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ABSTRACT The relationship between climate change and cities is complex. City-based activities contribute significant amounts of greenhouse gases and, simultaneously, are often more vulnerable to the impacts of climate change. Dhaka is now the world's eighth largest city and a significant proportion of Bangladesh's greenhouse gases are generated there although, relative to total emissions worldwide, the contribution is negligible. But this contribution is likely to increase rapidly with the continuing growth of the city's population, economy and electricity consumption, as well as increased motor vehicle use. At the same time, Dhaka is prone to damaging and costly flooding, both from the rivers that bound it and from rainfall that generates runoff that is beyond the capacity of the drains. In less than 20 years, the city has faced three major floods, each causing huge damage and economic loss. Although the government has taken a number of measures to improve both Dhaka's air quality and its capacity to withstand floods, there are further opportunities in both areas. This paper discusses, in specific terms, the scale of the threats, the measures taken to address them and the potential for more effective action.

KEYWORDS climate change / Dhaka / flood / greenhouse gases / opportunities / vulnerability

I. INTRODUCTION

Dhaka, the capital of Bangladesh and one of the world's largest megacities accommodates more than 13.1 million people within its 1,353 square kilometre area.(1) According to the most recent UN estimate, its population will reach 16.8 million by 2015.(2) This megacity comprises Dhaka City Corporation and five adjacent municipal areas, namely Savar, Narayanganj, Gazipur, Kadamrasul and Tongi.(3) In 2005, Dhaka City Corporation, the heart of the megacity, covered 276 square kilometres and had a total population of 8.4 million. The city is surrounded by the Buriganga River to the south, the Balu and Shitalakhya rivers to the east, the Tongi canal to the north and the Turag River to the west.

Dhaka is 2–13 metres above mean sea level, with most of the urbanized areas at elevations of 6–8 metres. It has been reported that about 20 square kilometres of land are more than eight metres above mean sea level, about 75 square kilometres are between six and eight metres, and 170 square kilometres are below six metres.(4) Dhaka has hot, humid summers, short, mild winters and heavy rain during the monsoon season.(5)

1. BBS (2003), *Bangladesh Population Census 2001,*

a. Brief history and growth

Human settlement and the development of infrastructure started in the sixteenth century in the southern part of the present city corporation that is known as "old Dhaka". Over the last 400 years, the city has experienced a number of dramatic historic events. Political changes and shifts in power have also brought about changes in demography and structural development.

Over the last few centuries, Dhaka has extended to approximately 40 kilometres from north to south and 14 kilometres from east to west. In 1951, it covered 85 square kilometres and had 0.4 million inhabitants. It experienced a very rapid expansion in area and population after independence in 1971. Since then, the rapid development of human settlements, the growth of national and international business, the opening of new trades and the expansion of private and public establishments, industry and infrastructure have made Dhaka one of the most unplanned urban centres. To meet the rapidly growing demands of different sectors, utility services were established and expanded at different times, but not at the same pace as population growth and demand. This disparity and the unequal development and management of the utility services, and improper management of the natural resources and natural hazards (for instance floods, excessive rainfall) have degraded the overall environment of the city.

b. Key concerns

The high rate of population growth for Dhaka, much of it the result of rural–urban migration, is not a new or unusual problem. Many cities in low- and middle-income nations have long faced a number of environmental and developmental problems. But now they will face additional stresses as the global climate continues to warm and as they have fewer of the resources needed to adapt or respond to the impact of climate change. Stresses for the cities related to global warming include higher temperatures, water shortages, increased flooding and rising sea levels, particularly for coastal cities.

Dhaka, as a megacity, is already facing a number of environmental problems and risks related to natural disasters. Most environmental problems are human induced, resulting either from a lack of compliance with national policies, rules and regulations, or from resource constraints to implementing different measures. Flooding is the most common disaster in Dhaka.

Other key environmental concerns for the city include air quality (both indoors and outdoors), surface water contamination, a reduction in groundwater, inadequate solid waste and sewage management, waterlogging, transport congestion and the expansion of slums and squatter settlements. Erratic changes in temperature and rainfall and increased frequency of floods are becoming more evident. There are also particular problems of drainage congestion due to excessive rainfall, and flooding rivers. Both are a major concern to city dwellers, posing adverse effects on different sectors including infrastructure (road, rail, housing), industry (large, medium and small), trade and commerce (through a disruption of communications, for instance), utility services (water supply and sanitation), sewage management and the supply of electricity and gas.

National Report (Provisional), Volume 1, Dhaka; also United Nations Environment Programme (UNEP) (2005), *Dhaka City State of Environment Report:2005*, United Nations Environment Programme (UNEP), Dhaka.

2. United Nations (2006), *World Urbanization Prospects: the 2005 Revision*, United Nations Population Division, Department of Economic and Social Affairs, CD-ROM Edition – data in digital form (POP/DB/WUP/Rev.2005), United Nations, New York.

