Asian Journal of Water, Environment and Pollution, Vol. 9, No. 2 (2012), pp. 1–9.

Impact of Land Use and Urbanization Activities on Water Quality of the Mega City, Dhaka

A.M.M. Maruf Hossain* and Shafiqur Rahman[1]

Department of Environmental Science and Engineering, Gwangju Institute of Science and Technology (GIST)
Buk-gu Gwangju 500-712, Gwangju, Republic of Korea
[1]Department of Soil, Water and Environment, Faculty of Biological Sciences
University of Dhaka, Dhaka – 1000, Bangladesh
✉ mueed_abd@yahoo.com

Received September 28, 2010; revised and accepted March 20, 2012

Abstract: The capital of Bangladesh, Dhaka, is a mega city with around 12 million people in 2006. Its urban growth rate is one of the fastest in the world. The city is surrounded by four rivers with well distributed streams and drainage channels as well as inlands and open water bodies. The chemical and biological environments of these water bodies profoundly influence the inhabitants' life in numerous ways. Agriculture, economy, health, as well as expansion of the city are influenced by the environment of these water bodies. The untreated domestic sewage and uncontrolled industrial discharges are turning the water quality from bad to worse. Groundwater storage is on the verge of great threat because of increasing pollution of the surface water. Ecological balance of these water streams is facing serious threat due to pollution with severely limiting fish growth. Unplanned urbanization and industrialization in the city are contributing largely to all the problems regarding water environment. Seasonal open water bodies are still considered suitable for development of fishery and aesthetic applications. Development activities are required to ensure various environments of water bodies safe and sustained, and regulations are needed to be imposed to protect these environments.

Key words: Dhaka mega-city, water quality, water management.

Introduction

Long ago, Dhaka was founded as a provincial capital in 1608. However, during the last four centuries, its importance has gone through a series of ups and downs. With its emergence as the capital of Bangladesh as the independent country in 1971, it is witnessing one of the fastest growths in population (around 5% per year) among mega cities in the world. The population has grown from around half a million in 1965 to more than 12 million in 2006. It is predicted that the population will grow to more than 20 million around the year 2015 (Choudhury, 2007).

The city of Dhaka is surrounded by four rivers, Balu, Tongi, Turag and Buriganga. The drainage of the city is mostly dependent on the water levels of the peripheral rivers. The drainage channels are well distributed over the city, which collect catchment runoff as well as wastewater and drain to the peripheral rivers. There are also several permanent lakes as well as stored flood waters comprising seasonal water bodies during monsoon.

The mega cities of the world are now facing great challenges of sustainability due to their enormously bigger dimensions than in cities. Water and waterbodies would count for one of the foremost subjects to be challenged. Pollution and scarcity of water needs to be addressed seriously to ensure sustainability of city and city-life. Therefore, studying the impacts of land use and

*Corresponding Author

urbanization activities, which may count for the largest source of anthropogenic activities, threatening water and waterbodies of the mega cities, warrants greater significance. This paper attempts to investigate the impacts of land use and urbanization activities on water quality of Dhaka. The adverse impacts would in turn profoundly influence the inhabitants' life and the ecosystems in numerous ways.

Pollution of the Water Bodies

The main chemical, physical and microbial factors that may be involved in polluting water bodies, thus deteriorating water quality around Dhaka, include:

1. Organic pollutants, which easily decompose in water and consume dissolved oxygen, resulting in depletion of fish population and ultimately leads to eutrophication. They mainly originate from industrial wastewater and domestic sewage, as well as from seepage of old and new landfills.
2. Nutrients include mainly phosphate and nitrate, and their increased concentration can lead to eutrophication. These originate from human and animal waste, detergents and run-off from agricultural fertilizers.
3. Heavy metals which tend to be localized around industrial and mining centres.
4. Microbial contamination from bacteria such as *Escherichia coli*, protists and amoebae that come from untreated sewage as well as animal husbandry.
5. Toxic organic compounds comprise industrial chemicals, plastics, dioxins, agricultural pesticides, oil and petroleum (group of hydrocarbons), and polycyclic hydrocarbons generated from burning of fuel. Many persistent organic pollutants (POPs) are difficult and costly to analyze and monitor. Therefore their potential effects on humans are difficult to establish (Nixon et al., 2000).
6. Traces of chemicals and pharmaceutical drugs from medical waste are hazardous substances that are not necessarily removed by conventional drinking water treatment processes. They are now being recognized as carcinogens and endocrine disrupters and pose a great threat to water quality (Cosgrove and Rijsberman, 2000).
7. Suspended particles, either inorganic or organic, originating mainly from agricultural practices and land use change such as deforestation, and conversion to pasture at slopes leading to erosion.
8. Acidification due to sulfuric deposition produced by industrial activity and also urban emissions.

