CHARACTERIZATION OF COMBINED SEWAGE IN HATIRJHEEL DIVERSION SEWER SYSTEM AND ITS IMPLICATIONS ON THE DASHERKANDI STP

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A Thesis Submitted by

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The thesis titled "**Characterization of Combined Sewage in Hatirjheel Diversion Sewer System and Its Implications on the Dasherkandi STP**" submitted by Md Ziaul Ahsan Biswas, Roll No. 1015042119P, Session: October, 2015 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Science in Civil and Environmental Engineering on 11 August 2018.

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Md. Ziaul Ahsan Biswas

Dedicated

To

My Loving Family

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ABSTRACT

Hatirjheel serves very important hydrological functions of draining and detaining storm water from a large area (about 24 sq. km) of Dhaka city. Its main diversion sewer system running along the periphery of Hatirjheel, carries domestic sewage during dry season, and mixture of storm water and domestic sewage during wet season, received through 9 major storm sewer outfalls, as there is virtually no operational sanitary sewer network in the city. The combined wastewater of main diversion sewer system of Hatirjheel would be transported to the under-construction Dasherkandi STP for treatment. The main focus of this research work was to assess characteristics of the wastewater flowing through the diversion sewers of Hatirjheel, and to assess impacts wastewater characteristics and ongoing/future projects of DWASA on the operation of Dasherkandi STP.

Wastewater samples from Hatirjheel main diversion sewer system were collected during April-May 2017 (summer), July-August 2017 (wet season) and December-January 2017-18 (dry season). Water samples were collected in on a weekday and on a holiday in each season; on each sampling day, samples were collected at 0600, 0800, 1000, 1200, 1400 and 1600 hrs.

It has been found that the characteristics of combined sewage of Hatirjheel main diversion sewer vary significantly with the time of the day. Concentration of most of the parameters, particularly Turbidity, TSS, Ammonia, Phosphate, BOD_5 and COD increases as the day progresses, and reaches their peak values at around 1400 hours. Concentrations of Turbidity, TSS, BOD_5 and COD appears to be slightly higher during the weekend, compared to weekdays; while concentration of ammonia and phosphate appear to be slightly lower during the weekend, compared to weekdays. BOD_5/COD ratio of combined wastewater during dry season varied from 0.49 to 0.63, indicating that the wastewater does not contain significant non-biodegradable waste and it could be easily treatable by biological means.

The characteristics of wastewater coming from northern and southern sides of the main diversion sewer are comparable, although the organic load coming from the southern side appears to be slightly higher. The BOD_5/COD ratio of wastewater coming from the northern side is slightly lower than that coming from the southern side, indicating relatively higher contribution of industrial sewage from the northern side of Hatirjheel.

The characteristics of combined wastewater change significantly during the wet season due to dilution with rainwater. The peak BOD_5 concentration (420 mg/l) recorded in December 2017 (dry season) has been found to be over four times higher than that of the sample collected in August 2017 during heavy rainfall. The COD (672 mg/l) and Ammonia (21.2 mg/l) concentrations in December (dry season) were found to be over two times higher than those recorded in August 2017 (wet season). The operational parameters of the Dasherkandi

STP (e.g., detention times in aeration tanks and secondary clarifier; sludge management) need to be adjusted to accommodate these variations in wastewater characteristics. The flow coming through the "southern main diversion sewer of Hatirjheel" carries sewage mainly from Pagla and Rayerbazar catchments, would carry primarily storm water during wet season, after separating these two catchments. This would cause even more dilution of sewage during the wet season, requiring further adjustments at the Dasherkandi STP. Again separate and independent sanitary sewerage network for Dasherkandi could solve these difficulties.

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LIST OF ABBREVIATIONS

BOD	Biochemical Oxygen Demand
BRTC	Bureau of Research, Testing and Consultation
BUET	Bangladesh University of Engineering and Technology
COD	Chemical Oxygen Demand
DWASA	Dhaka Water Supply and Sewerage Authority
DND	Dhaka-Narayangonj-Demra
DUIIP	Urban Infrastructure Improvement Project
DOHS	Defence Officers Housing Estate
EC	Electrical Conductivity
GoB	Government of Bangladesh
IWM	Institute of Water Modeling
JICA	Japan International Cooperation Agency
LGED	Local Government Engineering Department
LGRD&C	Local Government, Rural Development and Cooperatives
MLD	Million Liters per Day
RAJUK	Rajdhani Unnayan Kartripakkha
SSDS	Special Sewage Diversion Structure
STP	Sewage Treatment Plant
SLS	Sewage Lift pumping Stations
TDS	Total Dissolved Solid
TS	Total Solid
TSS	Total Supspended Solid
USEPA	United States Environmental Protection Agency
DWF	Dry Weather Flow
DMA	Dhaka Metropolitan Area
BWDB	Bangladesh Water Development Board

CHAPTER 1

INTRODUCTION

1.1 Background

The Hatirjheel serves very important hydrological functions of draining and detaining storm water from a large area (about 24 sq. km.) of Dhaka city (DWASA, 2015). The "main diversion sewers" running along the periphery of Hatirjheel receives combined storm water and sewage discharges through 9 major storm sewer outfalls. During dry season, the sewers carry domestic sewage as well as some industrial wastewater, while during wet season they carry mixture of storm water and sewage. The dry season flows through the sewers currently drains through Begunbarikhal-NoraiKhal-Balu river system (DWASA, 2015). A sewage lifting station to be built under the Dasherkandi STP project would carry the sewage to the Dasherkandi STP for treatment (DWASA, 2013). Currently during wet season, part of the combined storm water-sewage flow reaching Hatirjheel is carried through the main diversion sewers and reaches the interim pumping station near Rampura Bridge, from where it either flows by gravity or pumped (when d/s water level is high) to Begunbari Khal system. This part of the wet season flow would be pumped to Dasherkandi STP for treatment when the treatment plant would become operational. Due to considerable dilution by storm/rain water, the sewage reaching Dasherkandi is likely to be much diluted during the wet season (compared to dry season). It is therefore important to understand the nature of variation in characteristics of sewage for design and operation of the Dasherkandi STP.

Dhaka WASA is planning to develop a separate sewerage network in Dasherkandi STP catchment area for carrying domestic sewage to Dasherkandi. At the same time, DWASA is planning separate sewerage system and treatment plant for Pagla catchment and Rayerbazar catchment areas; storm water and sewage from large parts of these two catchments currently drain through Hatirjheel main diversion sewer (DWASA, 2013). It is important to understand the possible changes in composition and flow of storm water and sewage when these DWASA projects would be implemented. In particular it would be interesting to see if the sewage lifting station being built under Dasherkandi STP project would continue to be used for pumping sewage to Dasherkandi STP under the changed scenario; it would also be useful to assess the possible changes in characteristics and flow of sewage reaching Hatirjheel system when Pagla and Rayerbazar sewerage system (and associated STPs) would become operational.

1.2 Objectives

The overall objective of the present research is to assess the characteristics of combined flow of storm water and sewage flowing through the Hatirjheel main diversion sewer system and implications of ongoing/future sewerage development works on Dasherkandi STP. The specific objectives include the following:

a. Assessment of the characteristics of dry weather flow carried through main diver sewer system of Hatirjheel, which would be carried to Dasherkandi STP for treatment during dry season. The combined dry weather flow, as well as dry weather flows coming from northern and southern sides of Hatirjheel would be characterized separately.

b. Assessment of the characteristics of combined sewage-storm water flow carried through main diver sewer system of Hatirjheel during wet season, which would also be carried to Dasherkandi STP for treatment during wet season.

c. Assessment of possible impact of sewage characteristics and flow during dry and wet seasons on the performance/operation of Dasherkandi STP.

d. Assessment of possible impacts of ongoing/planned projects of DWASA (e.g., sewerage networks and STPs in Pagla and Rayerbazar catchments) on operation (e.g., use of lifting station, management of sewage-storm water flow from southern side of Hatirjheel) of Dasherkandi STP.

1.3 Outline of Methodology

For characterization of dry season and wet season flows through the main diversion sewers of Hatirjheel, wastewater samples were collected from the pit/manhole (located close to Rampura Bridge) which receives flows from "main diversion sewers" from both northern and southern sides of Hatirjheel. In addition, additional samples were collected for characterization of flows coming from northern and southern sides of Hatirjheel.

Water-wastewater samples were collected during April-May 2017 (dry season), July-August 2017 (wet season) and December-January 2017-18 (dry season).Collection was done in two alternative working and holidays in every season. On each sampling day, samples were collected at 0600, 0800, 1000, 1200, 1400 & 1600 hrs.

The collected samples were analyzed for a wide range of parameters including pH, color, turbidity, electrical conductivity (EC), TDS, TSS, alkalinity, ammonia, nitrate, phosphate, COD, and BOD_5.

Data from these analysis and those from (BRTC, 2016) were used as assess characteristics of flows during dry and wet seasons. Analysis of water quality was made together with rainfall data, to see effects of rainfall intensity on water quality. For assessing effects of ongoing (e.g., sewerage system for Dasherkandi catchment and Dasherkandi STP) and planned projects of DWASA (e.g., Pagla STP renovation, Rayerbazar STP and associated sewerage system), the sewerage master plan of DWASA (DWASA, 2013) and relevant drainage master plans (DWASA, 2015) were carefully analyzed. Efforts were made to identify portion of sewage that would not come into Hatirjheel diversion sewer system after implementation of these projects. Discussions were made held with DWASA (and consultants appointed by DWASA) regarding design of Dasherkandi STP and Dasherkandi sewerage system.

1.4 Organization of The Study

This thesis comprises of five chapters. The contents of each chapter are summarized below:

Chapter One: This introductory chapter describes the background and objectives of the present study. It also presents a brief overview of the methodology followed in this study.

Chapter Two: This chapter presents literature review covering background information on the Hatirjheel area. It describes the drainage function and sewerage system of Dhaka city. It also briefly describes the detention and drainage functions of Hatirjheel. Some information about sewage quality of Hatirjheel SSDS and operational plan of Dasherkandi STP have also been included in this chapter.

Chapter Three: This chapter describes in detail the methodology followed in this study, including details of sewage sample collection from Hatirjheel main diver sewer system and testing in laboratory. It also describes the methodology followed for characterization of combined sewage from Hatirjheel main diver sewer system and its implications on Dasherkandi STP, considering the sewerage master plan of DWASA.

Chapter Four: This chapter presents the results obtained from this study. It provides detail analysis of combined sewage through Hatirjheel main diversion sewer system and the implications of sewage quality parameters for future planning of Dasherkandi STP based on a year-long monitoring program. It also presents the variation of sewerage characteristics between northern and southern side of SSDS.

Chapter Five: This final chapter summarizes the major conclusions from the present study. It also presents some recommendations for future study.

CHAPTER 2

LITERATURE REVIEW

2.1 General

Dhaka is geographically located between tropical and equinoctial region. Topography wise, the region is commonly a flat land and located mainly on fertile and silty alluvial terrace, technically known as the Modhupur terrace of the Pleistocene period (Miah & Bazlee, 1968). Four major rivers, namely the Buriganga, Turag, Tongi and Balu, surround Dhaka with their many tributaries and flow to the south, west, north and east sides of the city respectively. The annual average precipitation of Dhaka city has been estimated to be about 2,000 mm, almost 80% of which occur during the rainy season or monsoon (Samad, 2009). The western part of Dhaka city is protected from river inundation by an encircling embankment known as the Dhaka-Narayanganj-Demra (DND) embankment. During most of the rainy season, the water level in these surrounding river systems remains higher than the water level inside embankment within the city area. This fact alone emphasizes the dependency of the drainage system of Dhaka city on the water levels of the peripheral river systems. The situation becomes worse when monsoon runoff is generated from short duration and high intensity rainfall and combines with high water level in river system. Main causes of floods in Dhaka City can be classified into two types (FAP, 1991): The first one results from high water level of peripheral river system and the other caused by rainfall in the city. Flooding in Dhaka City in September, 1996 caused by local high rainfall occurred in the built-up areas of the city. The severe flooding in 1988 and water logging in 1996is believed to have originated from insufficient drainage capacity of drainage system in Dhaka.