3. Akash, M M and D Singha (2003), "Provision of water points in low-income communities in Dhaka, Bangladesh", Paper prepared for the Civil Society Consultation on the 2003 Commonwealth Finance Ministers Meeting, Bandar Seri Begawan; also BBS (1991), *Statistical Year Book of Bangladesh*, Bangladesh Bureau of Statistics, Ministry of Planning, Government of Bangladesh.

4. Japan International Cooperation Agency (JICA) (1987), "Study on stormwater drainage system improvement project in Dhaka city", Supporting Report, Local Government Division of Ministry of Local Government, Rural Development and Cooperatives, Dhaka.

5. Siddique, K, A Ghosh, K S Bhowmik, S A Siddique, M Mitra, S Kapuria, N Ranjan and J Ahmed (2004), *Megacity Governing in South Asia: A Comparative Study*, The University Press Limited, Dhaka.

Of course, they also bring very serious problems in relation to human health and livelihoods, especially for the poor.

c. Key institutions

The government of Bangladesh has divided administrative, regulatory and utility services among different ministries, departments and agencies, with specific mandates and responsibilities. The Dhaka City Corporation, Dhaka Water and Sewerage Authority, Dhaka Electric Supply Authority, Titas Gas Limited, Bangladesh Telephone and Telegraph Board, Rajdhani Unnyan Kortripakhkha and Dhaka Electric Supply Company are responsible for providing utility services to different sectors, including the domestic, industrial and commercial sectors. The Department of Environment, under the Ministry of Environment and Forests, is primarily responsible for implementing environmental rules and regulations, including those related to climate change issues. Dhaka Metropolitan Police is responsible for law and order in daily life and also during natural disasters. Health, education, planning, housing, transportation and other infrastructure-related organizations also exist in the city area, along with NGOs, development partners, corporate business and trade communities and other related organizations concerned with environmental issues in the city.

II. DHAKA'S CONTRIBUTION TO GLOBAL CLIMATE CHANGE

Climate and cities have a long relationship that is now becoming more complex. The United Nations forecasts that by 2050, some 65 per cent of the world's population will be living in urban areas – as these increasingly become the world's centres of culture, industry and economy. Many cities have grown to a size that is unprecedented historically. The United Nations Population Division forecasts that by 2015, 35 cities – more than half of them in coastal zones – will have populations exceeding 8 million.[6] While modern cities cannot be considered separately from the larger regional climate systems, they exert profound effects on both regional weather and global climate, as they are concentrated islands that absorb heat. Production and consumption that are concentrated within their boundaries are also generators of the heat and carbon dioxide emissions that have been driving global climate change.

Greenhouse gases come from both natural and anthropogenic activities. Anthropogenic activities, mainly the burning of fossil fuels in different sectors, are a key source of greenhouse gases. A national greenhouse gas inventory for Bangladesh revealed that the energy sector contributes more than 60 per cent of the total greenhouse gases of 15,178 Gigagrammes per year.[7] Energy industries, other industries, transport and the residential sector are key consumers of different types of fossil fuels. Among these sectors, the energy industry contributes more than 35 per cent of the greenhouse gases while transport (road, rail, navigation and domestic aviation) contributes about 17 per cent, of which 70 per cent comes from the road transport system.

As the country's capital city, and with its multiplicity of sectors, Dhaka is consuming different types of fossil fuels. The commercial, residential and industrial sectors are using mainly electricity, of which more than

6. See reference 2.

7. MoEF (2002), *Initial National Communication to the United Nations Framework Convention on Climate Change*, Ministry of Environment and Forests, Government of Bangladesh, Dhaka.

85 per cent is generated from natural gas. They also use gasoline and diesel-fuelled generators to meet electricity demand during electricity outages. The transport sector depends mostly on petroleum products i.e. diesel and gasoline. Very recently, compressed natural gas entered into the energy mix within the transport sector. Residential and some commercial sectors are also using natural gas for cooking, while slum dwellers are using mostly biomass as their primary fuel for cooking.

Dhaka Electric Supply Authority (DESA) and Dhaka Electric Supply Company (DESCO) provide electricity in the city. DESA was created in 1990 to improve services to consumers and to enhance revenue collection by reducing high system losses. DESCO was created in 1996 and started its operations in 1998 as part of a process to restructure the power sector and improve the key operational and financial activities in the electricity distribution system.

Bangladesh Power Development Board (BPDB) performance data show that energy imported by DESA and DESCO accounts for almost 50 per cent of the total energy sold by BPDB. However, data for the fiscal year 2003–04 and 2004–05 show that imports have declined for Dhaka against total energy sold by BPDB. This may be due to higher demand at the national level against lower generation. Table 1 provides figures for net energy generation, energy sold and energy imported by DESA and DESCO from 1991–92 to 2004–05.

