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Pollution of water bodies within and around Dhaka city: the Case of Gulshan lake

Md. Ibrahim Sabit[1] and Muhammad Ashraf Ali[2]

[1]Titas Gas Transmission and Distribution Company Limited, Kawran Bazar, Dhaka 1000
[2]Department of Civil Engineering
Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh

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Abstract

Gulshan Lake is the northernmost lake in a chain of water bodies in Dhaka (Gulshan Lake, Hatirjheel, Begunbari Khal, Balu River and Shitalakhya River), all suffering from serious pollution, due to encroachment, disposal of untreated wastewater and dumping of solid wastes. The types of outfalls contributing to the pollution of Gulshan Lake include (i) Storm sewers, (ii) Open channels, (iii) Box culverts, and (iv) Small private outfalls. A total of 102 outfalls have been identified in the Lake, which included 24 major (diameter/ size min. 24 inch or significant flow) outfalls. Outfall discharges are characterized by high concentrations of BOD5 (56-160 mg/l), COD (129-188 mg/l), Ammonia (16-28 mg/l), and Phosphate (3.55-13.4 mg/l). Water quality monitoring of Gulshan Lake showed fluctuations in chemical composition of Lake water, both spatially and temporally. The Lake water has been characterized by very low DO (mostly below 2 mg/l), and high fecal coliform (FC), BOD5 (up to 46.0 mg/l) and COD (up to 130 mg/l), indicating significant fecal and organic pollution. A trend of decreasing DO and increasing BOD with the advancement of dry season was observed. The Lake water has been found to contain high concentration of nutrients (10 to 20 mg/l ammonia; up to 8.55 mg/l phosphate) during dry season. Color, TDS and Ammonia showed the most significant seasonal variation; EC and phosphate showed significant spatial variation, with increasing concentration towards downstream. The Lake sediments have high concentrations of Cadmium and Lead, and very high oxygen demand (pSOD), which may be responsible for persistent low DO in Lake water. The inability of the city authority to separate domestic and storm sewer networks is causing serious pollution of not only Gulshan Lake, but all Lakes and water bodies within the city and the rivers surrounding the city. Discharge of untreated effluent, solid wastes and sludge (including fecal sludge) into storm sewer network is aggravating the pollution scenario. A comprehensive Lake management plan, including development of domestic sewer network in the Gulshan Lake watershed areas, is urgently needed to save the Lake.

Keywords: Gulshan Lake, Water Quality, Outfalls, Dissolve Oxygen, Sediment, Metal, pSOD

1. Introduction

Dhaka, with an estimated population of over 16 million, is the largest city in Bangladesh and the 8th largest city in the world. Dhaka is also one of the world's most densely populated cities. Rapid population growth together with unplanned urban development and industrial activities within the city has put tremendous pressure on its environment. Dhaka is surrounded by five rivers – Buriganga, Turag, Sitalakhya, Balu, and Tongikhal. Besides, there used to be large number of khals (canals) and lakes crisscrossing the city, which were hydraulically connected to the surrounding rivers. The khals and lakes within the city serve the very important hydraulic function of retaining and draining storm water during the rainy season. However, due to encroachment and filling up by vested quarters, many of these natural khals have completely disappeared, while others are under severe threat. This practice has given rise to significant water logging and drainage congestion within the city. On top of that, poor storm water and wastewater management has severely polluted the water bodies both within and surrounding the city. Sewerage system covers only a small part (less than 20%) of Dhaka city, and there is only one municipal sewage treatment plant for the entire city. With increase in population density, the onsite sanitation system (primarily septic tank system, which relies on infiltration capacity of soil) also does not perform well, especially during the wet season. As a result, over the years, direct disposal of domestic (as well as non-residential) wastewater into storm water drainage network and open khals/canals/drains has become a common practice. Thus, the storm sewers and drains carry domestic/ non-residential sewage throughout the year, and mixture of sewage and storm water during the rainy season. The storm sewer networks in Dhaka are designed to discharge into khals and lakes within the city, from where the storm water drains into the surrounding rivers either by gravity (on the eastern side of the city) or by pumping (western side of the city). As a result, the khals and lakes within the city and the rivers surrounding it are continuously being polluted by sewage. Domestic sewage accounts for about 40% of total waste load discharging into the surrounding rivers, while industrial sources (primarily comprising untreated effluent from textile dyeing, tannery and other industries) account for the remaining 60% (IWM, 2007).