Under the circumstances, a preliminary study was carried out (BRTC, 2005a) during 2004-05 by BRTC of BUET, funded by RAJUK, to assess the development potentials of the Hatirjheel area as a reservoir, given the picture of existing critical drainage conditions of Dhaka east. The study revealed that the lowlands behind the Sonargaon Hotel and Hatirjheel perform very important functions of detention and conveyance of accumulated storm runoff generated from the adjoining catchments area of over 30 sq. km. While it was recommended that the low-lying floodplain areas of Hatirjheel must be preserved for the retention of storm runoff from a large catchments area, the study also recognized, from traffic points of view, that there exist a missing link between the Tongi Diversion Road and the Pragati Swarani. Based on the recommendations of this and other studies, the government came up with proposals for the development of Hatirjheel lowlands and constructions of at-grade roadway and walkway along the periphery of the Hatirjheel in 2007. The project was founded on fulfilling three very important criteria relevant to project site:

a. Restoration and conservation of environment in and around the project area.
b. Preserving the low-lying floodplain areas of Hatirjheel and the lowlands behind Sonargaon Hotel for the retention of storm runoff from a large catchment area, and
c. Alleviating local traffic congestions through constructions of peripheral road and walkways

As part of the integrated development of Hatirjheel area, Hatirjheel restoration project (by BUET, SWO-Bangladesh Army, RAJUK, LGED and DWASA) was implemented to divert all the domestic and industrial wastewaters discharged into the Hatirjheel . The diversion of the wastewater was implemented through construction of large diameter diversion sewers (1820mm) running along the southern and northern peripheries of the project site. For diversion of wastewater, special sewage diversion structures (SSDSs) were constructed at 11 outfall locations surrounding Hatirjheel. These diversion structures divert the entire dry season flow coming through the storm sewers, consisting mostly of domestic and industrial wastewater; while during wet season, a portion of the combined flow coming through these sewers divert through the diversion sewers, while the remaining fraction discharges into the Hatiljheel.

This Chapter presents an overview of the drainage and sewerage system of Dhaka city. It also presents a detail assessment of the functions of Hatirjheel and its main diversion sewer system for drainage of dry and wet season. This Chapter then presents an assessment of combined sewer quality of Hatirjheel main diversion sewer system based on available data and information. It also identifies the important parameters for characterization of sewage quality and discusses the significance of these important sewage quality parameters.

2.2 Drainage Function of Hatirjheel

Considering the drainage problem and water logging in Dhaka city, even after light rain, requirement of some retarding basin was felt necessary. As part of city development, Hatirjheel was chosen to develop as a retarding pond where rain water would be kept for a certain time in the event of rainfall and the lake would also be used for some recreation.

2.2.1 Areas surrounding Hatirjheel

Hatirjheel is surrounded by Gulshan, Banabi,Tejgaon,north-Khilgaon and Badda in its north, Rayerbazar, Kamrangirchar, Mohammadpur, Hazaribag and Dhanmondi in its west and Pagla,Lalbag,Kotwali,Sutrapur,Shayampur,Ramna,Motijheel,Sabujbag and Khilgaon in its south. Towards east it discharges water in the Begunbari khal-Balu river and ultimately to Sitalakhya river. This low lying area is located in an area which is rapidly developing into a major business center of the capital city of Dhaka. Fig.2.1 below shows the areas surrounding Hatirjheel as per drainage function.

Fig.2.1: Areas surrounding Hatirjheel as per drainage function

The climate of Bangladesh is tropical, with a pleasantly warm and sunny winter from November to February, a short hot spring between March and May, and a long rainy season from June to October, due to the summer monsoon. The country is flat and occupied by the huge Ganges-Brahmaputra Delta, and is therefore exposed to floods, as well as to storm surges when cyclones hit the Bay of Bengal.

The amount of rainfall is directly proportional to the amount of storm discharge considering the terrain, formation and surface runoff coefficient of that area. The monsoon in Dhaka city begins in April and lasts till October with its peak around the month of June-July. A quick review of the historical data on daily rainfall over the study area for the last 14 years reveals that the peak rainfall has started to shift from May-June to August-September. On 03 August 2017, the Met office of Dhaka recorded highest rainfall in three hours for last 10 years, which later left many roads and areas of the capital severely waterlogged. Fig.2.2 shows the average rainy days and fig.2.3 shows average precipitation in Dhaka.

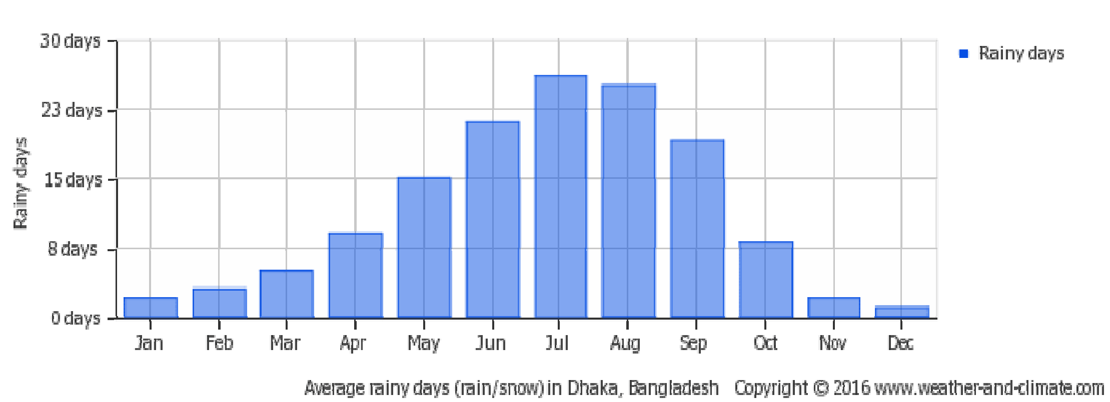

Fig.2.2: Average rainy days in Dhaka (www.weather-and-climate.com)

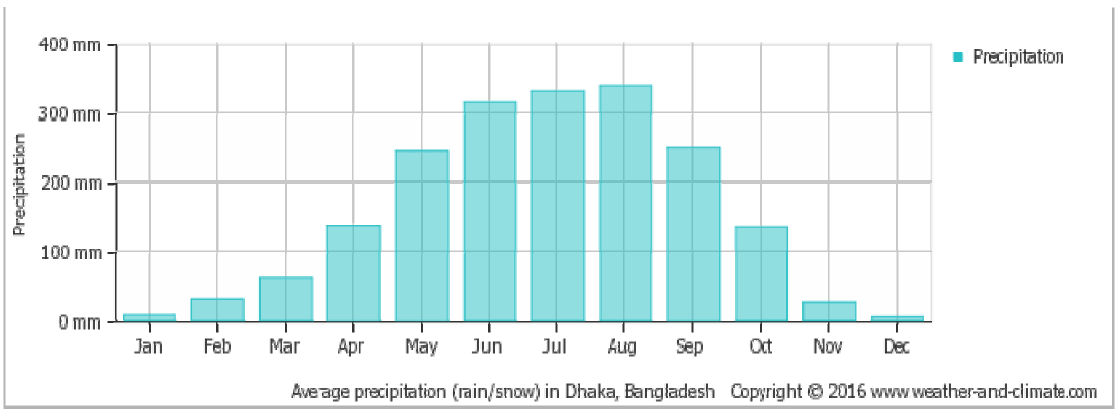

Fig.2.3: Average precipitation in Dhaka (www.weather-and-climate.com)

Storm water drainage in Dhaka West including Hatirjheel is accomplished by a combination of pump and gravity drainage. At present, there are five pump stations in the city, to pump out logged water in case of any emergency situation. The stations are at Kamalapur, Rampura, Dholai khal, Kallyanpur and Goran Chand Bari. Fig. 2.4 shows (Khan, 2008) a comparison of the water levels inside and outside the regulator at Rampura when temporary pumps were in operation.

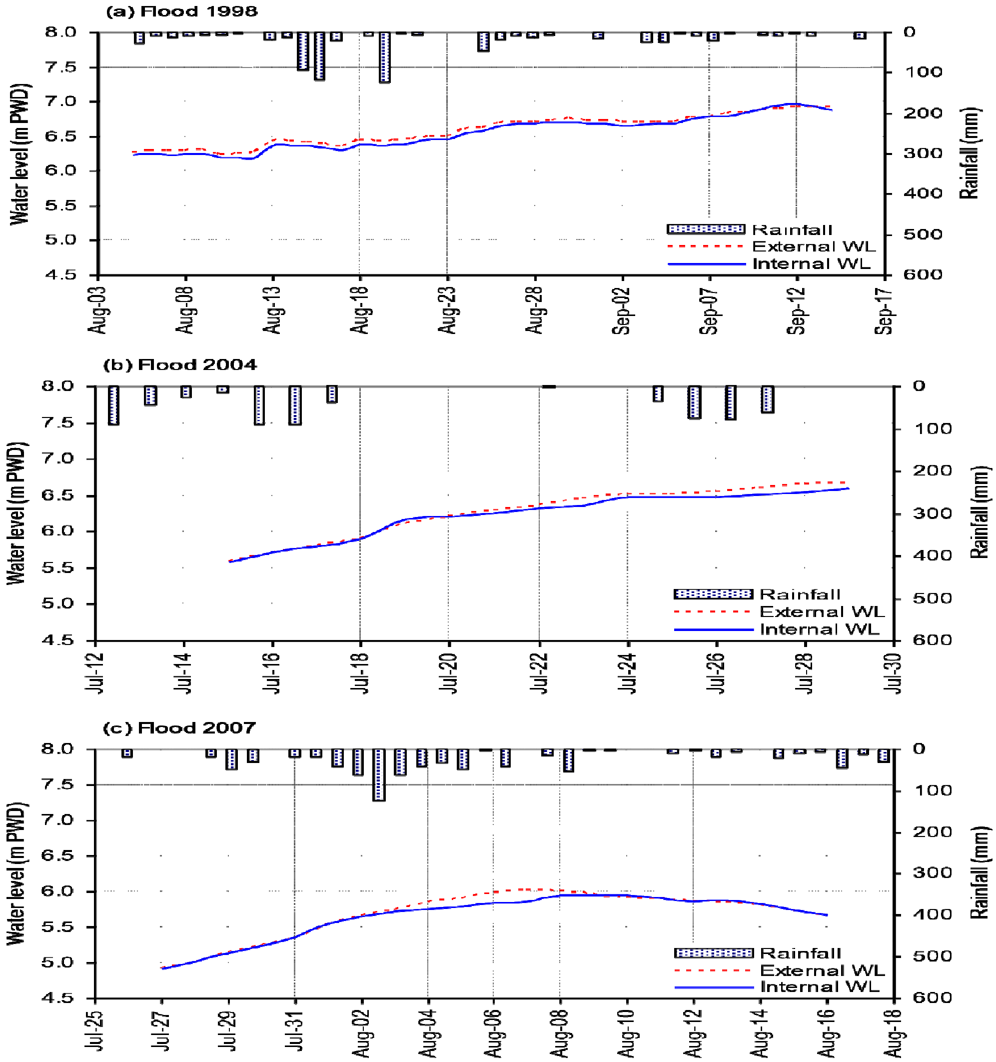

Fig. 2.4: Observed water level at Rampura during major floods (Khan, 2008)

2.2.2 Detention and drainage function of Hatirjheel

The low lying area behind Sonargaon Hotel receives run off and wastewater flows from box culvert coming from the west along the Panthapath, a brick sewer (Paribag khal) comes from the south- west and a major storm sewer coming from the Kawranbazar area. During dry season, storm water primarily carries domestic wastewater. During wet season storm water flows through the sewers increases significantly and entire low-lying area behind Sonargaon used to become submerged with drainage water. Now Hatirjheel serves very important purpose of retaining drainage water during the rainy season, especially when the Rampura regulator is kept during dry season and also during 3 months of rainy season (July - September) to prevent intrusion of river water into the city.

Hatirjheel provides detention storage and drainage passage to about 31.3 km^2 area of western Dhaka city, of which 13.7 km^2 are in drainage zone F and 17.6 km^2 are in zone G (see Fig. 2.5). Storm runoff from zone F (Fig. 2.6) is drained to the lowlands behind the Sonargaon Hotel and Hatirjheel by local khals, underground sewers and box culverts. Important commercial, residential and industrial areas are located in the Shahbag, Paribagh, Elephant road, Mirpur road, Panthapath, Green road, Farmgate, Kawranbazar, Maghbazar, Malibagh and Tejgaon areas in zone F. Gulshan and Banani lakes are in zone G. The combined storm runoff from F and G is drained through the Rampura regulator just downstream of the Rampura Bridge (BRTC, 2006).