The registration database for Bangladesh Road Transport Authority reveals that about 45 per cent of all vehicles in the nation (up to 2005) are registered in Dhaka. National estimates suggest that about 70 per cent of emissions from the transport sector are from road transport. The fact

TABLE 1
Bangladesh Power Development Board performance

Year	Net energy generation	Total energy sold	Energy imported by DESA and DESCO	Percentage of imported energy against total energy sold
	Gigawatt hours			
1991–92	8,393	6,329	3,066	48.44
1992–93	8,699	6,906	3,356	48.60
1993–94	9,221	7,447	3,696	49.63
1994–95	10,166	8,371	4,162	49.72
1995–96	10,832	8,995	4,550	50.58
1996–97	11,242	9,446	4,961	52.52
1997–98	12,194	10,176	5,418	53.24
1998–99	13,637	11,352	5,946	52.38
1999–00	14,739	12,468	6,504	52.17
2000–01	16,254	14,002	7,241	51.71
2001–02	17,444	15,243	7,845	51.47
2002–03	18,422	16,331	8,320	50.95
2003–04	20,062	18,023	7,070	39.23
2004–05	21,162	19,195	6,977	36.35

SOURCE: Bangladesh Power Development Board (2006), accessible at http://www.bpdb.gov.bd/execituve.htm.

that movements of vehicles do not follow administrative boundaries makes estimates problematic. But considering the types of vehicle registered in Dhaka and Bangladesh, and the amounts of different types of fuel consumed, it may be concluded that about 25–30 per cent of the emissions from the road transport system come from Dhaka city. Table 2 shows the types and numbers of vehicles registered in Bangladesh and Dhaka up to 2005.

Thus, a large proportion of greenhouse gases comes from the electricity and transport sectors, although their contribution to total global greenhouse gas emissions is negligible. Given the rate of population growth in Dhaka, electricity consumption and the transport sector, the city's contribution to global greenhouse gases will increase. It must be noted that brick kilns around the city and landfill sites also contribute to global greenhouse gases. They usually operate for about six months a year, and every year in the dry season, they burn nearly 2 million tons of coal.[8]

8. *The Daily Prothom Alo*, 5 March 2004, Dhaka.

III. THE EFFECTS OF CLIMATE CHANGE IN DHAKA

Climate change will affect Dhaka primarily in two ways: through floods/drainage congestion and through heat stress. The melting of glaciers and snow in the Himalaya and increasing rainfall will lead to more frequent flooding in Bangladesh. The waterlogging and drainage congestion due to river floods and excessive rainfall during the monsoon are already causing very serious damage. Furthermore, Dhaka may also face "heat island"[9] problems because temperatures in the city are a few degrees higher than in the surrounding areas. Indeed, vehicle exhaust emissions, industrial activity and increasing use of air conditioning are contributing to heat

9. A "heat island" is an area that is significantly warmer than its surroundings. On hot summer days, urban air can be 2–6°C hotter than the surrounding countryside. This phenomenon is not to be confused with global warming, and scientists call it the "urban heat island effect".

TABLE 2
Types and number of vehicles registered in Bangladesh and Dhaka up to 2005

Type of vehicle	Number of vehicles registered in Bangladesh	Number of vehicles registered in Dhaka	Percentage registered in Dhaka
Motor car	128,037	98,233	6.72
Jeep/station wagon/microbus	55,837	37,808	67.71
Taxi	11,987	10,406	86.81
Bus	32,257	4,121	12.78
Minibus	34,347	7,946	23.13
Truck	56,749	22,883	40.32
Auto-rickshaw/ auto-tempo	112,330	39,599	35.25
Human haller	1,349	829	61.45
Covered van	581	527	90.71
Motorcycle	389,514	140,050	35.96
Other	29,488	16,175	54.85
Total	852,476	378,577	44.41

SOURCE: Bangladesh Road Transport Authority (2006), accessible at www.brta.gov.bd.

generation and this will increase in the future. An overview of the major floods that have affected Dhaka is given below.

a. Major floods in Dhaka

Dhaka has faced a number of severe floods since its early days and its vulnerability to these resulted in the building of the Buriganga River flood embankment in 1864. Severe flooding in Greater Dhaka is mainly the result of spillover from surrounding rivers that flow to and from the major rivers of the country, as well as internal waterlogging. In recent history, Dhaka has experienced major floods in 1954, 1955, 1970, 1974, 1980, 1987, 1988, 1998 and 2004, due to overflowing of surrounding rivers. Of these, the 1988, 1998 and 2004 floods were the most damaging.

Flooding due to excessive rainfall is also a severe problem in certain parts of the city, which are inundated for several days mainly due to drainage congestion and inadequate pumping facilities to remove the stagnant water. The water depth in some areas may be as high as 40–60 centimetres, which creates large infrastructure problems for the city, economic losses in production and damage to existing property and goods. The impacts of river flooding are even more severe and disrupt economic activities and the livelihoods of people dependent upon urban activities.

During July and August 2004, devastating floods seriously affected Bangladesh. The north and west-central districts suffered severe flooding, which continued to spread, eventually reaching Dhaka and other central districts. The floods affected about 38 per cent of Bangladesh and caused extensive damage to standing crops, physical and social infrastructure, the environment and the livelihoods of 36 million people. Furthermore, in September 2004, a localized low pressure depression swept over Bangladesh, resulting in excessive rainfall – three times the normal levels. This intense rainfall caused another round of flooding in Dhaka and central and southwestern districts.