The Gulshan Lake lies in the central Dhaka metropolitan area, and is among the largest lakes in the city (Fig. 1). It serves the very important hydrologic functions of draining and detaining storm sewer from exclusive VIP zone of Dhaka city. It is also used for pisciculture. Its northern end is located just to the south of Baridhara DOHS area, from where it stretches along the eastern side of the Gulshan Avenue and Tejgaon-Gulshan Link Road up to the Hatirjheel near Gulshan Shooting Complex. Badda area and Pragati Sharani are located on the eastern side of the Lake. Gulshan Lake is composed of four major segments, stretching from north to south. These are: (i) from just south to Baridhara DOHS area to Madani Avenue (Gulshan 1-Badda Police station link road), (ii) from Madani Avenue to Bayjid road (near Manarat Dhaka International College), (iii) from Bayjid Road to South Avenue (Gulshan-Badda Link road), and (iv) from South Avenue to Gulshan Shooting Complex (Fig. 1).

Gulshan Lake receives sewage from domestic and commercial establishments located in the surrounding areas. In the absence of separate domestic sewer networks, storm sewers and drains also carry sewage from surrounding areas and eventually discharge into the Lake. According to press reports, more than 12,000 cubic meters of untreated toxic chemical and human wastes from Tejgaon, Badda, and Pragati Sharani are dumped every day into the Lake. A number of past studies have reported significant contamination of water and sediment of Gulshan Lake (Chowdhury et al., 1998; Ahmed et al., 2005; Samad, 2009; Quaraishi et al., 2010). Samad (2009) reported that the quality of Gulshan Lake water during dry season at a point close to its confluence with Hatirjheel resembled that of domestic sewage, with very high BOD (120 mg/l), COD (197 mg/l), ammonia (22.85 mg/l), and very low Dissolved Oxygen (0.14 mg/l). Incidences of fish kill are quite common in different segments of Gulshan Lake; a major fish-kill incidence occurred in 2002. Considering the sensitive nature of the water body and the level of pollution, Gulshan Lake was declared an Ecologically Critical Area (ECA) in 2001; but little has been done to prevent continuous pollution of the Lake.