The organic pollutants can be both biodegradable and non-biodegradable in nature. The biodegradable organic components degrade water quality during decomposition by depleting dissolved oxygen. The non-biodegradable organic components persist in the water system for a long time and pass into the food chain (Ahmed and Reazuddin, 2000). Inorganic pollutants are mostly metallic salts, and basic and acidic compounds. These inorganic components undergo different chemical and biochemical interactions in the river system, and deteriorate water quality.

Industrial Pollution

There are three designated industrial zones within the city corporation area, viz., Hazaribagh, Tejgaon and Shyampur. Different types of industries including tannery, dyeing and textile, printing, metals, rubber, chemicals and pesticides, battery, distillery, plastics, brick manufacturing, jute, etc., are a few mentionable ones. A number of industries or factories are also scattered around the city. In addition, nearly 2000 garment factories have been established within the city area during the last two decades.

The most problematic industries for the water sector are textiles, tanneries, pulp and paper mills, fertilizer, industrial chemical production and refineries. A complex mixture of hazardous chemicals, both organic and inorganic, is discharged into the water bodies from all these industries usually without treatment. Concerns over surface water quality are gradually merging due to the dispersed locations of polluting industries, and the adverse effect on surrounding land and aquatic ecosystems, as well as subsequent impact on the livelihood system of the local community. The extreme examples of this type of effect are near Dhaka at Konabari and Savar, where industrial effluents are discharged into nearby land and water bodies without any treatment.

Among the polluted areas, the worst problems are in the river Buriganga, where the most significant source of pollution appears to be from tanneries in Hazaribagh area. In dry season, the dissolved oxygen level becomes very low or non-existent and the river becomes toxic (WARPO, 1999). The seasonal variation of water quality in the Buriganga is linked with seasonal variation of water flow and the operation of tanneries. The recent construction of the nearby flood protection embankment, whilst concentrating the effluent near the works, may have the possible advantage of restricting the wider dispersion of this heavy pollution.

Water of the river Balu is badly contaminated by urban and industrial wastes from Tongi and the effluent flowing out through the Begunbari *Khal*, most of which emanates from the Tejgaon industrial area in Dhaka. In the rivers Balu and Turag, water quality in the dry season becomes worse, with dissolved oxygen (DO) concentrations becoming almost zero (Saad, 2000).

Pollution of Waters due to Use of Agrochemicals

The main suspected sources of agricultural runoff pollution are from the use of fertilizers and agrochemicals, including herbicides and pesticides. Urea, triple super phosphate (TSP), muriate of potash (MP) and gypsum are the major chemical fertilizers used. With the increase of irrigated areas and cultivation of high yield variety (HYV) rice, there is increase in fertilizer use. Pesticide use was introduced in Bangladesh in 1957. Insecticide is commonly used for pest control, which accounts for about 90 per cent of the total consumed pesticide (BBS, 1998).

Fecal Pollution of Surface and Groundwater

There is one sewage treatment plant in the whole country, serving only a part of Dhaka. A major programme for provision of sewerage is needed to arrest the increasing fecal pollution of open watercourses around all urban areas in Bangladesh, particularly Dhaka. In some areas, annual flooding is also a problem for adequately designing sealed latrine system. Moreover, poor management of wellhead areas may be the most significant source of fecal contamination rather than direct aquifer pollution. More than two-thirds of the city sewage is falling into rivers garlanding the city, thereby causing deterioration of these waters for decades (*The Daily Star*, 2008b).