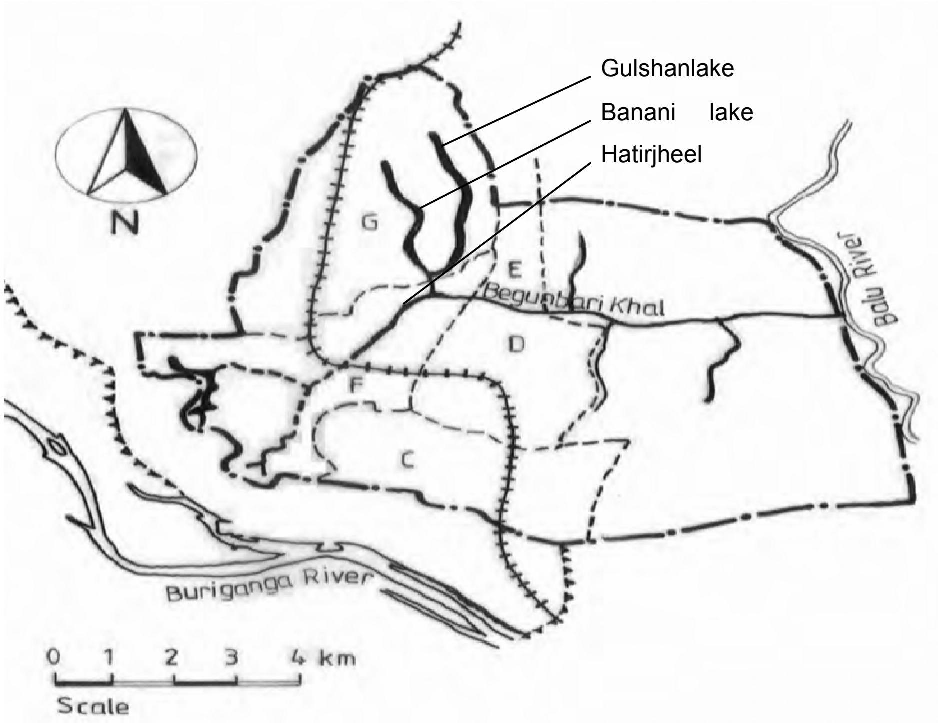

Fig.2.5: Drainage zones related to the Hatirjheel system

As a part of Hatirjheel restoration project, "main diversion sewers" have been constructed along the periphery of Hatirjheel, which are carrying the entire dry weather flow (diverted at the SSDSs). During wet season, a part of the combined flow is diverted to the main diversion sewer, while the remaining part is discharged into Hatirjheel through the overflow structure of the SSDSs. The main diversion sewers of Hatirjheel were designed to carry the entire dry weather flow that comes through the storm sewer network. However, in the absence of expansion of domestic sewer network in Dhaka city and increasing population in the city, more and more domestic sewage are being diverted into the storm sewer network.

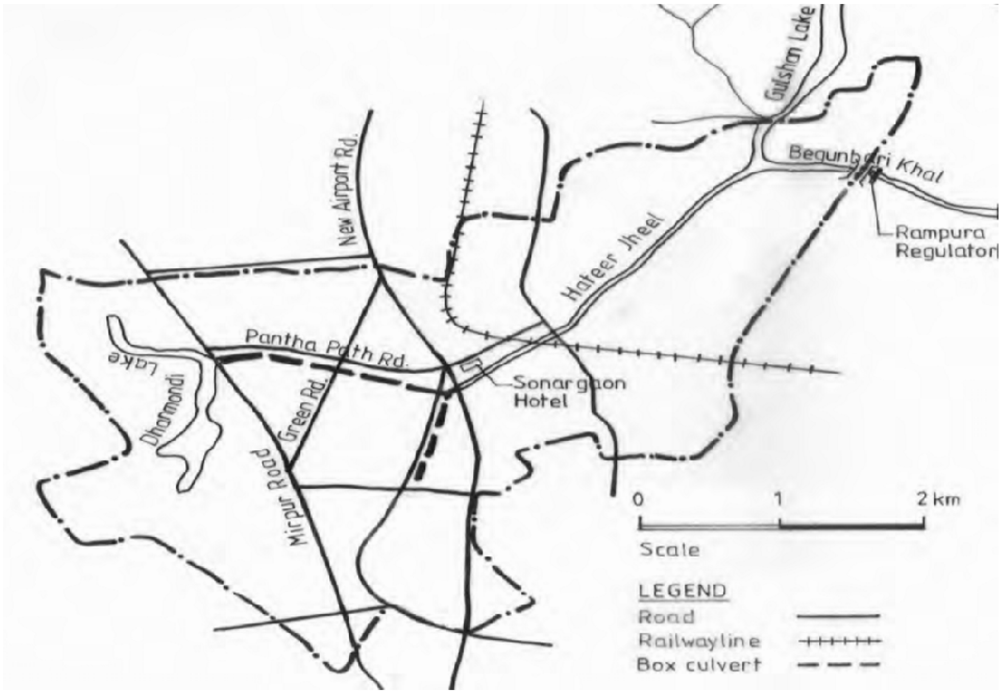

Fig. 2.6: Drainage zone F

2.2.3 Functions of sewage diversion structures

Hatirjheel drainage system consists of Special Sewage Diversion Structures (SSDSs) and the peripheral main diversion sewers. There are 11 SSDSs around Hatirjheel; six SSDSs (SSDS-1 to SSDS-6) are located along the southern periphery of Hatirjheel, while five SSDSs (SSDS-7 to SSDS-11) are located along the northern periphery of Hatirjheel. Among these 11 SSDSs, 9 SSDSs (except SSDS-6 and SSDS-11) are major contributors to main diversion sewer. Overflows from SSDS-6 and SSDS-11 directly flow into Begunbari khal just upstream of Rampura Bridge. Banani and Gulshan Lakes are also connected to Hatirjheel, and contribute significantly to the inflow into Hatirjheel. Fig. 2.7 shows the locations of 11 SSDSs along the periphery of Hatirjheel.

Fig 2.7: Locations of 11 SSDSs along the periphery of Hatirjheel (Google Earth map)

The SSDSs are described below:

a. The SSDS-1, behind the Sonargaon Hotel, is the largest one in terms of flow. It receives storm water and wastewater coming from Panthapath area (through Panthapath box culvert) in the west and Kawranbazar from the east. It also receives storm water/ wastewater coming from the eastern part of Dhanmondi Lake and Kalabagan area.

Fig 2.8: SSDS-1 behind Sonargoan Hotel in Hatirjheel

b. The SSDS-2 is located immediately to the east of Tongi diversion road on the southern periphery of Hatirjheel. It receives storm water and wastewater mainly from a portion of Ramna, Baily road and Eskaton area.

c. The SSDS-3 is located at Madhubagh, Wireless Road, Nayatola (at Gudaraghat). The Tejgaon Sewage Lifting Station of DWASA is located just on the other side of Hatirjheel at this location. It receives storm water and wastewater from a portion of areas under Ramna Thana.

d. The SSDS-4 is located north of Mohanagar Housing Area. It is located on the southern periphery of Hatirjheel close to the Bridge-1 (over Hatirjheel) that connects Tejgaon and Gulshan to Mohanagar Housing Area. It receives storm water and wastewater mainly from Mohanagar Housing Area.

e. The SSDS-5 located along the southern periphery of Hatirjheel receives storm sewer and wastewater that comes from Ulon area.

f. The SSDS-6 receives storm water and wastewater from Mouchak-Rampura area. It is located immediately to the west of the Pragati Swarani (close to Rampura Bridge). The northern portion of the surrounding Rampura DIT Road areas also contributes to it. The sewage flows from Mouchak, outer circular road also go to SSDS-6 through storm sewer network. The overflow from SSDS-6 does not discharge within Hatirjheel, rather it is discharged into Begunbari khal just upstream of Rampura Bridge.

g. The SSDS-7 is located immediately to the east of Tongi Diversion Road on the northern side of Hatirjheel. It receives storm water and wastewater (including industrial discharge) from a part of Tejgaon industrial area.

h. The SSDS-8 receives storm water and wastewater (including industrial wastewater) from a part of Tejgaon area. SSDS-8 is located along the northern periphery of Hatirjheel just to the east of Bridge-2 that connects Tejgaon to Gudaraghat at Madhubagh.

i. The SSDS-9 receives storm water and wastewater (including industrial wastewater) from a part of Tejgaon area.

j. The SSDS-10 has been built at the outfall location of Mohakhali box culvert. The box culvert (5.5 m × 3.8 m box culvert) carries storm water and wastewater from Nakhalpara and Niketon areas. The overflow from SSDS-10 combines with the flow of Banani Lake before discharging into Hatirjheel.

k. The SSDS-11 receives storm sewer and wastewater flows from the Badda area. The overflow from SSDS-11 does not discharge within Hatirjheel, rather it is discharged into Begunbari khal just upstream of Rampura Bridge.

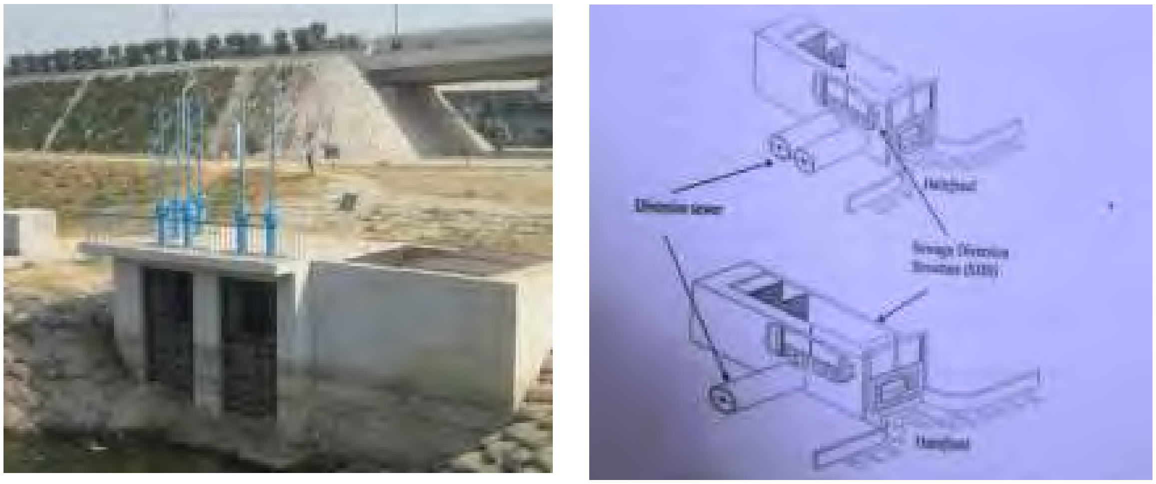

Fig 2.9: Picture of SSDS -3 in Madhubagh area in Hatirjheel (left) and typical diagram of SSDS and diversion sewers (right)

Fig 2.9 shows a typical picture of one SSDS to control wastewater flow coming through the storm sewers. It is seen that during dry season there is no discharge into the Hatirjheel, and the entire dry weather flow is diverted through large diameter single or twin diversion sewers. But during wet season, when the combined flow of wastewater and rainwater come through the storm sewers, the same quantity of flow (i.e., approximately equivalent to the dry weather flow) is diverted by these diversion Sewers and the remaining wastewater-storm water mixture spills over and discharge into the Hatirjheel through the overflow arrangement of the SSDSs.

2.2.4 Quality of flow in the main diversion sewer system

The storm sewers discharging into the low-lying areas behind Sonargaon Hotel carry domestic sewage during the dry season, and mixture of storm water and sewage during the wet season. In June 2004, before the construction of Hatirjheel project, drainage water samples were collected from three different locations - from behind Sonargaon Hotel, from Hatirjheel area near Tongi diversion road, and from drainage canal east of Rampura regulator. Drainage water collected from the low-lying area behind Sonargaon Hotel was found very poor quality with very high BOD_5 and solids content, and its characteristics were similar to that of domestic sewage. The quality of drainage water improved to some extent as it moves downstream to Tongi diversion road and then to the Rampura bridge (Atauzzaman, 2015)

In 2008 (i.e., before the construction of the SSDSs and main diversion sewers), a detail wastewater survey was carried out through collected and analysis of samples from all major storm sewer outfalls discharging into Hatirjheel during both dry (January-March 2008) and wet season (July-August 2008) (Samad, 2009).Tables 2.1 shows the characteristics of dry weather flow discharging into Hatirjheel during January-March 2008. Table 2.2 shows characteristics of wastewater of selected outfalls during the wet season (July-August 2008). It should be noted that the characteristics of mixed wastewater coming through the storm sewers during wet season varied significantly depending on the quantity of precipitation.