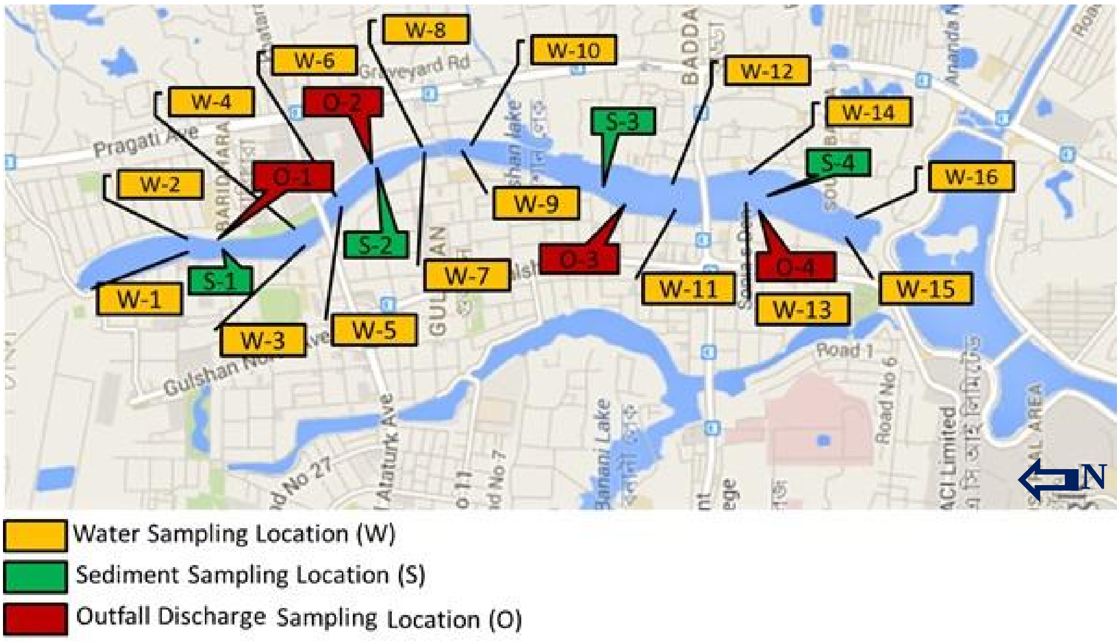

Fig. 1. A view of Gulshan Lake showing sampling locations

The major objectives of this study were to assess the characteristics of water and sediment of Gulshan Lake and identify its major pollution sources. As a part of this study, all outfalls discharging into Gulshan Lake have been identified; discharges at selected major outfalls were also characterized. Water quality of the Lake was assessed through periodic monitoring at selected locations; sediment quality was also assessed at selected locations. This study highlights the continued pollution of water bodies in Dhaka city due to unwise practice of storm water and wastewater management and suggests ways for improving the situation.

2. Materials and Methods

2.1 Outfall Identification

A number of storm sewer outfalls, carrying both storm water and domestic sewage, discharge into Gulshan Lake. These and other outfalls also bring in pollutants from a variety of other sources, e.g. runoff from streets, wastewaters from market places, automobile workshops, community centers, clinics and hospitals. Besides, there are numerous illegal domestic sewage outfalls discharging directly into the Lake. The outfalls along Gulshan Lake have been identified through field surveys, analysis of available maps (on drainage and storm sewer network of Dhaka), and discussions with officials of Dhaka Water Supply and Sewerage Authority (DWASA), responsible for management of both domestic sewage and storm water drainage. A detailed inventory of outfalls of Gulshan Lake has been prepared, which included information on: (i) Outfall location (GPS coordinates), (ii) Outfall type (e.g., open drain, closed pipe), (iii) Outfall shape and dimension and (iv) Outfall status, i.e. active, hidden or not in use (Sabit, 2011).

2.2 Outfall Discharge Characterization

For characterization of outfall discharge, samples were collected during dry season, when there was no storm water flow. Wastewater samples were collected from four outfalls among 24 major outfalls. For characterization of discharge, one major outfall from each of the four segments of the Lake was selected (see Fig. 1). The wastewater samples were collected in pre-washed plastic containers, and then poured into 1L pre-washed pre-labeled plastic bottles. After collection, the samples were stored in ice-box and then carried to the laboratory for analysis within four hours of collection. The wastewater samples were analyzed for BOD_5, COD, Color, TDS, TSS, NH_3-N, NO_3-N, NO_2-N, PO_4, S^{2-} and SO_4^{2-}. Ammonia, Nitrate, Nitrite, Phosphate and Sulfide concentrations were analyzed with a Spectrophotometer (HACH, DR4000U). Lead concentration was determined using GF-AAS (Shimadzu, AA6800). Other parameters (e.g. BOD_5, COD, TDS, TSS) were measured following Standard Methods. Flow rate through the outfalls were measured by recording the time required to fill a 10L container.

2.3 Water Quality

Water quality monitoring was carried out during both dry and wet seasons. Sixteen locations along 8 cross sections (two from each of the four segments) through the Lake were selected for sampling; these are identified as W-1 to W-16 in Fig. 1. Sampling locations were selected at sufficient distances away from the major sources of pollution. Water samples were collected at six different times, approximately once a month during November 2009 to August 2010. Five sampling campaigns were carried out during the dry season and one during the wet season (in August 2010); each sampling campaign took two days. At all locations, water samples were collected from points about 1m away from the Lake-shore and at a depth of about 0.3m from water surface. Water samples were collected in two 1L pre-washed plastic bottles. All collected samples were analyzed for Dissolved Oxygen (DO), pH, Electrical Conductivity (EC), Color, Biochemical Oxygen Demand (BOD_5), Ammonia (NH_3-N), Phosphate (PO_4), Total Dissolved Solids (TDS) and Total Suspended Solids (TSS); selected samples were analyzed for Chemical Oxygen Demand (COD), Fecal Coliform (FC), Nitrate (NO_3-N), Nitrite (NO_2-N), Sulfides (S^{2-}) and Lead (Pb).