The area and type of current sanitation coverage of Dhaka city is as follows (*The Daily Star*, 2003).

- Conventional water-borne sewerage system (30%)
- Separate sewerage system (20%)
- Septic tank (11%)
- Pit sanitation (18%)
- The remaining population in Dhaka do not have any form of acceptable sanitary disposal system.

Baridhara and Uttara are environmentally less polluted than Gulshan and Dhanmondi as the former do not have water-borne sewerage whereas the latter have. At many points of the existing trunk sewerage lines from Tejgaon to Pagla either have leakage or are damaged or broken; therefore, no planning would be feasible without replacing the entire Tejgaon-Pagla trunk line. A World Bank study shows that a modern water-borne waste disposal system, to replace the current one will cost US $300 per city dweller (*The Daily Star*, 2003). WASA has already found microbial contamination of ground water in old Dhaka (UNEP, 2005).

Trend in the Pollution of Water Bodies

River Pollution

The contamination picture of river water around Dhaka city for the dry season of 1980-1997 is presented in Table 1 (Rahman, 2004).

From Table 1, it can be seen that:

- DO value was much lower in 1997 than in 1980 in Buriganga and Balu than the standard.
- Number of coliform bacteria was very much high in the rivers.
- Orthophosphate was very high, NO_3^- was high except Tongi/Turag, and NH_4^+ was within the range.
- Al content was many times higher than the standard.
- Cd content was slightly above the standard.
- Cr content in Buriganga and Turag was much higher than the standard.
- Pb and Hg contents were above the standard.

An international study regarding river water pollution of three countries reveals that the Buriganga river was suffering from severe pollution. The dry season average biochemical oxygen demand (BOD) ranged between 20-30 mg/l while the total coliform was as high as 104-105 MPN/100 ml. Per capita pollution load discharge of urban areas has been estimated to be about 25 g BOD/capita/day in Buriganga river. The analysis reveals that pollution loads are steadily increasing nearly in step with the trend in urbanization. The DO level of Buriganga river is declining at an average annual rate of nearly 0.3 mg/litre/year (Karn and Harada, 2001).

Some studies conducted in 2003-2004 reveal a very poor condition of Dhaka surface water, especially in the dry season (World Bank, 2006). For some six months of the year, the flow rate of the rivers is negligible, often with only a tidal pulse, but the volume of effluent entering the canal and river system remains about the same as during the wet season. Consequently, dilution of contaminants is drastically reduced in the dry season. Table 2 and Figure 1 (World Bank, 2006) represent the contamination scenario and the pollution hotspots of water bodies around Dhaka city.

The level of pollution in the Buriganga and most parts of Turag river is so high that no living organism can survive in these waters other than some invertebrates and small organisms during high water flow in rainy season (*The Daily Star*, 2008a). The DO levels of those rivers

Table 1: Contamination of river water around Dhaka city for the period of 1980-1997

Parameters	*Year of measurement*	*Buriganga River*	*Tongi /Turag River*	*Balu River*	*Standard**
pH	1980		6.5 – 8.5		
	1997				
DO, mg/l	1980	2.8 – 4.2	3.1 – 3.3	4.2 – 6.1	≥ 4
	1997	0.1 – 1.0	4.8 – 5.6	0.2 – 1.6	
Coliform bacteria, cfu/100 ml	1980	1000 – 14000	1000 – 6000	NA	5000
	1997	3000 – 910000	29000 – 80000	8500 – 203000	
NH_4^+, mg/l	1980	NA	NA	NA	0 – 1.5
	1997	0.04 – 0.20	NA	0.20 – 0.30	
NO_3^-, mg/l	1980	NA	NA	NA	0 – 1.5
	1997	0.10 – 2.40	0.50 – 0.80	0.60 – 1.60	
Orthophosphate, mg/l	1980	NA	NA	NA	0 – 0.01
	1997	0.57 – 4.45	1.59 – 2.10	1.16 – 8.76	
Al, mg/l	1980	NA	NA	NA	0.2
	1997	3.26 – 5.40	11.884	2.166	
Cd, mg/l	1980	NA	NA	NA	0.005
	1997	0.006 – 0.014	0.018	0.006	
Cr, mg/l	1980	NA	NA	NA	0.05
	1997	0.006 – 0.232	0.11	0.0224	
Pb, mg/l	1980	NA	NA	NA	0.05
	1997	ND – 0.47	0.394	ND	
Hg, mg/l	1980	NA	NA	NA	0.001
	1997	0.0016 – 0.0033	0.0058	0.001	
Se, mg/l	1980	NA	NA	NA	0.01
	1997	ND – 0.001	0.0002	ND	
Zn, mg/l	1980	NA	NA	NA	5
	1997	0.406 – 0.984	1.005	1.122	