The main reason for the 1998 flood was excessive rainfall over the catchment area of the Ganges–Brahmaputra–Meghna river basin. Three different flood waves passed through this river basin and the last one coincided with peak flows in the Ganges and the Brahmaputra. In addition, the impact of the lunar cycle, and the resulting high tide, was responsible for the slow recession of the floodwaters. These factors resulted in prolonged flooding in both the country and the city for two months.

The main causes of flooding inside the protected area were hydraulic leakage, a failure to operate the regulators (sluice gates) and a lack of timely pumping of accumulated water upstream from the Rampura regulator. As 75 per cent of the work for Phase I of the Dhaka Integrated Flood Protection Project had been completed, it was assumed that the Gulshan, Banani, Baridhara and Tejgaon areas would not be flooded. However, four or more drainage pipes measuring about four feet in diameter connect this part of the city with the floodplain on the eastern side, and hydraulic leakage and failure in the operation of the Rampura regulator resulted in flooding in these areas. There was an apparent lack of coordination between the Bangladesh Water Development Board and the Dhaka Water Supply and Sewerage Authority to prevent the flooding. Although the authority is responsible for ensuring proper drainage, the Bangladesh Water

Development Board is in charge of operating the regulators and gates. In fact, there was neither operating policy nor assigned person to operate the Rampura regulator that controls the drainage of 40 per cent of the protected area under Phase I of Dhaka Integrated Flood Protection Project

In the 1998 flood, there was excessive rainfall in Dhaka, causing short duration flooding in the areas of Shantinagar, Nayapaltan, Rajarbag, Dhanmodi, Azimpur and Green Road. The runoff generated by the rainfall could not flow into the surrounding rivers as the river stage was higher than the inside flow.[10] Therefore, the accumulated runoff in low-lying areas remained stagnant until the river stage receded, causing extensive waterlogging in Dhaka West. Figure 1 shows the extent of 1998 flooding in Dhaka.

In 1988, one of the most severe floods in recent history hit Dhaka and inundated 85 per cent of the city. It was estimated that floods of this intensity hit the country only once every 70 years. Inundation depths ranged from 0.3 to more than 4.5 metres and about 60 per cent of the city dwellers were affected.[11] This unprecedented level of flooding disrupted city life and air travel, and communications between Dhaka and the outside world were cut off for about 2 weeks. Data on the impacts and damage from the 1988 flood were compiled and analyzed according to component eight of the flood action plan. All of eastern Dhaka and all the low-lying areas of western Dhaka were under floodwater. Only parts of Mirpur, Tejgaon, Banani, Sher-e-Banglanagar, Azimpur and the Old Town were not flooded.

10. "River stage" refers to the river water level, and "inside flow" to the water level of the runoff flow.

11. Japan International Cooperation Agency (JICA) (1991), "Master plan for Greater Dhaka flood protection project, FAP 8A", Main Report and Supporting Report I and II, Flood Plan Coordination Organization (presently WARPO), Dhaka; also Japan International Cooperation Agency (JICA) (1992), "Feasibility study of Greater Dhaka Flood Protection Project, FAP 8A", Interim and Main Reports, Flood Plan Coordination Organization (presently WARPO), Dhaka.

b. Overall rainfall patterns and trends

The Bangladesh Meteorological Department has 35 meteorological stations throughout the country. Rainfall data from the Dhaka station for 1971 to 2005 show that the annual average rainfall in the city is about 2,120 millimetres, of which about 50 per cent falls during the months of June, July and August, generally referred to as the monsoon season. Average rainfall during the winter months (December, January and February) is negligible, less than 2 per cent of annual rainfall.

While Dhaka's long-term trend in annual rainfall shows no significant change, the trend in seasonal rainfall appears to be erratic. Two important facts support this finding. First, trend analysis reveals that although there is no significant change in annual average rainfall, the number of "days without rainfall" is increasing. Second, seasonal rainfall data in both the monsoon (June, July, August) and winter (December, January, February) seasons show a decreasing trend over time. However, it should be noted that the R^2 value (denoting the statistical strength of this trend) is very low. Figure 2 shows annual average rainfall and "days without rainfall". However, these two facts together indicate that more rainfall is occurring in other months of the year and that rainfall intensity is increasing.

IV. IMPACTED SECTORS AND VULNERABILITIES

Infrastructure, industry, trade and commerce and utility services are key sectors that are vulnerable to floods and their impacts. The limited

FIGURE 1
Extent of 1998 flooding in Dhaka city

SOURCE: Adapted from the Geographical Information Systems Division of Bangladesh Centre for Advanced Studies (BCAS).

performance of these sectors during and after flooding increases the vulnerability of city dwellers, and this vulnerability varies according to economic and social status. Loss of life and livelihoods and impacts on human health are key vulnerabilities for lower-income groups.