2.4 Sediment Quality

Sediment samples were collected from four locations (one from each of the four segments of the Lake) (see Fig. 1), using a boat equipped with a sediment sampler. At each location, top 20cm of sediment was collected. The sediment samples were analyzed for moisture content, organic matter content, metal content (Cd, Cr and Pb) and potential sediment oxygen demand (pSOD). Heavy metal contents were determined after extraction with aqua-regia, using GF-AAS (Shimadzu, Japan, AA6800). The potential sediment oxygen demand (pSOD) was estimated using the ex-situ method outlined by Matlock et al. (2003); the results were expressed as “g O_2/m^3 sediment/day”.

2. Result and Discussions

3.1 Outfall Identification

A total of 102 outfalls were identified along the periphery of Gulshan Lake (Sabit, 2011), which included 24 major outfalls (with respect to size and flow). The major types of wastewater/ storm water outfalls contributing to the pollution of Gulshan Lake include

- Storm sewer pipes
- Open channels
- Box culverts
- Small private outfalls

Table 1 shows the 24 major outfalls.

Table 1
Details of 24 major outfalls along the periphery of Gulshan Lake

Sl. No.	Outfall ID	Specification (Dimension, Shape)	GPS Co-ordinate		Location	Lake Segment
			Latitude (N)	Longitude (E)		
1	10	24" dia pipe	23°48'00.5"	90°25'01.3"	along R#84	1st
2	14	24" dia pipe	23°48'10.9"	90°25'00.0"	between R#80 & R#79	
3	15	Hidden	23°48'11.2"	90°24'59.9"	between R#78 & R#76	
4	17	Hidden	23°48'15.1"	90°24'58.4"	along R#71	
5	21	Hidden	23°48'19.2"	90°24'57.2"	along R#72	
6	22	Box culvert	23°48'22.9"	90°24'56.3"	along Baridahara DOHS	
7	23	Box culvert	23°48'23.6"	90°24'57.0"	along Baridahara DOHS	
8	25	48" dia pipe	23°48'24.1"	90°24'57.6"	along Baridahara DOHS	
9	28	Hidden	23°48'20.6"	90°25'01.4"	between R#11 & R#10	
10	32	24" dia pipe	23°48'13.4"	90°25'04.9"	along R#7	
11	33	24" dia pipe	23°48'11.3"	90°25'05.2"	along R#6	
12	34	24" dia pipe	23°48'08.6"	90°25'05.4"	along R#5	
13	37	24" drain	23°48'06.5"	90°25'05.9"	along R#4	
14	53	24" dia pipe	23°47'38.6"	90°25'17.9"	near Marium Tower-1	2nd
15	55	24" dia pipe	23°46'50.1"	90°25'07.1"	D/s of Marium Tower-1	3rd
16	56	18" dia pipe	23°46'55.6"	90°25'08.2"	D/s of Marium Tower-1	
17	59	18" dia pipe	23°47'01.8"	90°25'09.7"	D/s of Marium Tower-1	
18	60	18" dia pipe	23°47'02.3"	90°25'09.5"	along R#128	
19	62	18" drain	23°47'09.3"	90°25'10.4"	along R#123	
20	64	24" dia pipe	23°47'11.5"	90°25'13.6"	along R#121	
21	66	18" dia pipe	23°47'14.1"	90°25'14.8"	along R#120	
22	82	10" drain	23°46'40.8"	90°25'08.3"	along R#136	4th
23	83	24" dia pipe	23°46'43.0"	90°25'08.6"	along R#135	
24	88	24" dia pipe	23°46'44.6"	90°25'15.5"	east side of lake	

3.2 Outfall Discharge Characterization

Table 2 shows characteristics of the wastewater samples collected from four major outfalls of Gulshan Lake; it also shows the national discharge standards (GoB, 1997) for comparison.

Table 2 shows that the discharges are characterized by relatively high concentrations of COD (129 to 188 mg/l), BOD_5 (56 to 160 mg/l), Ammonia (16 to 28 mg/l), Phosphate (3.55 to 13.4 mg/l) and Color (76 to 200 Pt-Co). High COD, BOD_5, and ammonia concentrations are characteristics of fresh domestic sewage. Concentration of some of the parameters exceeds the national discharge standards for effluent.