NA = Not Available, ND = Not Detected, * = Standard range or allowable value for the parameters (DoE, 1991)
Source: Rahman, 2004

were also found to be less than 1 mg/l even after the monsoon while a level of 4-6 mg/l is required for fish survival.

Pollution of Storm Water, Catchments and Lakes in Dhaka as Interconnected with one another

Runoff from urban areas as a result of rainfall is generally higher than those from rural areas. This is because urban area has many impervious surfaces, e.g., roofs of houses, paved roads and parking lots, etc. It is also found that runoff ratios in commercial areas are much higher than those in residential areas (Chowdhury et al., 1998).

Storm water in Dhaka city is polluted in several ways. The primary concern is the unauthorized connection of domestic sewers with the storm sewers and with the receiving water bodies. Other causes of relatively high level of pollution in storm water include dumping of wastes beside the roads, near the receiving water bodies, and open surface drains. Apart from hampering the drainage, these wastes cause significant increase in the level of pollution in storm water. Khan and Chowdhury (1997) reported relatively high total coliform count (1.20 × 10^4 to 1.96 × 10^8 per 100 ml) in storm water. Among different land uses coliform counts were higher in residential areas. Relatively high BOD_5 values (96.1 mg/l to 142.6 mg/l) were also found, and among some other parameters TSS, TDS, NO_3^- and NO_2^- were found as 640 to 3643 mg/l, 219 to 602 mg/l, 6.0 to 12.0 mg/l and 1.1 to 2.1 mg/l, respectively.

Storm runoff generated from the catchment areas carry significant amount of pollutants. However, the major concern is high sediment load washed away from construction sites. The level of pollution in the storm water and in the receiving water bodies is generally a matter of concern. Sometimes the level of pollution is comparable with that of domestic waste water. This is probably one of the reasons for the deteriorating quality of river water around Dhaka city (Khan and Chowdhury, 1997).

Table 2: Water quality in the river and canal system around Dhaka, 2003-04

Location	*Season*	*Water layer*	*Parameter (all mg/l)*				
			Total dissolved solids	*Dissolved oxygen*	*Biological oxygen demand*	*Chemical oxygen demand*	*Ammonia*
Postogola (Buriganga River)	Dry	surface	**319**	**2.3**	**29.9**	**82.7**	**7.4**
		bottom	**319**	**2.0**	**35.4**	**113.3**	**7.3**
	Wet	surface	69	8.3	0.9	**67.3**	0.4
		bottom	66	8.5	0.9	**76.0**	0.4
Balu River	Dry	surface	**257**	**2.1**	**28.0**	**151.7**	**6.7**
		bottom	**258**	**1.6**	**30.5**	**215.3**	**6.7**
	Wet	surface	76	6.4	1.4	**81.3**	0.7
		bottom	71	6.4	1.1	**62.7**	0.7
Ashulia (Turag River)	Dry	surface	**326**	6.4	**5.1**	**98.7**	**2.2**
		bottom	**344**	6.6	4.5	**85.3**	1.6
	Wet	surface	62	8.2	0.9	58.0	0.4
		bottom	59	8.0	0.7	**60.7**	**0.3**
Uttar Khal	Dry	surface	**356**	7.3	**12.1**	41.7	**4.5**
		bottom	**376**	7.9	12.0	54.0	4.2
	Wet	surface	53	8.0	0.8	52.7	0.4
		bottom	62	8.1	0.7	44.0	0.3
Dholai Khal (Dhaka East)	Dry	surface	**396**	**2.4**	**77.7**	**167.8**	**20.8**
		bottom	**388**	**2.3**	**94.9**	**199.0**	**19.5**
	Wet	surface	-	-	-	-	-
		bottom	-	-	-	-	-
Begunbari Khal (Dhaka East)	Dry	surface	**386**	**2.1**	**75.9**	**187.5**	**24.4**
		bottom	**385**	**2.4**	**71.2**	**163.3**	**21.8**
	Wet	surface	-	-	-	-	-
		bottom	-	-	-	-	-
Norai Khal (Dhaka East)	Dry	surface	**343**	**2.6**	**54.8**	**137.9**	**21.5**
		bottom	**316**	**2.9**	**53.9**	**135.1**	**22.0**
	Wet	surface	-	-	-	-	-
		bottom	-	-	-	-	-
Saidabad Beel (Dhaka East)	Dry	surface	**179**	5.3	**11.0**	**64.8**	**2.2**
		bottom	**181**	5.8	**10.2**	**65.8**	**2.3**
	Wet	surface	-	-	-	-	-
		bottom	-	-	-	-	-
Hot spots (contaminated water) indicated as follows:			**>100**	**<5**	**<5**	**>60**	**>1**