Table 2.1: Characteristics of dry weather flow (January-March 2008) near different SSDS of Main Diversion Sewer in (Samad, 2009)

Sampling location (nearest SSDS)	P^H	EC (μS/cm)	TDS (mg/l)	TSS (mg/l)	PO_4 (mg/l)	NO_3 (mg/l)	BOD_5 (mg/l)	COD (mg/l)
SSDS-1	7.11	-	490	570	10.22	.3	80	302
SSDS-2	7.05	-	430	668	9.52	.4	190	343
SSDS-7	8.94	-	731	1038	3.23	.2	210	315
SSDS-4	7.01	-	471	704	9.68	.3	240	622
SSDS-10	7.01	943	494	725	10.04	.3	68	555

Table 2.2: Characteristics of Wet Season Flow (July-August 2008) near Different SSDS of Main Diversion Sewer in (Samad, 2009)

Sampling location (nearest SSDS)	P^H	EC (μS/cm)	TDS (mg/l)	TSS (mg/l)	PO_4 (mg/l)	NO_3 (mg/l)	BOD_5 (mg/l)	COD (mg/l)
SSDS-1	7.01	710	386	735	6.792	.5	188	275
SSDS-2	6.98	740	389	703	7.332	.4	250	346
SSDS-10	7.05	695	254	293	3.648	.3	42	76

It was found that in the year 2008, the dry weather flows discharged in the main diversion sewer contained high concentrations of BOD_5, COD, PO_4 etc. The characteristics of the dry weather flow have been found to be comparable to those of medium and high strength domestic sewage. The characteristics of wastewater improved to some extent during the wet season, due to dilution with rainwater.

2.3 Sewerage and Sanitation of Dhaka City

Dhaka city lacks adequate sanitation infrastructure. Only about 20% of the city population is covered by sewerage system connected to the Pagla Sewage Treatment Plant. Septic tanks and pour-flush sanitation systems are typically used by the majority of the population. As Dhaka is surrounded by rivers and inter-connected with canals, almost all domestic and industrial wastewaters enter Dhaka's surface waters untreated, with risk of infiltration to the groundwater. As a result of this uncontrolled effluent discharge, the inland water bodies (lakes, canals) and peripheral water bodies of Dhaka have become heavily polluted.

The southern part (the old part and central part) of Dhaka is covered by a conventional sewerage system. DWASA installed a 'Small Bore Sewerage System' in Mirpur under the Dhaka Urban Infrastructure Improvement Project (DUIIP) in 1996 which was financed by ADB; however this system was never properly commissioned. Within the DWASA service area, approximately 20%of the population is potentially served by the centralized separate sewerage system. About 33% of the population is estimated to dispose their sewage by connecting into the drainage networks and open channels. Improved on-site sanitation is estimated to be the sanitation system utilized by approximately 25% of the population within the DWASA Service Area, with the remaining 22% served by unhygienic on-site sanitation means including pit and hanging latrines and open defecation showed in Fig 2.10 (DWASA, 2013).

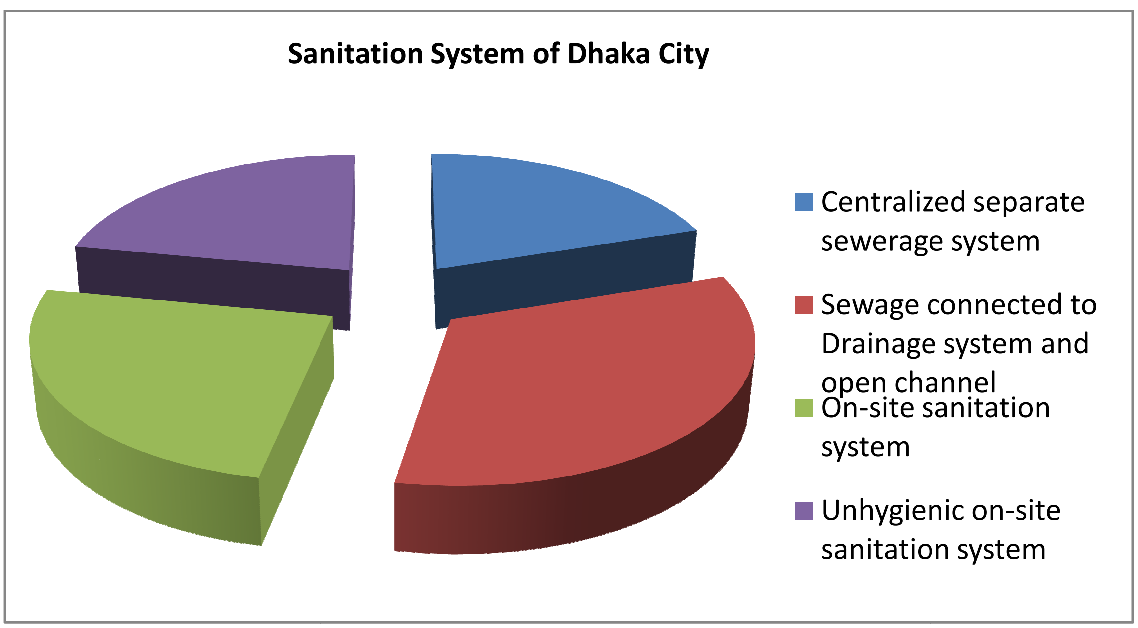

Fig 2.10: Sanitation system of Dhaka city

2.3.1 Infrastructure of sewerage system

The administrative authority for wastewater management in Dhaka City is vested with Dhaka Water Supply and Sewerage Authority (DWASA). DWASA was established in 1963 as an autonomous entity under the Ministry of Local Government, Rural Development and Cooperatives (LGRD&C). Currently DWASA provides three services to the city dwellers i.e. potable water supply, collection and safe disposal of sewage and storm water drainage.

The first piped sewer system for Dhaka City was constructed in 1923. Since then, the sewerage system in Dhaka has been developed slowly due to various limitations. In terms of infrastructure, the city has only 881km of sewer network (of varying pipe materials, status and sizes from Ø100mm to Ø1350 mm) and 64,059 sewer connections (compared to 3036 km of water network and 311,064 water connections), 27 pumping and lifting stations and a sewage treatment plant at Pagla with a peak capacity of 120 MLD (DWASA, 2013).

The sewer network consists of relatively small diameter sewers that are connected via branch lines to the main transmission mains known as ‘trunk sewers’. Within the city, there are 24 sewage ‘lift’ stations (SLSs) and one central pumping station at Narinda that are designed to raise the hydraulic level of the sewage so that it can flow by gravity via the 5 trunk sewers to the treatment plant at Pagla (DWASA, 2013). Manholes have been provided on the route of the mains but most are now inaccessible and in a very poor state, with many being used as receptacles for household waste. Currently only 30% of the city area is served by the sewerage system of which only 20% of the population have connections.

Nearly all of the sewer pipelines have fallen into disuse and disrepair either through sediment build-up, damage or collapse, external construction impacts or overloading. During the condition survey and site visits, it was noted that sewage flows collected in the northeast (Gulshan/Tejgaon) and old/central (Narinda) in addition to the Bashaboo and Swamibagh areas are not being conveyed to Pagla STP and are simply by-passed to local drainage water bodies. As most of the trunk sewers are in a poor state of repair, many of the pumping stations are not operational as there is no available discharge point, and as such the performance of these SLS cannot be confirmed. A common design of the pump stations includes the wet well located under the pump well, which does not facilitate maintenance to remove grit and debris.

2.3.2 Description of the main trunk sewers

There are three main recognized trunk sewers in the city - the eastern trunk sewer, the western trunk sewer, and the south-western trunk sewer. Figure 2.11 shows the three main trunk sewers. The details of the trunk mains including existing conditions, based on the DWASA Sewerage Master Plan (DWASA, 2013) are described as follows:

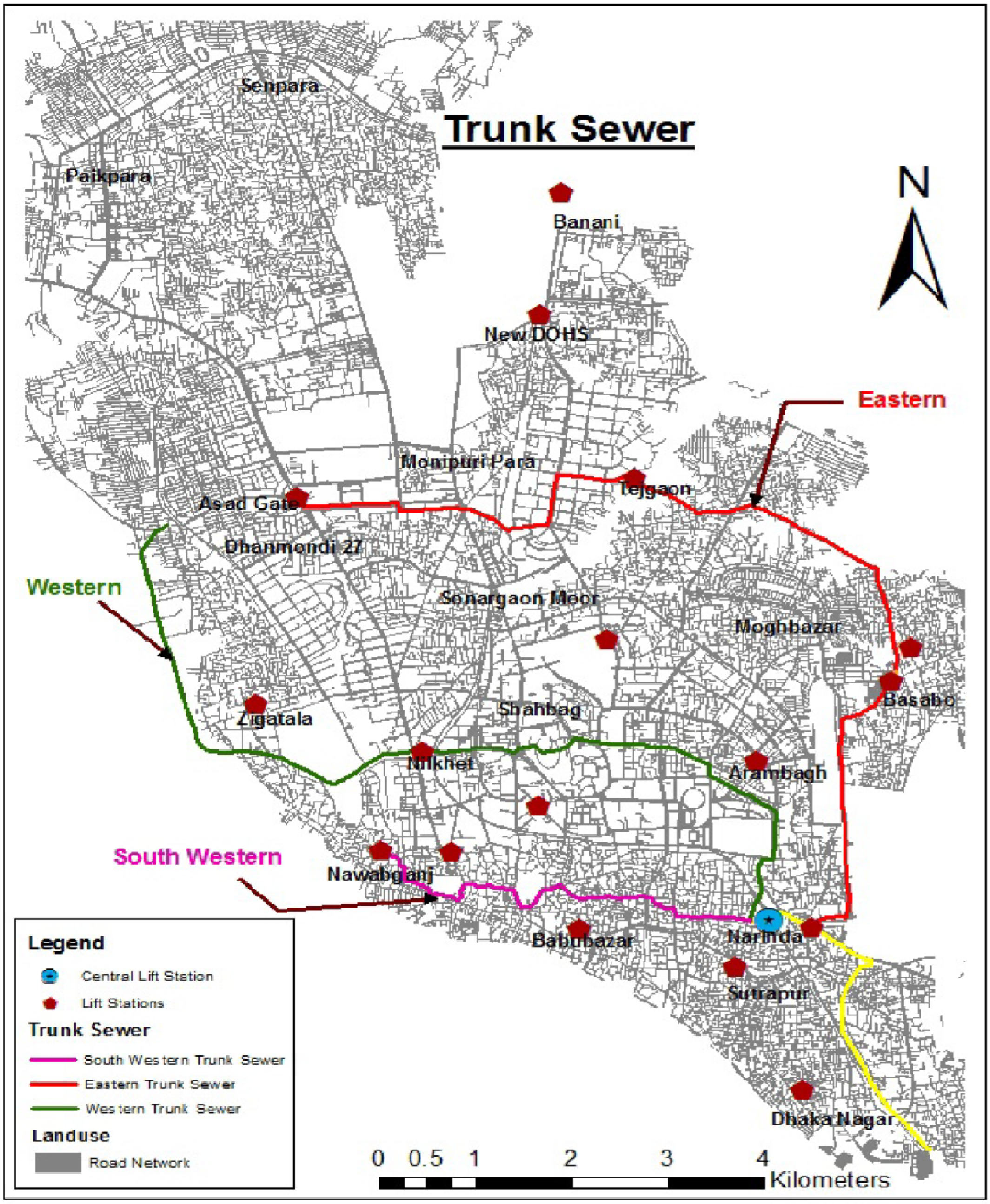

Fig 2.11: Three major trunk sewers and associated lift stations of DWASA Sewerage system (DWASA, 2013)

(i) The eastern trunk sewer: The Eastern Trunk Sewer (see Fig. 2.11) is 14 km in length and the diameter is from 450 mm to 1360 mm routed from Asad Gate to Pagla STP through the lift stations of Tejgaon, Basaboo and Swamibagh. This trunk sewer begins at Asad Gate and ends at Swamibagh pumping station. There are ten pumping stations, which are: Japan Garden City, Asadgate, BijoyShawrani, DOHS Banani, DOHS Mohakhali, Tejgaon, Goran, Madertek, Basaboo and Swamibagh SLSs. For collection and transportation of sewage towards the Pagla sewage treatment plant, pumping stations are used.

(ii) The western trunk sewer: sewer of 6km in overall length and sewer diameter ranging from 600mm to 900mm, routed from Bashbari and Mohammadpur to Narinda PS through Hazaribagh, Nilkhet, Segunbaghicha, Purana Paltan and Motijheel. This trunk sewer starts in the area adjacent to the Hazaribag tannery and ends at Tipusultan road near Narinda graveyard. At this point the main is connected to trunk sewer Hazaribagh Nawabganj - Narinda main, and after these two sewers combined the sewage and it is conveyed to Narinda central pumping station There are five sewage lift pumping stations (SLS) associated with this trunk sewer, viz.: Hazaribag, New Market, Moghbazar T&T and Zikatola. These lift stations collect wastewater from the related catchments and deliver to this trunk sewer which forwards flow by gravity to the Narinda central pumping station.

(iii) The south western trunk sewer: sewer of 6km in length and diameter ranging from 400mm to 1000mm, is located in the south-west part of the city and is routed from Nawabgong to Narinda PS via Lalbagh, Jailkhan Gate, Abul Hasnat Road, Nawabpur Road and Tipu Sultan. This trunk main was rehabilitated in the year 2003. Most of the collection system can be put into operation by extensive cleaning and closing of the bypasses made with the storm water drains.