Table 2
Characteristics of four outfall discharges

Sl. No.	Parameter	Unit	Outfall ID				Average	Discharge Standard*
			O-1	O-2	O-3	O-4		
1	COD	mg/l	129	186	188	185	172	200 (b)
2	BOD_5	mg/l	56	135	80	160	108	40 (a); 50 (b)
3	NH_3-N	mg/l	16.25	16	18	27.75	19.5	5 (b)
4	TDS	mg/l	277	321	335	413	337	2100 (b)
5	TSS	mg/l	11	53	24	7	24	100 (a); 150 (b)
6	Color	Pt-Co	164	303	235	321	256	--
7	PO_4	mg/l	5.8	3.55	5.65	13.4	7.1	35 (a); 8 (as P) (b)
8	NO_3-N	mg/l	0	0	0	0	0	100 (a); 10 (b)
9	NO_2-N	mg/l	0	0	0	0	0	--
10	SO_4^{2-}	mg/l	10	20	15	50	23.8	--
11	S^{2-}	μg/l	0.07	0.085	0.076	0.102	0.083	--
12	Flow rate	L/s	2.80	1.92	2.16	2.40		--
13	Outfall ID	--	37	53	62	83	--	--

** (GoB, 1997); Standards for discharge into natural water body; a: domestic; b: industrial effluent*

3.3 Water Quality

2.3.1 pH

The pH of Gulshan Lake water varied from 6.41 to 8.04 (see Fig. 2). In general, pH value increased slightly toward the downstream. The two pH values along a cross-section were comparable, possibly indicating that the Lake water is well mixed. The pH of the Lake water was relatively high in dry season, with an average of 7.58, which is in agreement with data reported by Ahmed et al. (2005).

3.3.2 Color

All the water samples collected from Gulshan Lake were greenish in color and odorous. Floating materials like algae, other plant materials, and suspended materials were present in most of the samples. High color values (close to 200 Pt-Co units) have been recorded, especially for samples collected from the upstream section of the lake (Fig. 3). Southernmost segment of the Lake (i.e. sampling cross sections 7 and 8) shows lowest intensity of color (less than 105 Pt-Co units). Slightly decreasing trend of color towards downstream of Lake was noticed.

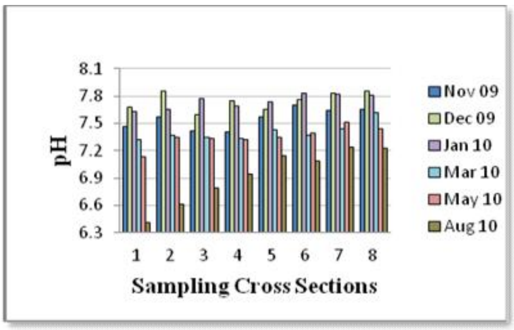

Fig. 2. Spatial and seasonal variation of pH of Lake water

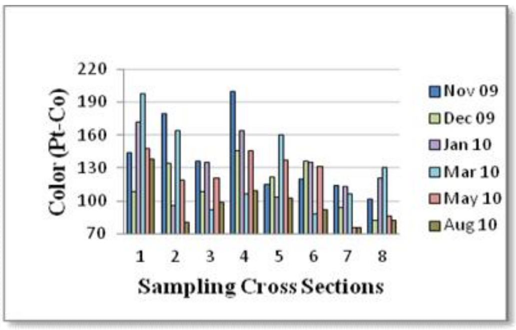

Fig. 3. Spatial and seasonal variation of Color of Lake water

3.3.3 Electrical Conductivity (EC), TDS and TSS

No marked spatial variation of Electrical Conductivity (Fig. 4) and TDS (Fig. 5) was observed. The two EC values along a cross-section were comparable. The EC values varied from 421 to 643 µS/cm (average 495 µS/cm) during dry season, and 418 to 461 µS/cm (average 440 µS/cm) during wet season. During dry season, TDS ranged from 216 to 355 mg/l, with an average of 284 mg/l; during wet season, TDS varied from 137 to 201 mg/l, with an average of 173 mg/l. The lowering of EC and TDS in August (wet season) is most likely due to dilution of Lake water by rainfall. The EC values recorded in this study are relatively higher than those reported by Ahmed et al. (2005) [426 to 510 µS/cm] and Quaraishi et al. (2010) [367 to 397 µS/cm]. The apparent increase in EC values could be attributed to continued discharge of wastewater into the Lake. It should be noted that TDS values did not correlate well with the EC values.