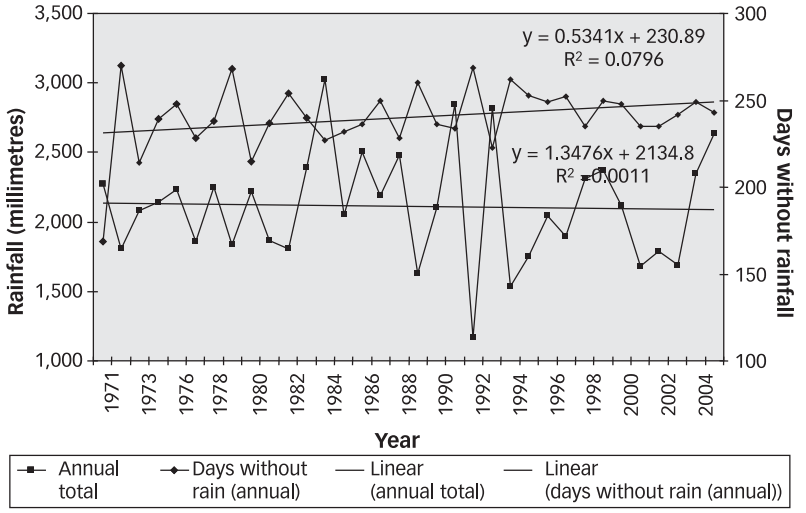

FIGURE 2
Trend for annual rainfall and days without rainfall

SOURCE: Author's analysis of meteorological data.

a. Infrastructure

Extreme events such as floods, drainage congestion and waterlogging due to excessive rainfall cause very serious damage to such infrastructure as roads and railways, formal and informal housing and educational institutions. According to available literature, the eastern part (nearly 119 square kilometres) of Dhaka was 100 per cent inundated in the floods that occurred in 1988, 1998 and 2004. In western Dhaka, 117 square kilometres (75 per cent) were submerged in 1988, but due to the construction of the flood protection embankment along the Turag River and Buriganga River, only 36 square kilometres (23 per cent) were submerged in the 1998 flood.[12] Waterlogging due to continuous rainfall is a near-regular occurrence in the rainy season in the eastern part of the city. In 1998 and 2004, both inter- and intra-city bus links from eastern Dhaka were shut down due to inundation.

It is estimated that the number of institutions and houses affected by the 1988 flood was 14,000 and 400,000, respectively. The estimated damage was about Tk. 4 billion for residential buildings and more than Tk. 400 million for institutions. The 1998 flood caused damage to more than 262,000 shelter units, or 30 per cent of the 860,552 units in the Dhaka Metropolitan Area, at a cost of Tk. 2.3 billion.[13] Of these, 32 per cent were permanent and semi-permanent structures belonging to wealthy or well-to-do households not dependent on help for repairs and rehabilitation. About 36 per cent of shelter units that were temporary or of poor quality (of *katcha*–1 type) and belonged to lower-middle and poorer classes suffered damage of Tk. 283 million. Their owners had the ability to cope with repairs but would likely face hardship. In the bottom rung, nearly

12. Nishat, N, M Reazuddin, R Amin and A R Khan (editors) (2000), "An assessment of environmental impacts of the 1998 flood on Dhaka city", Department of Environment and International Union for Conservation of Nature, Dhaka.

13. To get some sense of the scale of these figures, one US dollar was roughly equivalent to 32 taka in 1988, 48.6 taka in 1998 and 61.5 taka in 2004.

32 per cent of shelter units of *katcha*–2 and *Jupri* types, belonging to poorer groups (including the poorest – known as hard core poor, who lack the income needed for sufficient food) suffered severe damage of Tk. 195 million. The owners were too poor to mobilize funds on their own.[14]

It is evident from various studies that damage to infrastructure, including roads, water supply and housing, was severe in 1998. It has been reported that more than 600 kilometres of the total 2,300 kilometres of road were damaged in this flood. All the informal settlements and business enterprises located in eastern Dhaka were affected. All academic institutions (primary schools, high schools, colleges) in the area were also closed during the flood. It was estimated that 384 kilometres of paved road were inundated, a large proportion in Gulshan *thana*.[15] There was also severe damage in Sabujbag *thana* and in Demra. The most severe disruption to water supplies from deep tubewells was in the Cantonment *thana*, also in Gulshan and Uttara. Considering the major impacts of the floodwater, it appears that Sabujbag and Gulshan *thanas* were the worst affected, followed by Demra, Uttara and Cantonment *thanas*.[16]

14. Islam, N and Ali, K (1999), "Housing damage study", Centre for Urban Studies (CUS), Dhaka.

15. A *thana* is a sub-district.

16. See reference 12.

b. Industry

Most small-, medium- and large-scale industries and factories are affected by floods. This includes garments, textiles, leather, cold storage, timber and furniture, and food and agro-based industries. Most of the affected industries and factories usually discontinue their operations during floods as floodwater often disrupts physical, mechanical and electronic functioning. As a result, garment industries, for example, often fail to meet shipment or delivery deadlines in both the local and international markets. The total loss to large-scale industry in Dhaka in the 1998 flood was equivalent to more than US$ 30 million, while the loss to small and medium size industry in the city was US$ 36 million.[17]