Figure 2.12 below shows the major lift stations in different sewerage command areas of DWASA sewerage system (DWASA, 2013).

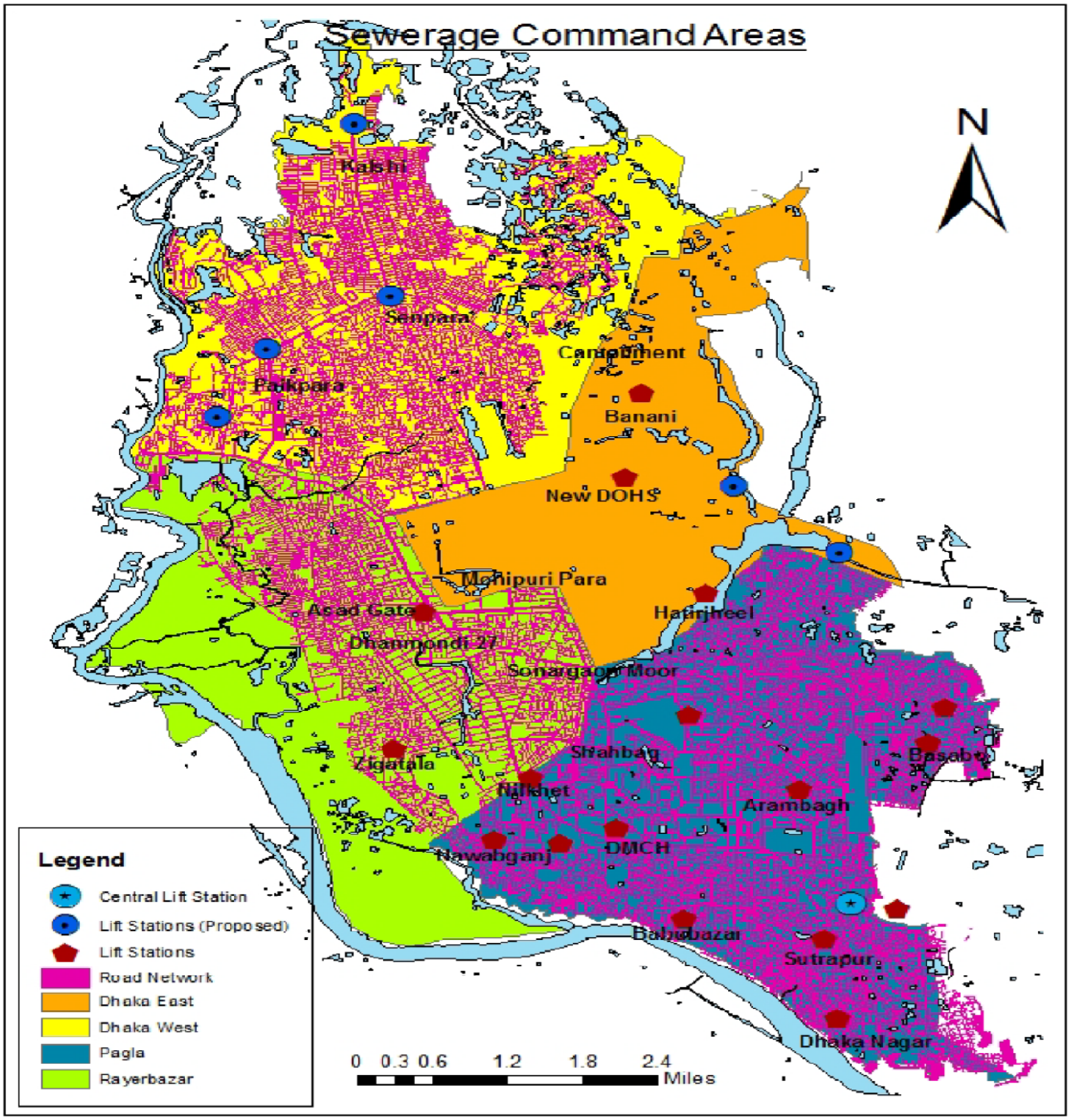

Fig 2.12: Major lift stations (including those proposed in the Sewerage Mater Plan) of DWASA sewerage system (DWASA, 2013)

2.3.3. Condition of trunk mains

The major trunk mains are not operational and suffer from the following problems:

(i) **Eastern trunk main:**

a. The cross-sectional area is semi-circular in shape with a shallow v-shape flat bottom which is hydraulically inefficient.

b. The shape is not amenable to maintenance or rehabilitation. Installation of a new pipeline within the old trunk mains would have far too low capacity to be considered cost-effective.

c. The slope of the trunk main is very shallow (slopes down to 0-0.45/1000) leading to low velocities and consequent deposition of material.

d. The original construction of the trunk mains was in low-lying land. Subsequent to the installation of the trunk mains, the level of the land has been raised by up to 6-7m, possibly leading to structural deficiencies in the pipeline. Additional damage may also have been caused by various construction works.

e. The majority of the trunk sewer manholes have been constructed over by road works hence DWASA MODS do not have access for maintenance. The remaining manholes are often used for disposal of household wastes, leading to downstream blockage. Manhole condition indicates severe corrosion of concrete.

f. DWASA MODS have insufficient sewer cleaning material to implement cleaning of the mains.

g. Illegal connections to the trunk mains and cross connections to the stormwater system.

h. The size (cross-sectional area and slope) of the trunk mains have insufficient capacity (est. 120MLD) to transport the wastewater quantity in the catchment neither to serve the existing catchment (est. 300MLD) nor at the design horizon of year 2035 (up to 500MLD).

i. Parts of the trunk mains require to be re-located due to construction of the Gulistan flyover.

(ii) **Western trunk main:**

a. This 600mm dia. RCC Trunk main traverses from Mohammedpur to Hazaribagh.

b. This Trunk main was constructed in a low lying swampy land. The bed was not properly compacted during construction. As a result some parts of this Trunk main have settled.

c. The joints of the pipes have dislocated.

d. The sewer network of the part of Mohammedpur, Royerbazar and Zigatola area have been connected with this Trunk main.

e. Due to non-functioning of this trunk main, sewage from the related areas are discharged to the nearby low lying areas through the drainage system.

f. The extended part of this trunk main from Hazaribagh to Nilkhet is in good condition and a part of this trunk main has been rehabilitated recently.

g. The end part of this trunk main from Nilkhet to Narinda is functioning partially. Massive cleaning is necessary to make this part effective.

(iii) **South-western trunk main:**

a. This Trunk main traverse from Nawabgonj SLS to Narinda pumping station.

b. This trunk main has been rehabilitated recently and the condition is good, but due to blockage of lateral network it is functioning partially.

c. Cleaning of the related lateral network is essential to make the function of this trunk main effective.

d. By-passes of connections of the drainage system made with this trunk main are necessary to cut off.

2.3.4 Sanitation system

In Dhaka a large number of on-site or hybrid sanitation facilities are in operation, such as septic tanks and pit latrines, typically utilized in areas which are not covered by the conventional sewerage system. Not all sites are suitable for septic tank and on-site soak ways since the soil conditions encountered in Dhaka have low porosity and are not suitable for 'drain away' of the septic tank effluent, consequently the overflow is discharged to a nearby drainage system. The sludge, collected and accumulated in the tanks, should regularly be removed and disposed of in a safe and controlled manner, however there are no septic tank sludge treatment and disposal facilities. Consequently, waste collected from bucket latrines and sludge collected by private septic tank cleaning services are deposited in local lowlands, drains and "khals". The septic sludge collected is also disposed at municipal waste collection points, on road sides, in drainage canals and into sewer lines via manholes. This practice is illegal, highly hazardous, unregulated and contributes to the uncontrolled spreading of pollution and pathogenic organisms over large areas.

2.4 Analysis of Sewerage Master Plan of DWASA

The overall objective of the sewerage master plan of DWASA (DWASA, 2013) was updating/preparation of sewerage master plan of Dhaka city and preparation of detail design & bidding documents for priority works for existing sewerage system (Package DS-1A) with a view to develop a detailed and comprehensive master plan for the wastewater management and sanitation system of Dhaka city. In this master plan sanitation infrastructure planning was prepared based on sanitation catchment boundaries, associated population demographics for the year 2035 and the expected development of urban centers to be serviced by sewerage systems or transitional areas serviced by on-site and hybrid sanitation systems. Under the Master Plan, 11 sanitation catchment areas were taken into consideration, which are as follows:

1. Dhaka East (Dasherkandi) Sewerage Catchment.
2. Dhaka West (Mirpur) Sewerage Catchment
3. Rayerbazar (Kamrangirchar) Sewerage Catchment

4. Dhaka South (Pagla) Sewerage Catchment
5. DND-Demra Sewerage Catchment
6. Dhaka North (Uttara) Sewerage Catchment
7. Rupganj (Purbachal) Sewerage Catchment
8. Narayanganj Sewerage Catchment
   (8a) Narayanganj Paurashava (West bank of Lakhya River)
   (8b) Kadam Rasul Paurashava (East bank of Lakhya River)
9. Savar Sewerage Catchment
10. Tongi/Gazipur Sewerage Catchment
    (10a) Tongi Paurashava Area
    (10b) Gazipur Area
11. Keraniganj Sewerage Catchment

Table 2.3 below shows the catchments and the areas under these catchments. Thus, the DWASA Maters Plan covers a total area of 542.267 km^2, which includes 402.575 km^2 within DWASA service area, and 139.692 km^2 under greater Dhaka.

Table 2.3: DWASA Sewerage catchments and respective catchment areas

Sl. No.	Catchment	Area (km^2)
Greater Dhaka		
1	Savar	27.695
2	Tongi	33.073
Gazipur		38.723
3	Rupganj (Purbachal)	25.733
4	Keraniganj	14.468
DWASA Service Area		
1	Dhaka North (Uttara)	72.644
2	Dhaka West (Mirpur)	47.358
3	Dhaka East (Dasherkandi)	69.380
4	Rayerbazar (Kamrangirchar)	28.450
5	Dhaka South (Pagla)	62.539
6	Demra-DND	58.789
7	Narayanganj East	24.934
Narayanganj West		38.481
	Total	**542.267**

Figure 2.13 shows below the 11 sewerage catchments with proposed STPs under DWASA Sewerage Master Plan (DWASA, 2013).

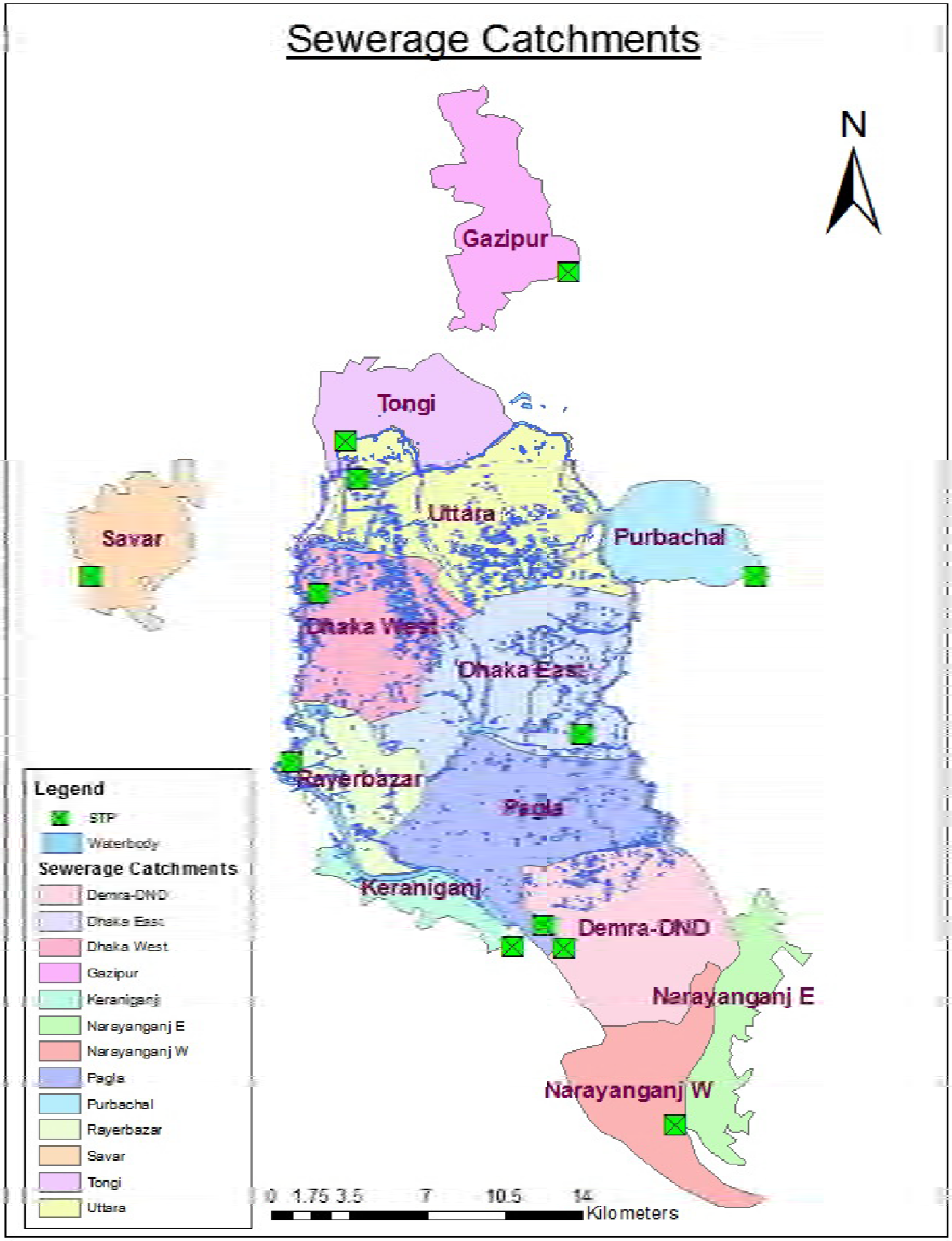

Fig 2.13: Sewerage catchments with proposed STP according to DWASA Master Plan (DWASA, 2013)