Relatively higher concentrations of TSS was recorded for all the samples collected in August (i.e., wet season) compared to those during of dry season (Sabit, 2011), which is most likely due to input of suspended materials into the Lake with storm runoff. This trend is observed for most natural water bodies.

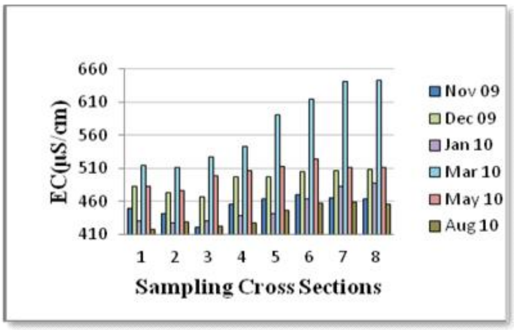

Fig. 4. Spatial and seasonal variation of EC of Lake water

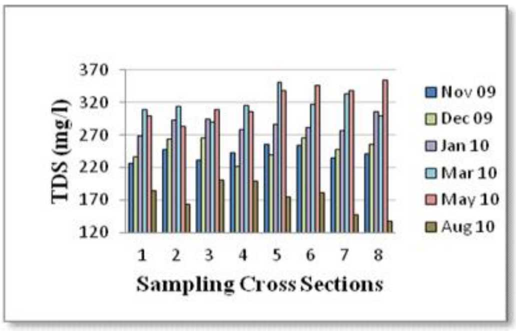

Fig. 5. Spatial and seasonal variation of TDS of Lake water

3.3.4 Dissolved Oxygen (DO)

All recorded DO values of Lake water were very low, mostly ranging from negligible to less than 2 mg/l, indicating very poor quality of the Lake water. Bangladesh sets a minimum DO requirement of 5 mg/l for different purposes including pisciculture; DO in Gulshan Lake remained far below this level throughout the study period. The intense odor encountered during sampling at many stretches of the Lake is due to anoxic conditions created by high organic loading in the Lake.

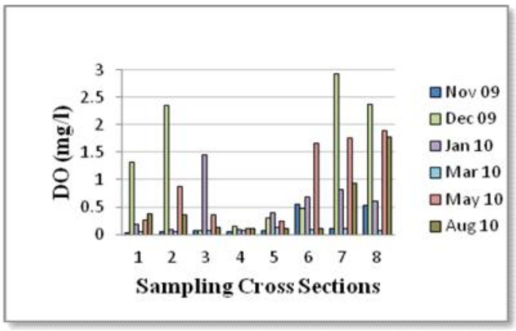

Fig. 6. Spatial and seasonal variation of DO in Gulshan Lake water

3.3.5 BOD_5 and COD

No particular trend of BOD_5 and COD of Lake water was observed. The BOD_5 values remained relatively high throughout the sampling period. Average dry season and wet season BOD_5 values were 15.45 mg/l and 12.52 mg/l, respectively (Fig. 7); while corresponding values for COD were 73.32 mg/l, and 47.94 mg/l, respectively (Fig. 8). BOD_5 did not drop significantly in August (i.e., wet season), possibly due to contaminated nature of storm runoff that the Lake receives. On the other hand COD dropped significantly, possibly indicating predominance of biodegradable organics in storm runoff. A comparison with Bangladesh standard for inland surface water quality (ECR, 1997) shows that BOD_5 of Gulshan Lake are much higher than the standards for different purposes.

3.3.6 Fecal Coliform (FC)

Since Gulshan Lake regularly receives domestic sewage from the surrounding areas, the FC concentration is very high throughout the Lake during the study period. Most of the values were TNTC (i.e., Too Numerous To Count). This indicates very high level of fecal pollution.