17. See reference 12.

c. Trade and commerce

Any disruption in communications causes a slowdown in the mechanisms of local, national and international trade and commerce. Both flooding and waterlogging due to excessive rainfall cause very serious damage in the trade and commercial sectors (Box 1). The waterlogging especially becomes a burden for the dwellers of Dhaka city as it poses challenges to social functioning, the environment and economic activity.

d. Utility services

Water supply, sanitation, solid waste management, sewage management, electricity and gas supplies and telecommunications all suffer damage as a result of flooding and waterlogging. For example, water becomes contaminated in the supply pipes as many of these are old and damaged and leak (Box 2). Both Dhaka City Corporation and Dhaka Water Supply and Sewerage Authority fail to manage the solid waste and sewerage network, and it was estimated that the total cost to repair and rehabilitate the damage to the sewerage system after the 1998 flood was more than US$ 9 million.[18] Another estimate calculates the total damage to the

18. Dhaka Water and Sewerage Authority (WASA) (1998), Minutes of the 12th Special Emergency Board Meeting of the Dhaka WASA held on 19 September 1998, WASA, Kawran Bazar, Dhaka.

BOX 1
Effects of waterlogging

In September 2004, business and economic activities came to a virtual standstill in Dhaka as a result of heavy rainfall. On the 12th and 13th of the month, constant rains inundated most of the business centres, including Motijheel commercial hub, and the Meteorological Department measured a record 315 millimetres rainfall in the city during those 48 hours. The overnight downpour forced the suspension of Dhaka's Stock Exchange and the weather also disrupted production in garment factories. Many workers could not reach the factories because the roads from their houses, mostly located in the city's low-lying areas, were inundated. Sales in shopping malls and activities in other business houses were unusually low – people preferred to stay at home unless there was an emergency. Many airline flights, especially on domestic routes, were delayed by one hour or two hours. A report by Dhaka's Water and Sewerage Authority (WASA) indicates that waterlogging during September affected 250 schools and 681 garment factories in Dhaka city, and the garment sector lost Taka 632 billion. Road repairs cost Taka 12.8 billion and damage to the telephone sector totalled Taka 175 million.

SOURCE: Tawhid, K G (2004), "Causes and effects of waterlogging in Dhaka city, Bangladesh". TRITA–LWR Master's Thesis, Department of Land and Water Resource Engineering, Royal Institute of Technology, Dhaka.

water, sewerage, electricity, gas and telephone services after the 1998 flood at more than US$ 20 million.[19] Roadside waste bins and containers are usually submerged during floods, and door to door solid waste collection and disposal services are impossible in many parts of the city. In fact, all utility services grind to a halt during flood events.

19. See reference 12.

BOX 2
Flood-hit Dhaka reels from water crisis

A late July newspaper report during the 2004 flood noted that more than 2 million city residents faced an acute drinking water crisis as supplies had become contaminated. Thirty water pumps operated by the Dhaka Water and Sewerage Authority (WASA) were inundated by rising floodwater. Water pipelines stretching over a few hundred kilometres and many reservoirs were also under water, posing a serious threat to public health. Floods had already affected more than 5 million people or half the total city population. People in 18 out of 22 *thanas* were marooned at that point.

SOURCE: *The Daily Star*, 26 July 2004, Dhaka.

During the 1998 flood, 44 deep tubewells were affected by floodwater and water production was suspended in 13 of them, with an estimated loss in production of 45 million litres per day. The remaining tubewells were kept operational by adopting protection measures, including the erection of a protection wall around the pump house and raising housing pipes and electrical appliances above the floodwater levels. Five of the 13 suspended tubewells were badly damaged and required replacement.

e. Population and health

Estimating the impact of flooding on people and their health is complex due to the many dimensions of the impacts. According to available literature and information, the death toll was about 150 in the 1988 flood but the affected population was reported as about 2.2 million people.[20] Professor Hye carried out a rapid appraisal on flood-affected people during the 1998 flood, dividing the flood-affected areas into three categories: most severely affected (MSA), severely affected (SA) and moderately affected (MA). It was found that the flood displaced or dislocated 94 per cent of families in the MSA areas, about 52 per cent of families in the SA areas and 50 per cent in the MA areas. The estimate for the total flood-affected population was about 4.55 million.[21]

Floods, waterlogging and extreme temperatures affect human health, local health infrastructure and routine health care services. The prevalence of disease during extreme events such as floods increases greatly. These diseases include diarrhoea, dysentery, acute respiratory infection, fever, skin diseases and eye infections (Box 3). One study shows that 191,867 people in Dhaka were admitted to different hospitals for treatment during the 1998 flood.[22] Of these, 284 died. Another study undertaken by the Bangladesh NGO BRAC shows that 10,217 people in 10 out of 22 *thanas* had suffered from diarrhoea during the 1998 flood.[23] It should be noted that in the same month in a normal year, the figure for those affected by diarrhoea is reported to be half.