Total 12 sewage treatment plants (STPs) (including the existing Pagla STP) have been proposed for the sewerage catchments; one STP has been proposed for each catchment, except for Tongi/Gazipur catchment, for which two STPs have been proposed, one in Tongi and one in Gazipur. In the Sewerage Master Plan, the location of each treatment plant has been identified considering the proximity of receiving waters, reasonable distance for transferring wastewater (preferably within 5 km of the urban center), availability of affordable land, and consistency with the DMDP Local Area Plans. Table 2.4 summarizes the important features of the STPs according to the DWASA Sewerage Master Plan.

Table 2.4: Important features of the STP proposed in the DWASA Sewerage Master Plan (DWASA, 2013)

Sl. No.	Catchment Served	STP Location	Population Served*	STP Area Reqd ** (ha)	Waste Water Flow Rate (m^3/day)		Receiving Water
					DWF	Peak	
1.	Savar	Savar	4,00,000	5	46,000	69,000	Dhaleswari
2.	Tongi	Tongi	8,00,000	10	92,000	1,38,000	Turag
3.	Gazipur	Gazipur	4,00,000	5	46,000	69,000	Tongi Khal
4.	Rupgang	Purbachal	5,00,000	6	57,500	86,250	Lakhya
5.	Keranigang	Keranigang	4,00,000	5	46,,000	69,000	Buriganga
6.	Dhaka North	Uttara	16,00,000	20	1,84,000	2,76,000	Tongi Khal
7.	Dhaka West	Mirpur	28,00,000	34	3,22,000	4,83,000	Turag
8.	Dhaka East	Dasherkandi	24,00,000	25	2,76,000	4,14,000	Balu
9.	Rayer Bazar	Rayer Bazar	16,00,000	20	1,84,000	2,76,000	Buriganga
10.	Dhaka South	Pagla	42,00,000	51	4,83,000	7,24,000	Buriganga
11.	DND-Demra	Pagla	9,00,000	12	1,03,500	1,55,250	Buriganga
12.	Narayangang	Gonganagar	14,00,000	17	1,61,000	2,41,500	Dhaleswari

*For the year 2025; **Considering Trickling Filter Process

2.5 Drainage System of Dhaka City

The existing internal drainage systems of Dhaka City having an area of approximately 275 km^2 consists of storm sewer lines, surface drains and open channels (locally known as Khals (JICA, 1991).This drainage system ideally carry the storm water as well as a part of waste water generated in the city to the surrounding river Buriganga in the south, river Balu in the east, river Turag in the west and Tongi canal in the north . Water levels in these rivers are lowest in January-February and the highest in August-September. Based on flood control infrastructures, greater Dhaka is divided in two parts, Dhaka West and Dhaka East where the lowlands are within the floodplain of the Balu River (KHAN, 2006) .These parts are divided by Mymensingh road, Pragati Swarani, DIT road and Biswa road that were raised after devastating flood of 1988 to perform as road-cum-embankment. Areas covered by Dhaka West and Dhaka East are156 km^2 and 119 km^2 respectively. Following figure 2.13 shows the drainage system of Dhaka city (DWASA, 2015).

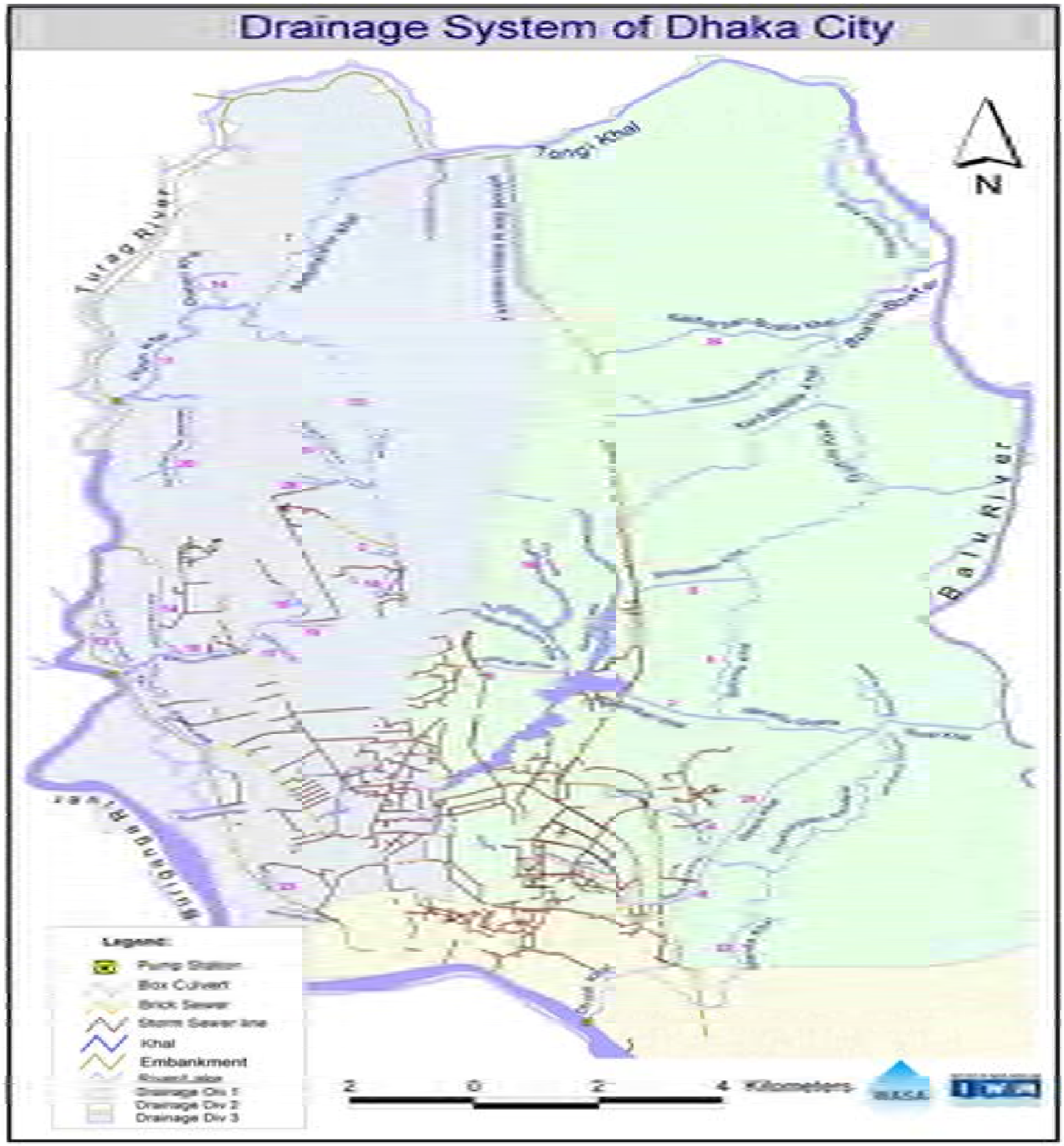

Fig 2.14: Drainage system map of Dhaka city (DWASA, 2015)

It may be mentioned that there were a good number of open channels in the city areas which played a vital role to provide storm water drainage to the city. Also there was sufficient low land around the city which acted as flood plan of the concerned command area to retain the excess water for time being. With rapid urbanization and unplanned development, most of these khals and flood plain have been filled up and the capacity of natural drainage has diminished dramatically. It is estimated that there are approximately 43 natural khals, totaling about 145 km that are part of the khal system. In addition to the open channels and lakes, there are about 280 km of storm sewer lines that covers about 140 km^2 of Dhaka and 10.5 km of box culverts that make up the storm water system of Dhaka. Storm sewer lines are range in the sizes from 0.6 m to 3.0 m in diameter made of brick and concrete.

Dhaka has a tropical monsoon climate with four climatologically seasons: pre-monsoon (March to May), monsoon (June to September), post-monsoon (October to November) and dry season (December to February). The monsoon is the rainy season with heavy rainfall. Annual average rainfall in Dhaka is approximately 2000mm. Maximum daily rainfall during this period is about 200 (Hossain et al., 2004). The pick monthly rainfall occurs before surrounding rivers attain the highest stage. Runoff from urban areas as a result of rainfall is generally higher than those from rural areas due to many impervious surfaces viz., roofs of houses, paved roads, parking lots etc in the urban areas.

2.5.1 Storm water drainage system

The growth of DMA represents a dramatic transformation of natural landscape. This growth and expansion characterized by a rapid and uncontrolled development, leads to wasteful use of land resources, higher infrastructure cost, excessive energy demand,, and consumption and degradation of environment. Land pressure is greater due to the high rate of population growth The natural drainage system in Greater Dhaka is composed of several lakes and lowlands, and about 40 khals, that drain storm-water from 80% of the city area to the surrounding rivers, comprising three major khal systems: (1) Degun-Ibrahimpur-Kallyanpur khal system which drains to Turag River; (2) Dhanmondi-Paribag-Gulshan-Banani-Mahakhali-Hatirjheel khal system which drains to Balu River; (3) Segubagicha-Gerani-Dholai khal system which drains to Balu and Buriganga Rivers. There are several lakes and lowlands that provide detention storage for internal storm-water in Dhaka West. Hatirjheel, a part of the Dhanmondi Gulshan-Begunbari khal system that drains about one-third of Dhaka West through the Rampura regulator, is a major detention area in Dhaka West and provides both storage and conveyance to the storm-water flow. The catchment area of the khals in the Dhaka West varies from 6 to 40 km^2 (Samad, 2009).

In the master plan for greater Dhaka protection project (JICA, 1991), the flood mitigation and storm water drainage plan was prepared following several previous studies. Again a subsequent feasibility study (JICA, 1992) has also been conducted. This plan includes several structural measures by dividing greater Dhaka in 3 drainage compartments and a number of sub-compartments. These compartments were rearranged as drainage zones of previous study done by (JICA, 1987). In those studies, the flood mitigation plan was laid out mainly for Dhaka east, which includes an eastern embankment along the Balu River and 3 cross embankments.

This storm water drainage plan demarcates pumping and gravity drainage areas. Here in addition to the 3 pump stations installed in Dhaka west, 4 more pump stations with about 180 cumsec of total pumping capacity were required in Dhaka East. The pumps were expected to operate from June to October, when the regulator and sluice gates would be closed because of relatively high external (river) water level. However, since this plan has been implemented only in Dhaka west, drainage zones F, G and C, which were planned to pump water through Dhaka East, remain as gravity drainage areas. The design rainfall in the hydraulic design criteria is 245 mm, which is 2-day cumulative rainfall having 5-year return period. The 2-day draining period by the pumps has been selected based on technical and economical justifications. A runoff ratio 0.8 was used for estimating the specific capacity of pumps and specific storage volume of retarding ponds, which were selected to be 1.14 cum/sec and 0.12x106 cum/km^2 of catchment area, respectively. However, in (Chowdhury et al., 1998) much lower runoff was found in the range between 0.4-0.7 based on measured data in different catchments of Dhaka city.

2.5.2 Flooding and drainage condition

In the greater Dhaka city, severe floods are mainly caused by spill from surrounding rivers namely Turag, Balu and Buriganga River, which are connected to the major rivers of the country and receive water discharges from the Brahmaputra-Jamuna River. Turag and Buriganga Rivers are distributaries of the old Brahmaputra River and Balu River is the tributary of the Lakhya Rive.Tongi khal connects the Turag River with the Balu River. Flooding in the Dhaka city usually occurs during the months of July to September when the surrounding rivers cannot accommodate the water flow within the main courses. The water levels in the surrounding rivers are affected by backwater from Dhaleswari, Shitalakhya and Meghna Rivers. The Balu, Turag and Buriganga Rivers are under influence of the tides in the lower Meghna (Samad, 2009).