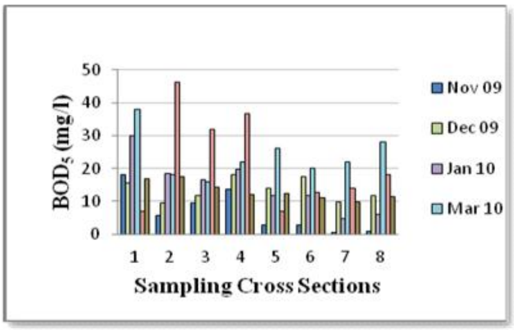

Fig. 7. Spatial and seasonal variation of BOD_5 of Lake water

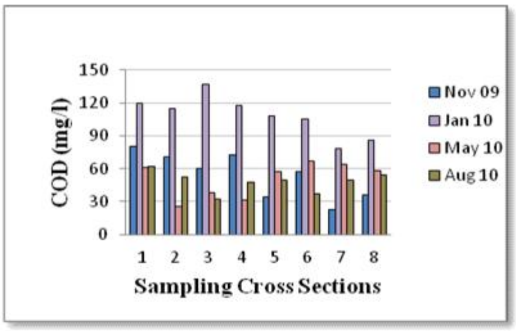

Fig. 8. Spatial and seasonal variation of COD of Lake water

3.3.7 Nutrients (N, P, S)

Water of Gulshan Lake was found to contain high concentration of nutrients, especially N and P. During dry season, very high concentration of ammonia was recorded in the Lake water, mostly ranging from about 10 to 20 mg/l (Fig. 9), with an average of 13.9 mg/l, indicating pollution from sewage. Ammonia concentration, however, decreased significantly in August (during wet season; average 1.96 mg/l). According to Bangladesh Environmental Conservation Rules 1997, maximum limit of ammonia for inland water used for pisciculture is 1.2 mg/l; Ammonia concentration in Gulshan Lake exceeded this standard by a large margin during the dry season. Ammonia is toxic to fish and aquatic organisms even at low concentrations, especially when water contains very little DO, pH is higher and water is warmer; as discussed above Gulshan Lake water remains alkaline and dissolved oxygen remains persistently low during the dry season. During the field survey, many dead fishes were found in the lake, which could be due to excessive concentration of ammonia. The concentration of nitrate (NO_3-N) remained almost unchanged during the study period, and ranged from < 0.1 mg/l to 0.4 mg/l. Nitrite (NO_2-N) concentration was found to be mostly lower than 0.02 mg/l in dry season and not more than 0.01 mg/l in wet season. At the upstream end, phosphate concentration was relatively low (mostly below 1 mg/l), while at the downstream end, it was higher (mostly exceeding 5 mg/l). During dry season, phosphate ranged from 0.21 to 8.55 mg/l, and in the wet season 3.1 to 5.5 mg/l (Fig. 10). Sulfide concentration in Lake water was relatively low and varied from 0.003 to 0.042 mg/l.

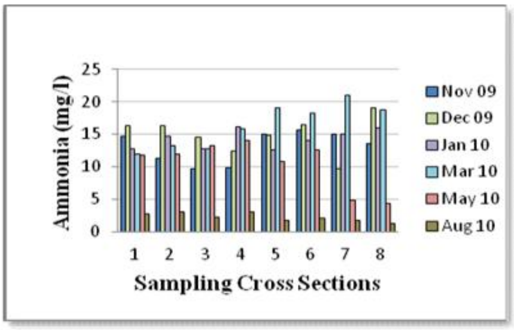

Fig. 9. Spatial and seasonal variation of NH_3 of Lake water

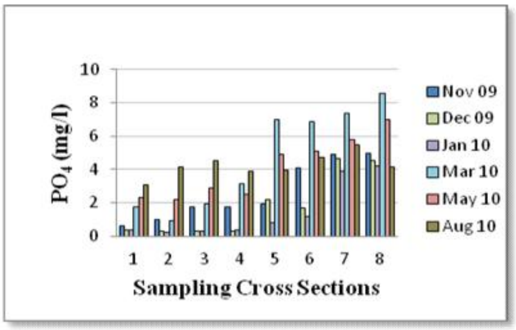

Fig. 10. Spatial and seasonal variation of PO_4 of Lake water

3.3.8 *Lead (Pb)*

Lead concentration in the Lake water samples varied from 0.01 to 0.042 mg/l; average lead concentration during dry and wet season were 0.037 mg/l and 0.02 mg/l, respectively. These values are relatively low compared to those reported for Dhanmondi Lake, another major Lake in Dhaka, by Ahsanuzzaman (1996); lead concentration in Dhanmondi Lake varied from 0.15 to 0.21 mg/l during dry season and from 0.03 to 0.12 mg/l during wet season.