World Bank, 2006

Rahman and Chowdhury (1999) studied water quality of three catchments of Dhaka, namely, Elephant Road – top, Elephant Road – middle, and Zigatola. Water samples collected from 13 rainfall events produced BOD values of 12-180 mg/l and 19-199 mg/l, and TDS values of 50-330 mg/l and 110-1360 mg/l, for Elephant Road and Zigatola catchments respectively. The pollutant load in Zigatola was higher because tannery wastes from nearby Hazaribagh area are transported through Zigatola trunk. The concentrations of different constituents from the catchments were very high compared to the secondary effluent treatment standard, which is only 30 mg/l for BOD. This shows the need for appropriate waste management practice and treatment facilities for urban storm runoff in Dhaka city.

Hossain et al. (2001) showed pollution of Dhanmondi Lake due to pollution in Satmosjid Road catchment. Satmosjid Road catchment has hydraulic connection with the Dhanmondi Lake. Almost one-third of the storm runoff goes into the lake. The storm sewer samples (157 samples) produced varying pH values of 7.4-8.7, BOD_5 of 98-180 mg/l, DO of only 1.1-2.8 mg/l, and maximum TDS and TSS values of 627-2094 mg/l and 725-4005 mg/l, respectively. Pollution of lake water was likely, as

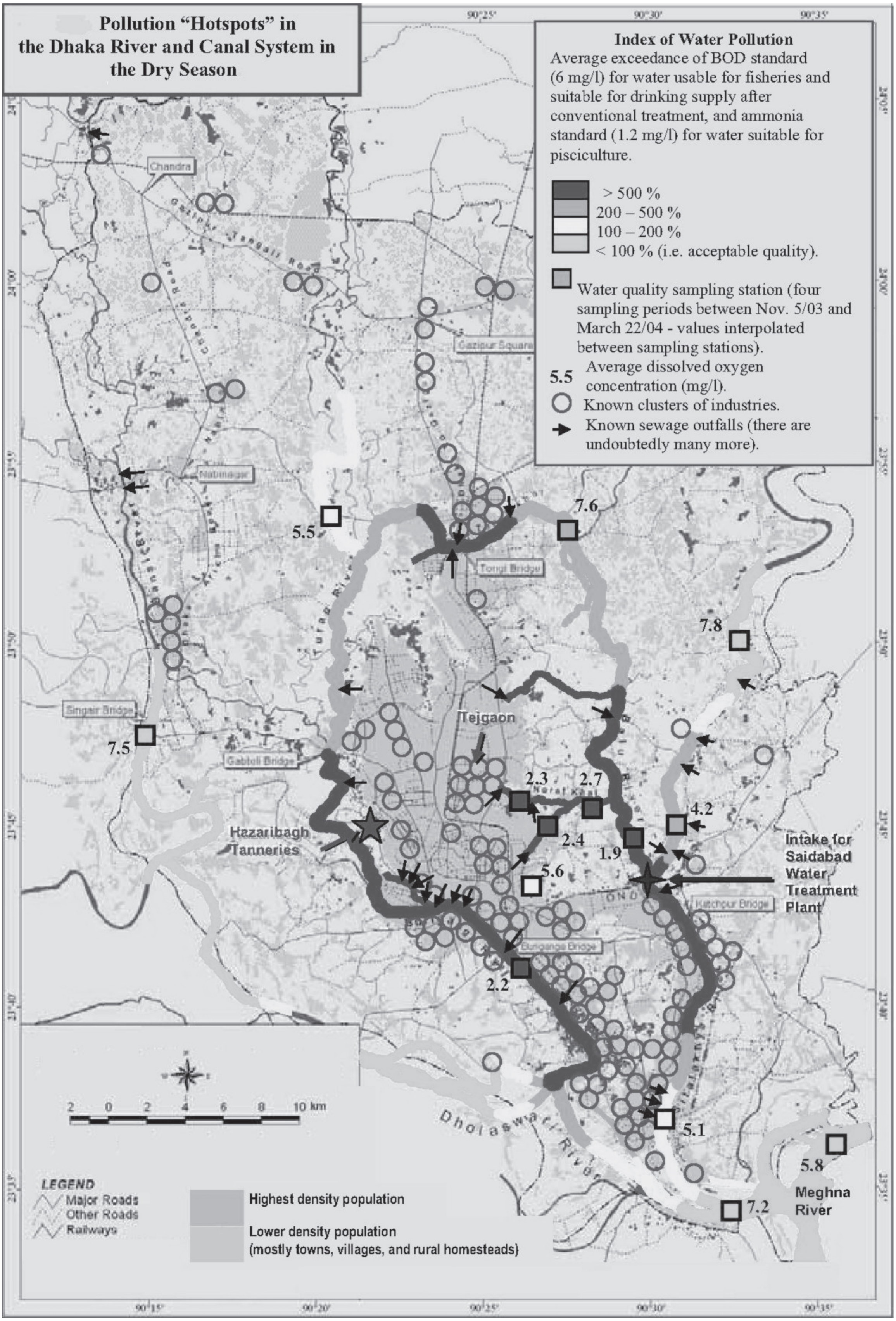

Figure 1: Pollution "Hotspots" in the Dhaka river and canal system in the dry season (World Bank, 2006).