20. See reference 11.

21. Hye, Professor S A (1999), "Livelihood of flood-affected people: disruption and rehabilitation", Bangladesh Unnayan Parishad (BUP), Dhaka.

22. Kafiluddin, Dr A K M (2000), "Impact study on health", National Institute of Preventive and Social Medicine (NIPSOM), Dhaka.

23. See reference 12.

BOX 3
Flooding and the health crisis in Dhaka, 2004

A massive health crisis is looming in Bangladesh as sewage mixes with floodwaters swirling through Dhaka. CNN correspondent Satinder Bindra described the health situation there as "quite grim". He said half the city was under water, the sewerage system had broken down and the risk of waterborne disease for Dhaka's population of 10 million was very high. Naseem-Ur Rehman, chief of communications in Bangladesh for the United Nations Children's Fund (UNICEF), said the situation for children in urban areas was "extremely dangerous". "*The water in the cities is filled with filth, and the children who are playing and walking through it are vulnerable. They are easy prey to infectious diseases*", he said. The UN said sludge was gushing out of manholes in many parts of Dhaka, and diseases such as acute respiratory infection, diarrhoea, watery dysentery, jaundice, typhoid and scabies were being reported.

SOURCE: CNN.com (2004), "Flood health crisis looms in Dhaka", accessed at http://www.cnn.com/2004/WORLD/asiapcf/07/29/southasia.floods/, 29 July 2004.

f. Livelihoods

Floods hit nearly half of the total area of the city. Around 40 per cent of the population live in "slums" and squatter settlements; they draw their livelihoods from industry (e.g. garments, textiles, leather etc.), the transport sector, shopping centres, hotels and restaurants, the construction sector and as domestic workers. These people are severely affected by floods,

waterlogging and other relevant problems. A field survey conducted during the 1998 flood found that at least 7.2 per cent of people had changed their occupation while 27.4 per cent were unemployed as a result of the flood. In addition, working hours were reduced for many workers. Poorer groups always suffer more from disasters such as floods.

V. RESPONSE MEASURES

The Ministry of Environment and Forests, the Dhaka Water Supply and Sewage Authority and the Bangladesh Water Development Board have undertaken several measures to improve environmental quality and manage floods, including addressing drainage congestion. Policy decisions and different measures have also been taken to reduce greenhouse gas emissions and to improve air quality in Dhaka. Most of these measures can be considered as win–win options.

a. Responses to improve air quality in Dhaka

The government of Bangladesh has undertaken several initiatives to improve the air quality in Dhaka, including the following:

- the introduction of compressed natural gas (CNG) for transport. Recent increases in gasoline prices have pushed this further and more vehicles are being converted to CNG;
- since 2002, the banning of buses more than 20 years old and trucks more than 25 years old in Bangladesh;
- since 1 January 2003, the banning of two-stroke engine three-wheeler vehicles in Dhaka;
- a reduction in the number of non-motorized vehicles along with restrictions on their movement within certain areas of the city and during specific periods of the day. This helps to reduce traffic congestion and thus reduces the consumption or burning of fuels;
- updating and installing new traffic signals and the construction of bypasses and flyovers for smoother traffic flows;
- the introduction in 2002 of an environmental clearance certificate, mandatory for the establishment of brick fields; and
- a movement to promote the use of compact fluorescent lamps in Bangladesh. These are used quite extensively at both domestic and commercial levels and consume around one-quarter of the electricity of incandescent bulbs.

The Dhaka Transportation Coordination Board is currently preparing a strategic transport plan, which will provide a long-term strategic vision for Dhaka's transport system.

b. Flood protection measures

The first flood protection embankment along the Buriganga River was constructed in 1864 to protect the riverbank from flooding and erosion and to modernize the riverside. Launched by C T Buckland, the Commissioner

of Dhaka at the time, this scheme (known as the Buckland Bound) was completed in three phases in the 1880s.

Plans for flood protection for Greater Dhaka have been under study and consideration for many years, but the extreme flooding that occurred in 1987 and 1988 brought into focus the urgent need for immediate action. Subsequently, the government of Bangladesh prepared an urgent flood protection and drainage plan, which included enclosing the Greater Dhaka area with flood embankments, reinforced concrete walls and drainage/flood regulation structures such as sluices and pumping stations.

Construction activities started with a "crash programme" in 1989, and most of the work defined under Phase I has been completed. It provides flood protection facilities to the western half of Dhaka city, which includes the most highly urbanized areas comprising about 87 per cent of the population in 1998. Important components of the flood protection measures are:

- approximately 30 kilometres of earthen embankment along the Tongi canal and the Turag and Buriganga rivers;
- approximately 37 kilometres of raised roads and floodwalls;
- a total of 11 regulators along the embankment at the outfall of *khals* (canals) to the surrounding rivers;
- one regulator and 12 sluice gates on the *khals* at the crossings with the Biswa, DIT, Pragati Sarani and Mymensingh roads and the railway line at Uttar Khan;
- one pumping station at the outfall of the Kallyanpur *khal* into the Turag River and another at the outfall of the Dholai *khal* to the Buriganga River. These pumping stations are for draining rainwater from parts of Dhaka West; and
- there is a special 10.53-kilometre embankment surrounding the Zia International Airport.