Recently Bangladesh experienced major floods in 1988, 1998 and 2004. After the 1998 flood, priority measures were undertaken to protect Dhaka West from river floods, which were partially completed before the 1998 flood. Although Dhaka West was protected after 1998, drainage improvement actions became necessary because of the ensuing internal storm water flooding occurrences (Samad, 2009). In 1998, Dhaka West was flooded mostly because of floodwater intrusion through incomplete parts of the protection work and failure of control structures (Chowdhury et al., 1998). Additionally, storm water flooding occurred in some areas after the regulator and sluice gates were closed. There is a special embankment at the Hazrat Shahjalal International Airport of 10.53 km length. Another rail/road cum embankment is proposed for the eastern part of the city that will run along the Balu River for a length of 29 km. The flood control and drainage works have brought major changes in the flood regime in Dhaka West (JICA, 1990).

2.6 Analysis of Drainage Master Plan of DWASA

The Drainage Master Plan of DWASA contains a study on storm water drainage issues in Dhaka city, with structural and non-structural proposals regarding the improvement of DWASA drainage conditions and management. The plan focuses on the period up to the year 2040.For formulating the master plan more effectively the whole area of Dhaka megacity has been divided into 13 drainage management zone and every management zone is divided into number of sub-catchment. All proposed structural and non-structural interventions for these zones are discussed below. The designated 13 Zones are shown below in table 2.7(DWASA, 2015).

Table 2.5: Designated Drainage Zone for Dhaka City (DWASA, 2015)

No	Zone name (and Code)	Area (Km^2)	No of Sub Catchments	Name of some of the localities	Area Classification
1.	Goranchatbari/ Uttara (GCB)	70.81	56	Abdullahpur,Uttara,New Airport,Mirpur,Pallabi,cantonment, Goranchatbari	Core
2.	Kallyanpur/Mirpur (KLN)	32.03	55	Mirpur,Mohammadpur,Kallyanpur,Katasur,Dhanmondi,Hajaribagh	Core
3.	Dolaikhal and Old Dhaka (DHK)	22.98	50	Lalbagh,Haaribagh,Kamrangirchar	Core
4.	Dhaka-Narayanganj-demra (DND)	97.47	47	Demra,Siddirganj,Kutubpur,Godnail, KadamRasul,Fatullah,Enayetnagar,Kashipur,Shyampur	Fringe
5.	Kamalapur/Khilgaon (KML)	43.06	36	Kamalapur,Khilgaon,Gerani Khal, Manda Khal, Segunbagicha	Core
6.	Hatirjheel/Rampura (RMP)	28.22	27	Gulshan,Tejgaon,Ramna	Core
7.	Badda (BDD)	45.45	13	Badda,Shahjadpur,Begunbari	Core
8.	Uttarkhan (UTK)	42.28	11	Uttarkhan,Azampur,Tongi	Fringe
9.	Gazipur and Tongi (GZT)	243.41	44	Gazipur,Pubail,Tongi Paurasava,Gachha,Basan	Fringe
10	Savar/Ashulia (SVR)	218.31	50	Kashimpur,Ashulia,Savar Paurasava,Banagram	Fringe
11.	Keraniganj (KRN)	183.15	40		Fringe
12.	Narayanganj(NRN)	183.15	40	Narayanganj,Murapara,TaraboMadanpur,Damgarh,Shambhupura,Kalagachia,Kanchan	Fringe
13.	Purbachal	156.94	26	Purbachal,Daudpur,Tumulia,Nagari,	Core

In Zone-6, in Hatirjheel/Rampura (RMP), Hatirjheel Lake and Gulshan-Banani Lake can play the role of water reservoir here. For this context Gulshan-Banani Lake need to be upgraded immediately with proper depth and width. The age-old faulty Trunk line runs through the Hatirjheel Lake need to be immediately removed / realigned/ rehabilitated. Considering Hatirjheel Lake the center point, sewer networks at North and East need to divert to Dasherkandi. The remaining networks at West need to divert to Pagla STP. The operational recommendations of DWASA Drainage Master Plan [8] are as follows:

a. DWASA has to transform the drainage demand into reality in order to achieve a water logging free Dhaka city.

b. Expansion and rehabilitation of the existing drainage system is required.

c. Sewer lines should be separated from storm water drainage system.

d. Adequate solid waste disposal system should be made available to the city dwellers to prevent clogging of the storm water drainage system. This should be accompanied by a public awareness campaign on the relation between basic hygiene, solid waste and storm water drainage.

e. All internal drainage and flood control infrastructure should be handed over to Dhaka WASA for operation and maintenance.

f. All the existing natural drainage routes should be freed from encroachment immediately.

g. A joint venture program with DCC is required. RAJUK should ensure that the development of eastern Dhaka is carried out under a master plan which should integrate land use development with that of service utilities, like storm water drainage, water supply and sewerage system.

Following fig.2.15 shows the proposed structural drainage improvement measures in Rampura Zone (DWASA, 2015):

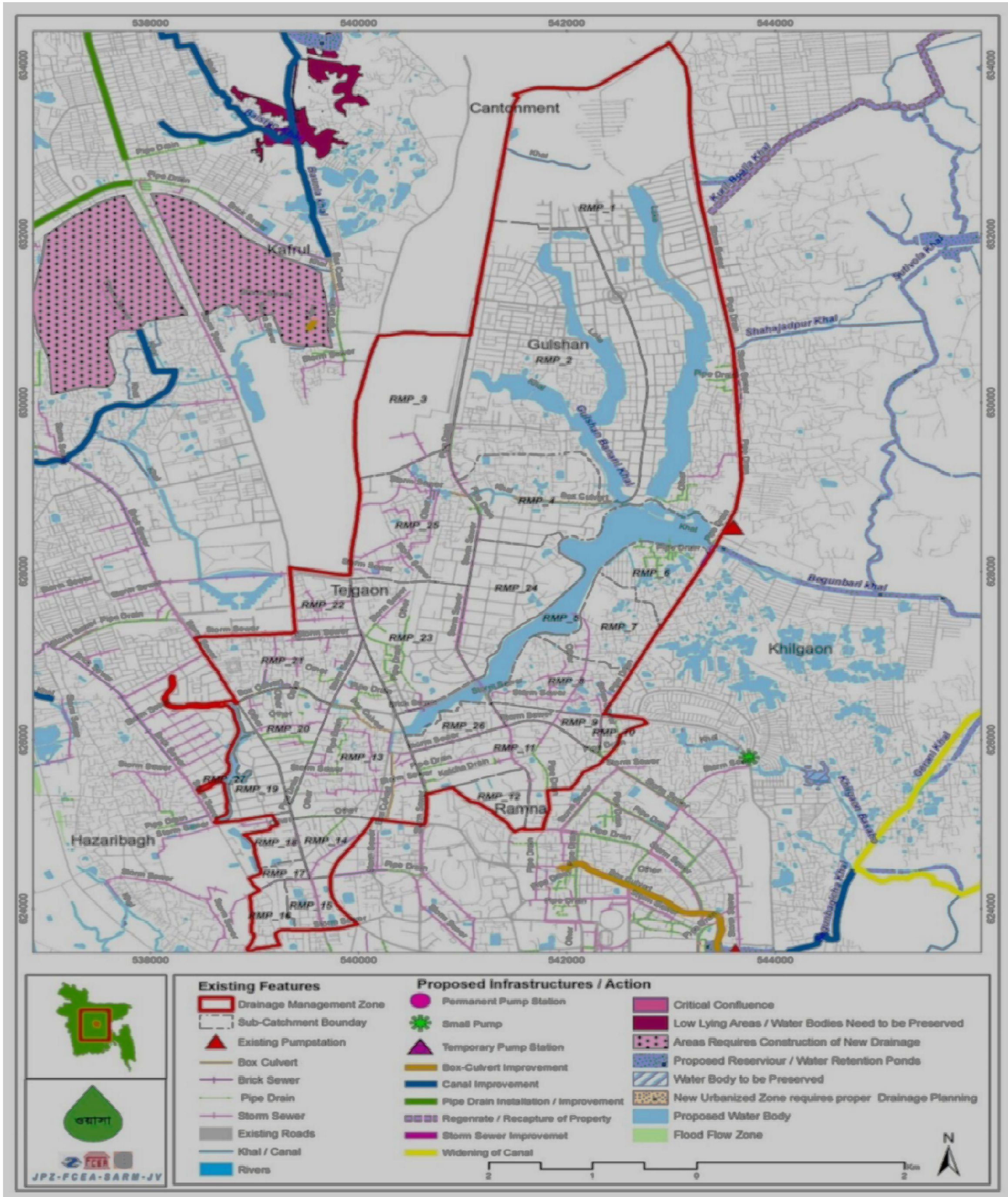

Fig 2.15: Proposed structural drainage improvement measures in Rampura zone (DWASA, 2015)

2.7 Wastewater Treatment Plant

DWASA operates a sewage treatment plant at Pagla (PSTP) located on an 110.5 ha site approximately 8km from the city centre in the south-east of Dhaka City and approximately 1km north of the Buriganga River. The Pagla STP was originally constructed in 1978 and provides treatment of the wastewater collected by the central sewerage system and is currently the only treatment facility in the city, although another is proposed for construction to service the Hartijheel scheme located at Dasherkandi. The current design capacity is 96 MLD (average flow rate) and 120 MLD (peak flow rate) while the current sewage generated within the catchment served by the centralized sewerage system is approximately 250- 300MLD, and is expected to exceed 500MLD at the Master Plan design horizon. Due to damage of the trunk mains and sewerage system, the actual flow rate entering the Pagla STP is approximately 30-40MLD, i.e. the treatment plant is significantly under-loaded and should provide a high level of treatment.

The table 2.5 & 2.6 below gives the basic design performance of the various stages of treatment that should result in a 50 mg/L BOD_5 and 60mg/L suspended solids discharge effluent (DWASA, 2013).

Table 2.6: Key Design Characteristics of Pagla Sewage Treatment Plant

Water Quality Parameters	Influent (mg/L)	Primary Sedimentation Tank		Facultative Lagoon		Total Removal Ratio (%)
		Removal Ratio (%)	Effluent (mg/L)	Removal Ratio (%)	Effluent (mg/L)	
BOD_5	200	40	120	59	50	75
SS	200	60	80	25	60	70

Table 2.7: Water Quality and Removal Rate of BOD_5 and Suspended Solids (2009-2010)

Date	Inlet (mg/L)		PST Effluent(mg/L)		Facultative lagoon Effluent(mg/L)		Overall Removal (%)	
	BOD_5	SS	BOD_5	SS	BOD_5	SS	BOD_5	SS
Average	340	351	127	119	49	58	85	83

There is limited unused area remaining on the existing site hence the existing treatment process of facultative ponds cannot be utilized to meet the long-term requirements of the Pagla catchment. Further, the existing treatment plant suffers from a number of operations and maintenance problems which decreases the quality of the effluent, including:

a. Primary sedimentation tank scrapers do not efficiently cover the tank floor hence sludge is not collected and removed. It is recommended to de-rate the capacity of the primary sedimentation tanks to 100MLD.
b. The facultative ponds have accumulated sludge which should be emptied; the disinfection system is not operational.

2.7 Summary

Dhaka WASA is planning to develop a separate sewerage network for Dasherkandi STP catchment. Dasherkandi Catchment includes high density areas in Gulshan, Tejgaon and north-east Khilgaon which will continue densification and low density area of Badda, which is expected to become medium density and also the southern region of Badda, which is already developing into a medium-high density area. Expected population in this catchment is projected to be 3.67 million by the year 2034. High density areas of the catchment are expected to have water-borne sewerage systems discharging to STP at Dasherkandi. At the same time, DWASA is planning separate sewerage system for Pagla catchment and Rayerbazar catchment areas; storm water and sewage from large parts of these two catchments currently drain through Hatirjheel main diversion sewer. It is important to understand the possible changes in composition of storm water and sewage when these DWASA projects would be implemented. The overall objective of this research work isto assess the characteristics of combined flow of storm water and sewage flowing through the Hatirjheel main diversion sewer system, and implications of ongoing/future sewerage development works on Dasherkandi STP.

CHAPTER 3

METHODOLOGY

3.1 General

The overall objective of the present research is to assess the characteristics of combined flow of storm water and sewage flowing through the Hatirjheel main diversion sewer system and implications of ongoing/future sewerage development works on Dasherkandi STP. This chapter presents detailed methodology for assessment of the characteristics of flow through the main diversion sewer during both dry and wet season. It then presents the considerations used for assessment of possible impact of sewage characteristics and its implications on Dasherkandi STP.