presence of tannery waste was observed in the water flowing from the sewer to the lake (Hossain et al., 2001). In one sense, storage of the storm water in the Dhanmondi Lake has reduced the risk of overflow of storm sewer in the area adjacent to Satmosjid Road. But on the other hand, the lake water is being contaminated by tannery wastes and is a threat to the lake environment. Information on other catchments in this regard are scarce.

Hazaribagh Tannery Area and Its Impact on Water Bodies

As per UNIDO's (United Nations Industrial Development Organization) estimation, about 5000 tons of municipal solid wastes and nearly 750 tons of BOD were generated everyday in 2000 in Dhaka city where only 120 tons were guided through DWASA's (Dhaka Water Supply and Sewerage Authority) sewerage network for treatment (UNIDO, 2000). The rest uncontrolled dumping of huge industrial wastes of point and non-point sources could be extremely hazardous when the pollutants are heavy metals and cannot be treated easily by conventional methods. The tannery industries of Hazaribagh are such point sources of the city environment. The over 50 years old tannery complex is discharging its solid wastes and effluents directly to the natural canals, in low lying areas, along road sides, and water bodies between the dike and residential area without proper treatment. They seep into the soil to pollute groundwater and carry through natural canals, and ultimately mixed with the river water of Buriganga and Turag.