A rail/road embankment that will run for 29 kilometres along the Balu River is proposed for the eastern part of the city. This will be constructed under Phase II of the Dhaka Integrated Flood Protection Project to protect the area between Biswa Road and the Balu River.

These flood control and drainage works have brought major changes in the flood regime of Dhaka West, including major changes in land use.

The embankment/road in the western part of Dhaka helped to protect more than 50 per cent of the city from the floods in 1998 and 2004. It saved people and property from complete inundation but it causes waterlogging or internal drainage congestion, which becomes severe during heavy rainfall. This may be due to inadequate pumping facilities and lack of proper planning and design of infrastructure. However, the lessons can be utilized in the construction of the eastern bypass, which is under consideration to protect the other half (eastern part) of the city.

c. Improvement of the drainage system

The surface drainage system is usually not very effective, even without extreme weather events, and is especially ineffective during floods. However, the banning of polythene bags has reduced the regular clogging of the city drainage system. The relevant government agencies have taken the initiative several times to recover the many canals and canal banks that are

illegally occupied by influential local people, most of them affiliated with local politics and the power structure. These recovery programmes have not been implemented fully in the past. These canals need to be recovered using any measures, to improve the city's natural drainage system. It has been reported that the Water and Sewerage Authority have recovered 15 out of the 26 canals that can still be rescued from encroachment.[24] The report also shows that Dhaka had 43 natural canals in the past, 17 of which no longer exist and can only be traced in history books. Eight of the canals were filled in to construct roads, but the rest of them are still occupied by either government or private sector buildings that had been built on top of filled-in canals.

24. *The Daily Star*, 25 September 2005, Dhaka.

d. Role of civil society organizations

During extreme events, including floods, NGOs, the business community and community-based organizations become very active with relief, recovery and rehabilitation programmes. During the 2004 flood, many individuals came forward to help flood-affected people, and NGOs have provided health and sanitation in many areas and also health services for poor pregnant women who normally do not get attention during relief operations.

VI. CONCLUSION

Cities have always been prone to disruption (such as traffic congestion) from heavy rainfall because of their large populations, high population densities and heavy concentration of businesses and other establishments. Because so many cities are on the coast and/or next to rivers, they are also severely affected by flooding. They also represent large areas of concrete, brick and asphalt, which absorb solar radiation and aggravate heatwaves. Air pollution from vehicle exhausts and industrial emissions contributes to heat and can contribute to the increased incidence of respiratory illnesses among city dwellers. Furthermore, industry, motor vehicle traffic, the heating, cooling and lighting of buildings, solid waste sites and brick kilns around the city produce a high proportion of total greenhouse gas emissions.

Dhaka has already undertaken a number of measures to improve ambient air quality. Many have been effective both in improving air quality and in reducing greenhouse gas emissions – for example, the introduction of compressed natural gas in the transport sector. But many other sectors that consume electricity have not undertaken any significant measures to improve efficiency on the demand side. There is still untapped potential and opportunity to reduce electricity consumption and thus reduce greenhouse gas emissions – for instance, by promoting energy-efficient lighting devices, using more efficient cooling systems at household and industrial levels, making changes in the transport sector and changing behaviour.

Devastating floods can cause extensive damage to the economy. Dhaka has already experienced three major floods in less than 20 years, and each has caused very serious damage to infrastructure, and significant economic loss. One of the key questions related to this is: can Dhaka afford frequent large-scale flood damage and economic losses, or should it prepare better to combat floods and reduce impacts and vulnerabilities?

Another important issue concerns the adverse impacts of climate change, which will not only affect Dhaka directly but will also have indirect effects in other parts of the country, particularly as a result of floods, riverbank erosion and cyclones. If these destroy or damage people's livelihoods, it is likely that rural–urban migration will increase and that more people will migrate to Dhaka.

To protect Dhaka from river floods, a flood protection embankment has been constructed on the western side and a comparable embankment is under consideration for the eastern side. The southeastern part of the megacity is protected by the Dhaka–Nayrayangong–Demra flood protection embankment. Recent erratic rainfall brought unusual urban flooding as a result of drainage congestion and inadequate facilities for pumping water from inside the embankment. This raises the question: are the existing flood management measures adequate to address future flooding, which is anticipated to be more frequent and intense? Thus, spatial planning for unbuilt areas of Dhaka should incorporate aspects of climate change and should include all necessary measures. It is also necessary to make changes to the design of the embankment/road and allow for adequate pumping systems to drain rainwater from the city – and overall, to adapt to allow Dhaka to cope with the changes in intensity and pattern of rainfall under a warmer climate.

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