3.4 *Sediment Quality*

Moisture content of the sediment samples varied from 40.4 to 43.3%; while organic matter content varied from 1.8 to 2.6%. Table 3 shows metal contents of the sediment samples. Average Cadmium concentration in Lake sediment was 1.3 mg/kg, which is much higher than the common range (0.01 to 0.7 mg/kg) and average concentration (0.06 mg/kg) reported for natural soils (USEPA, 1983). Average Chromium concentration in Lake sediment was 31.7 mg/kg, which falls within the typical range for natural soils (1 to 1000 mg/kg, USEPA 1983), and is much lower than the reported Cr concentration of Gulshan Lake sediment (105 to 124 mg/kg) by Ahmed et al. (2005) for samples collected in March 2002.

Average Lead concentration in Lake sediment was found to be 54.5 mg/kg, which is much higher than the average concentration (10 mg/kg) reported for natural soils (USEPA, 1983). The sediment lead concentrations found in this study are somewhat higher than the reported lead concentration of Gulshan Lake sediment (22 to 40 mg/kg) by Ahmed et al. (2005) for samples collected in March 2002, and comparable to those reported for Dhanmondi Lake (10 to 45 mg/kg) by Ahsanuzzaman (1996).

Leaded fuel, used in Bangladesh until its ban in 1999, could have contributed to the increased lead content in the lake sediments. Motor vehicle workshops located on the bank of the Lake might also have contributed to the higher lead content, as reported by Sengupta and Dalawani (2008).

Potential sediment oxygen demand (pSOD) is the total oxygen utilized (i.e. taken up) by all biological and chemical processes in sediment. The pSOD of the Lake sediment varied from 2477 to 3019 g O_2/m^3 sediment/day (Table 3). Khan (2008) reported pSOD of sediment of DND conveyance canal (situated at downstream of Gulshan Lake) to vary from 639 to 6977 g O_2/m^3 sediment/day, while Matlock et al. (2003) reported pSOD of sediment from Colorado River ranged from 19.2 to 2779.2 g O_2/m^3 sediment/day. Thus, Gulshan Lake sediment has relatively high pSOD values, which is one of the reasons of persistently low DO level in Lake water, even during the wet season.

Table 3
Metal contents and pSOD of the clayey sediment of Gulshan Lake

Serial	Sample ID	Cd, mg/l	Cr, mg/l	Pb, mg/l	pSOD, g O_2/m^3 sediment/day
1	S-1	1.3	35.0	51.0	3019
2	S-2	1.8	32.4	56.6	2477
3	S-3	1.3	30.1	55.2	3009
4	S-4	0.8	29.2	55.2	3019

4. Conclusions

The water quality of Gulshan Lake is very poor and appears to deteriorate progressively from January to May as dry season progresses, and is characterized by high concentrations of BOD_5, COD, Ammonia and low concentrations of DO. The major sources of pollution of Gulshan Lake are the outfalls, which discharge both storm water and sewage (both domestic and non-residential) into the Lake. The inability of the city authority to separate domestic and storm sewer networks is causing serious pollution of not only Gulshan Lake, but all Lakes and water bodies within the city and the rivers surrounding the city. Discharge of untreated effluent, solid wastes (e.g., from markets) and sludge (including septic tank/fecal sludge) into storm sewer network is quite common, which is aggravating the pollution scenario.

RAJUK, the capital city development authority, is currently implementing a project for improvement of Gulshan Lake. The data and information generated in the present study, especially the locations and characteristics of discharge of major outfalls, could be useful for devising ways to reduce pollution of Gulshan Lake. The DWASA has also taken up projects to expand storm and domestic sewer networks in Gulshan area. However, unless illegal domestic sewage connections to storm sewers are disconnected, the pollution of Gulshan Lake and other water bodies will continue. It is obvious that it is not possible to expand domestic sewer network in un-sewered areas throughout the city within a short time; however, the process of installing separate domestic sewer network must commence immediately, along with regular maintenance of existing sewers to keep them operational. At the same time, efforts must be made to ensure mandatory use of septic tank systems (i.e., septic tank and soakage pit) in all households and other establishments in un-sewered areas of the city.

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