The tanning industries of Hazaribagh are processing some 220 metric tons of hide a day with an associated release of 40-50 litres of liquid effluent for each kilogram and 600-1000 kg of solid waste resulting from production of each metric ton processed hide (Zahid et al., 2004). Large amounts of chrome powder and chrome liquor are used during tanning process. Some 47% collagen and 85% chemicals enter the waste streams as effluent (UNIDO, 2000). Hossain et al. (2007) reported that the maximum chromium content of the solid waste was found to be 3.2%. Zahid et al. (2004) reported that chromium concentration in effluents and canal water was 4.06 ppm and 0.443 ppm, respectively; whereas suspended materials in effluents and canal water contained as high as 2.88% and 2.02%. It is estimated that some 15,800 m^3 waste water is produced in a day which has 17,600 kg BOD load. Chromium is found to be very high as the tanning process requires huge amount of chromium for chrome tanning. Other than the chromium, higher concentrations of Fe, Mn, S, Ni, Pb, Na^+, Mg^{2+}, Ca^{2+}, NH_4^+, K^+, Cl^- and SO_4^{2-} have also been reported. All these are affecting surface as well as groundwater quality of Dhaka city.

Groundwater Depletion of Dhaka City

The DWASA (Dhaka Water Supply and Sewerage Authority) is responsible for the city's water supply. In 1995, the total water requirement of the city was 262 IMGD (Imperial Million Gallons per day), of which DWASA was only supplying 181 IMGD. The 89% of the supplied water was withdrawn from groundwater source and the rest 11% supplied from surface water treatment plant (IFCDR, 1996). It has been predicted that the total demand of the city will increase to 534 IMGD by the year 2020, which would be totally impossible by depending on groundwater only. Presently groundwater is the main source of potable water supply for domestic and industrial uses of Dhaka metropolitan. As surface water near the city is becoming increasingly polluted and costly to purify, public water utilities and other urban water users have turned to groundwater as potential source of cheaper and safer supply. In 1995, 96% of the total water use was abstracted from underground sources (IFCDR, 1996).

Suitability of Seasonal Open Water of Dhaka for Fishery

Khan et al. (2007) reported about the suitability of stored monsoon waters in a seasonal open water body of Ashulia for economic as well as aesthetic applications. During monsoon the water body keeps definite relation with the Turag River system. A total of 27 physical, chemical and biological aspects of the water body had been studied for suitability assessment for consecutive six months during 2006, among which sulphur deficiency was noticed. All other parameters were found suitable except slight excess in copper among the heavy metals. It was concluded that the water was suitable for fisheries if sulphur can be managed and also suitable for aesthetic infra-structure development. Aesthetic infrastructural development with the existing ones can reinforce economy of the region as well as provide recreational facility for city dwellers.

Conclusion

At the 1992 Rio Earth Summit, the main expressed problems affecting water quality and aquatic ecosystems were untreated domestic sewage, uncontrolled industrial discharges, deforestation and poor agricultural practices resulting in soil erosion and leaching of nutrients and pesticides. Public awareness regarding the protection of the freshwater resources as well as monitoring of the ecological and human health effects were also considered inadequate. The water bodies around Dhaka city are no exception from this. Unplanned urbanization and industrialization occurring in the city are largely responsible for this grave situation. Inadequate sewerage, on-site sanitation and wastewater treatment facilities in one hand, and lack of effective pollution control measures and their strict enforcement on the other are the major causes of rampant discharge of pollutants in the aquatic systems.

Water Policy of Bangladesh (Ministry of Water Resources, 1999) recognizes the need to frame rules, procedures and guidelines for combining water and land use planning, and stresses the need for water development and management to include restoration and preservation of the environment and biodiversity. Water and land management decisions need to take into account the contribution to alleviating poverty, supporting livelihoods, strengthening economy and sustaining ecosystems in order to make progress towards sustainable development.

References

Ahmed, A.U. and M. Reazuddin (2000). Industrial pollution of water systems in Bangladesh. *In:* Rahman, A.A. Huq, S. and Conway, G.R. (eds) Environmental Aspects of Surface Water Systems of Bangladesh. University Press Limited, Dhaka, Bangladesh.

BBS (1998). Statistical year book of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning, Dhaka, Bangladesh.

Choudhury, J.R. (2007). Urbanization and megacity risks: The Dhaka city scenario. Presented in 'Forum DKKV/CEDIM: Disaster Reduction in Climate Change', Karlsruhe University, Germany.

Chowdhury, J.U., Rahman, R., Bala, S.K. and A.K.M.S. Islam (1998). Impact of 1998 flood on Dhaka city and performance of flood control works. Report, IFCDR (at present IWFM), BUET, Dhaka, Bangladesh.

