water accumulating is the rising level of roads. For example, when roads were constructed, a few years back, the factories on both sides of one road were 60 cm above the road level. However, due to frequent resurfacing, the factories are now about 50 cm below the level of this particular road. Moreover, the drainage system beneath the road has ruptured.

Cleaning of sewers

Recent surveys have shown that in cities like Mumbai most of the trunk sewers have become structurally unsafe and have had their hydraulic capacity reduced by 40 to 60 per cent. Massive siltation has been identified as one of the factors. Although manual desilting is regularly carried out, the labourers are reluctant to go further than 5 m from the manholes, which are spaced at 50 to



This multi-storeyed building is being constructed on a storm drain

100 m intervals or more. This leaves long silt dunes between manholes. Sometimes, when private contractors with limited experience and equipment have undertaken the cleaning, workers have inhaled poisonous gases and died.

In Kolkata, most drains discharge via outfalls and a number of pumps are needed to pump out the excess storm-flows during the monsoon to the nearby channels. However, due to inadequate maintenance of the outfalls, the outfalls have become silted to such an extent that in some cases the storm drainage lines discharging into them now lie embedded in silt. Surcharging of sewers is commonly observed, resulting in waterlogging of nearby areas. Mechanical desilting, using jet rodding and bucket cleaning machines, has sometimes been attempted, for example in Chennai, but this is an isolated case.

Current developments

Major cities like Mumbai, Bangalore, Hyderabad, Kolkata and Chennai have recently begun rehabilitating and restoring trunk sewers, usually through grants or loans from the World Bank, Asian Development Bank, or the Indian Housing and Urban Development Corporation. At the same time, plans are being made to divert runoff from one part of the system to another, but these are again *ad hoc* measures that require detailed data collection, flow surveys and computer simulations before the measures should be implemented. The National River Conservation Directorate has also funded the interception, diversion and treatment of sewage in Chennai. In Rajasthan, six major cities including Jaipur are currently in the process of developing a drainage network to improve sanitation, with assistance from the Asian Development Bank.

Another centrally sponsored scheme, the Ganga Action Plan (GAP), implemented by the Central Ministry of Environment and Forestry, has sought to improve the sanitation facilities in 25 Class I cities (cities with a population of more than a hundred thousand) along the River Ganga in the States of Uttar Pradesh, Bihar and West Bengal. Under GAP phase I, sewage has been intercepted and diverted to sewage treatment works and low-cost sanitation units were set up, so that now 792 million l/day of sewage has been intercepted and diverted and 596 million l/day of sewage treatment facilities have been installed.

Cities like Mumbai and Chennai have recently demonstrated the successful application of trenchless technologies for laying sewer pipes to avoid disrupting road and rail traffic.

Use of models as decision-support system

Computer models such as WALLRUS and SWMM have been used in Mumbai and Kolkata for modelling the drainage systems. Some flow surveys for city sewers have been carried out for planning wastewater treatment plants, for example, in Mumbai. However, the flows in storm drains have seldom been measured and this makes it difficult to calibrate software models. Also, none of the municipalities have tipping-bucket rain gauges installed in their catchments, so data on historical rainfall distributions are scarce. To improve the ability of models for decision-support systems, future efforts need to be backed by appropriate instrumentation. Otherwise, no matter how good the software, it is of limited use.

Management structure

One of the main hurdles to the proper management of the drainage system in a majority of the cities is the multiplicity of authorities looking after the drains. For example, in Jaipur, there are as many as six government departments looking after the stormwater drains and sewer networks, while in Kolkata, the Department of Irrigation and Drainage, the Kolkata Municipal Corporation and the Kolkata Metropolitan Development Authority together look after the drainage of Kolkata.

Even when the drainage is looked after by a single organization, there are different departments, often administered by different heads, and sometimes working at cross-purposes. For instance, in Mumbai, there are three different departments within the Bombay Municipal Corporation looking after stormwater drainage, sewerage and solid-waste management. Most of the solid waste is thrown openly into the storm drains, and sewers often overflow into the storm drains.

Conclusions

There is an urgent need for planners to consider an integrated planning approach backed by adequate scientific data that combines the provision of water supply, wastewater disposal and a solid-waste disposal strategy into the urban planning process. These strands need to be implemented together, otherwise the present cycle of sewage in storm drains, flooding, disruption in monsoons and the outbreak of disease will continue to upset the quality of life.

About the author

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References

1 IMD (Indian Meteorological Department) (2002), Rainfall in major cities of India, available at http://www.imd.ernet.in/section/climate/newdelhiweb.htm)

Further reading

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