Cosgrove, W.J. and F.R. Rijsberman (2000). World water vision: Making Water Everybody's Business. Earthscan, London.

DoE (1991). Environmental water quality standard. Department of Environment, Government of Bangladesh, Dhaka, Bangladesh.

Hossain, A.M.M.M., Monir, T., Rezwan Ul Haque, A.M., Kazi, M.A.I., Islam, M.S. and S.F. Elahi (2007). Heavy metal concentration in tannery solid wastes used as poultry feed and the ecotoxicological consequences. *Bangladesh J. Sci. Ind. Res*., **42(4):** 397-416.

Hossain, M.S.A., Chowdhury, J.U. and M.R. Rahman (2001). Storm drainage in Satmosjid area of Dhaka city and pollution of Dhanmondi Lake. *IFCDR Research Bulletin* (presently Institute of Water and Flood Management, IWFM, BUET, Dhaka, Bangladesh), **2(1):** 22-30.

IFCDR (1996). An evaluation of Dhaka city groundwater conditions. Institute of Flood Control and Drainage Research (at present Institute of Water and Flood Management), BUET, Dhaka, Bangladesh.

Karn, S.K. and H. Harada (2001). Surface water pollution in three urban territories of Nepal, India and Bangladesh. *Environmental Management*, **28(4):** 483-496.

Khan, M.A.I., Hossain, A.M.M.M., Huda, M.E., Islam, M.S. and S.F. Elahi (2007). Physico-chemical and biological aspects of monsoon waters of Ashulia for economic and aesthetic applications: Preliminary Studies. *Bangladesh J. Sci. Ind. Res*., **42(4):** 377-396.

Khan, M.S.A. and J.U. Chowdhury (1997). An overview of storm water quality in Dhaka city. IFCDR (presently Institute of Water and Flood Management, IWFM), BUET, Dhaka, Bangladesh.

Ministry of Water Resources (1999). National water policy. Government of the People's Republic of Bangladesh.

Nixon, S.C., Lack, T.J., Hung, D.T.E., Lallana, C. and A.F. Boschet (2000). Sustainable use of Europe's water. Environmental Assessment Series, no. 7, Copenhagen, EEA.

Rahman, A.T.M.A. (2004). Present status of surface water and groundwater conditions in Dhaka city. *In:* Hassan, M.Q. (ed.) Water Resources Management and Development in Dhaka City. Goethe-Institut, Dhaka.

Rahman, R. and J.U. Chowdhury (1999). Dhaka city water quality assessment, Technical Report 2. IFCDR (presently Institute of Water and Flood Management, IWFM), BUET, Dhaka, Bangladesh.

Saad, M.S. (2000). Personal Communication. SWMC (at present Institute of Water Modelling), Dhaka, Bangladesh.

The Daily Star (2003). July 13 issue. Dhaka, online version at http://www.thedailystar.net

The Daily Star (2008a). June 15 issue. Dhaka, online version at http://www.thedailystar.net

The Daily Star (2008b). July 11 issue. Dhaka, online version available at http://www.thedailystar.net

UNEP (United Nations Environment Programme) (2005). Dhaka city state of environment: 2005. Available at http://www.rrcap.unep. org/pub/soe/dhakasoe05.cfm

UNIDO (United Nations Industrial Development Organization) (2000). Regional programme for pollution control in the tanning industry in south-east Asia: Chrome balance in leather processing. Prepared by J. Ludvik.

WARPO (Water Resources Planning Organization) (1999). Topic Paper 4, National water management plan project. Ministry of Water Resource, Government of Bangladesh.

World Bank (2006). Bangladesh: country environmental analysis. Bangladesh Development Series Paper No. 12. The World Bank Office, Dhaka.

Zahid, A., Balke, K.D., Hassan, M.Q. and M. Flegr (2004). Distribution of heavy metals in tannery effluent and their influence on sediments of Hazaribagh leather processing zone, Dhaka. *In:* Hassan, M.Q. (ed.) Water Resources Management and Development in Dhaka City. Goethe-Institut, Dhaka.

Asian Journal of Water, Environment and Pollution

Volume 8 Number 1 **January – March, 2011**

Contents