3.2 Assessment of Flow Characteristics of Main Diversion Sewer System

Assessment of flow characteristics of main diversion sewer system is discussed under location of collecting wastewater samples, sampling schedule, their analyzing parameters and the implications of these characteristics of future sewage development on Dasherkandi STP.

3.2.1 Collection of wastewater samples

In order to assess characteristics for dry season and wet season flows through the main diversion sewers of Hatirjheel, wastewater samples were collected from the pond area which receives wastewater flows of main diversion sewers from both southern and northern sides of Hatirjheel (located close to Rampura Bridge(Fig 3.1 and Fig 3.2) which receives flows of mainfrom diversion sewers from both northern and southern sides of Hatirjheel. In addition, wastewater samples were also collected for characterization of flows coming through the main diversion sewer from northern and southern sides of Hatirjheel (Fig 3.3).

Fig 3.1: Sampling location for collection of samples representing combined flows of main diversion sewer from southern and northern sides of Hatirjheel

Fig 3.2 Collection of wastewater sample from the pit/manhole which receives sewer from both northern and southern sides of Hatirjheel.

Fig 3.3: Sampling locations (pit/manhole) for collection of wastewater samples coming from the northern side (left) and Southern side (right) in Hatirjheel.

Table 3.1 below shows the schedule of sample collection. Collection of wastewater samples was carried out on two alternative working and holidays. During each sampling campaign, samples were collected at 0600 hrs, 0800 hrs, 1000 hrs, 1200 hrs, 1400 hrs and 1600 hrs.

Table 3.1: Sampling schedule for characterization of Hatirjheel main diversion sewer system

Sampling Cycle	**Date of sampling Collection**	**Season**	**Sewage sample**
1	12 May 2017 (Friday)	Summer	Main Diversion Sewer
2	14 May 2017 (Sunday)	Summer	Main Diversion Sewer
3	11 August 2017 (Friday)	Rainy /Monsoon	Main Diversion Sewer
4	12 August 2017 (Saturday)	Rainy /Monsoon	Main Diversion Sewer
5	14 December 2017 (Thursday)	Dry/Winter(Dry Season)	Main Diversion Sewer and sewer from northern and southern sides of Hatirjheel
6	15 December 2017 (Friday)	Dry/Winter(Dry Season)	Main Diversion Sewer and sewer from northern and southern sides of Hatirjheel

Wastewater samples were collected in pre-washed plastic containers; the containers were rinsed with the wastewater samples prior to sample collection. After collection of samples, the sampling containers were placed in ice-boxes for subsequent transport to the Environmental Engineering laboratory of BUET for analysis. A total of 44 wastewater samples were collected as part of this research for characterization of flows through the main diversion sewer of Hatirjheel.

3.2.2 Analysis of wastewater samples

All wastewater samples collected from the main diversion sewer systems of Hatirjheel were analyzed for a wide range of parameters including pH, Color, Turbidity, Temperature, Electrical Conductivity (EC), TDS, TSS, Alkalinity, Ammonia, Nitrate, Phosphate, Biochemical Oxygen Demand (BOD_5) and Chemical Oxygen Demand(COD). Available data suggest the flows through the diversion sewer do not contain sufficient concentration of heavy metals; therefore, heavy metal concentrations were not measured. p^H was measured with a p^H meter(Hach),turbidity with a Turbidity meter, and EC with a Conductivity meter. Alkalinity was measured by titration with standard sulfuric acid solution, following Standard Methods. Color, ammonia, nitrate and phosphate concentrations were measured with a Spectrophotometer (HACH, DR, 4000). Ammonia was measured using Nessler method, and nitrate was measured by Cadmium Reduction Method. BOD_5 was measured following Standard Methods and COD (dichromate) was measured with a Spectrophotometer, following Standard Methods. All chemicals used in this research were of reagent grade. Double distilled water was used for preparation of all reagents, and for dilution of samples.

3.3 Implications of Wastewater Quality and Future Sewage Development of Dasherkandi STP

As discussed earlier, the combined wastewater flows from the main diversion sewers of Hatirjheel will be carried to the Dasherkandi STP (using a pumping station to be built at Rampura) for treatment. During dry season the main diversion sewers of Hatirjheel carry primary domestic sewage, while during wet season it carries combined flow to sewage and storm water. Thus, flows through the main diversion sewer are likely to be significantly diluted compared to that during dry season. Possible impacts of wastewater quality during dry and wet seasons on the Dasherkandi STP were analyzed by comparing characteristics of wastewater flows during day and wet season.

Dhaka WASA is planning to implement a number of sewerage projects, which could significantly impact both flow and characteristics of wastewater flowing to Dasherkandi STP. The impacts of these projects on Dasherkandi STP have been assessed as a part of this research. In this assessment, the following projects/developments have been considered:

(1) Renovation of Pagla Sewerage Treatment Plant as associated sewerage system;
(2) Construction of Rayerbazar sewage Treatment Plant and associated sewerage system; and
(3) Development of sewerage network for Dasherkandi catchment.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The primary objective of this research was to assess the characteristics of storm water and sewage flowing through the Hatirjheel main diversion sewer system and implications of ongoing/future sewerage development works on Dasherkandi STP. This chapter presents an assessment of quality of combined sewage-storm water flowing through the main diversion sewers of Hatirjheel, during both dry and wet seasons, based on the test results of samples collected during the study. The combined flows from Hatirjheel main diversion sewers would be transported to the Dasherkandi STP for treatment. A comparison of the characteristics of the dry and wet weather flows of main diversion sewer system has been presented in this Chapter, in an effort to understand the characteristics of wastewater to be treated at the under-construction Dasherkandi STP. This Chapter also provides an assessment of possible impacts of ongoing/planned projects of DWASA like sewerage networks and STPs in Pagla and Rayerbazar catchments on operation of the Dasherkandi STP. Appendix presents the characteristics of all wastewater samples collected and analyzed in this study.

4.2 Characteristics of Wastewater: Dry Season

This section provides an assessment of the characteristics of flow of main diversion sewer system of Hatirjheel during both dry seasons, based on analysis of wastewater samples collected during this research work. The wastewater samples were analyzed for a wide range of parameters including pH, color, turbidity, electrical conductivity (EC), TDS, TSS, alkalinity, ammonia, nitrate, phosphate, COD and BOD_5.

4.2.1 Characteristics of combined flow during dry Season

In order to assess characteristics of dry weather flow through main diversion sewer system of Hatirjheel, combined wastewater samples were collected on 14th December 2017 (Thursday, a week day) and on 15th December (Friday, a holiday). The samples were collected at 0600, 0800, 1000, 1200, 1400 & and 1600 hrs, in order to understand the characteristics of wastewater as a function of time of the day. This Section presents the variation of different parameters of combined flow during the dry season.

(i) pH

Figure 4.1 shows variation of pH of the wastewater samples collected on 14th and 15th December 2017 at different sampling times. On the weekday (14th December), pH varied from 7.11 to 7.41 during the sampling period. It shows that the variation of pH value over the day is not very significant. During the weekend (i.e., 15th December), pH value varied from 6.15 to 7.32; the variation of pH over the day was not very significant. In general, the pH values recorded during weekend are slightly lower than those recorded during the weekday.

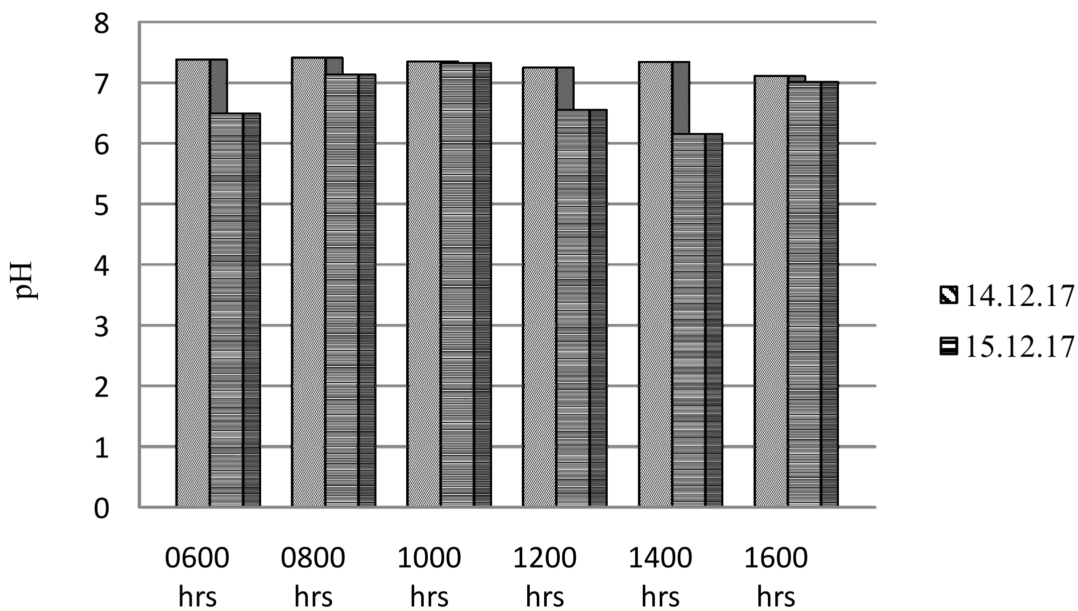

Fig 4.1: Variation of pH of wastewater samples collected in December 2017 (dry season)

(ii) Color

Figure 4.2 shows the variation of color of the wastewater samples collected in December 2017. On the weekday (14th December), color value varied from 283 to 398 Pt-Co unit. No particular trend was observed in the variation of color with time. During the weekend (15th December), color varied from 256 to 535 Pt.Co. unit; in this case also no particular trend was observed for variation of color with time of the day. Relatively high concentration of color was recorded during the weekend (compared to weekday).

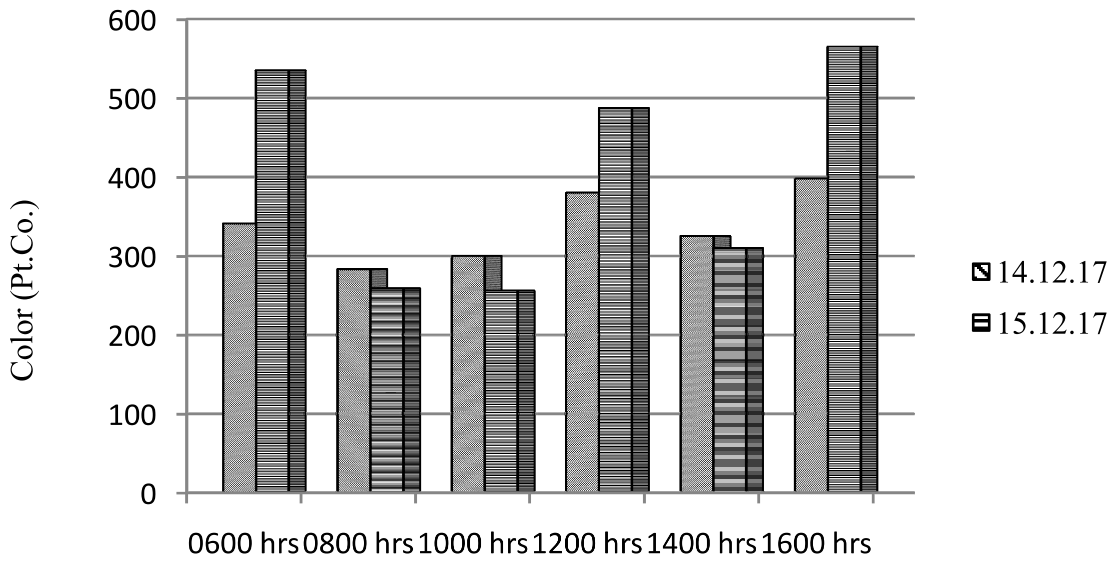

Fig 4.2: Color of combined wastewater samples collected during dry season in December 2017

(iii) Turbidity

Figure 4.3 shows variation of Turbidity of wastewater samples collected in December 2017. Figure 4.3 shows a clear trend of the variation of Turbidity with time of the day; Turbidity of wastewater samples increases as the day progresses. This suggests Turbidity increases as water use increases with progress of the day. During the weekday (14^{th} December), Turbidity varied from 37.7 to 217 NTU; the lowest Turbidity of 37.7 NTU was recorded at 0600 hours, while the highest Turbidity of 217 NTU was recorded at 1600 hours. On the weekday (15^{th} December), Turbidity varied from 81 to 284 NTU; highest Turbidity of 284 NTU was recorded at 1400 hours. In general, Turbidity values during the weekend were found to be higher compared to those during the weekday.

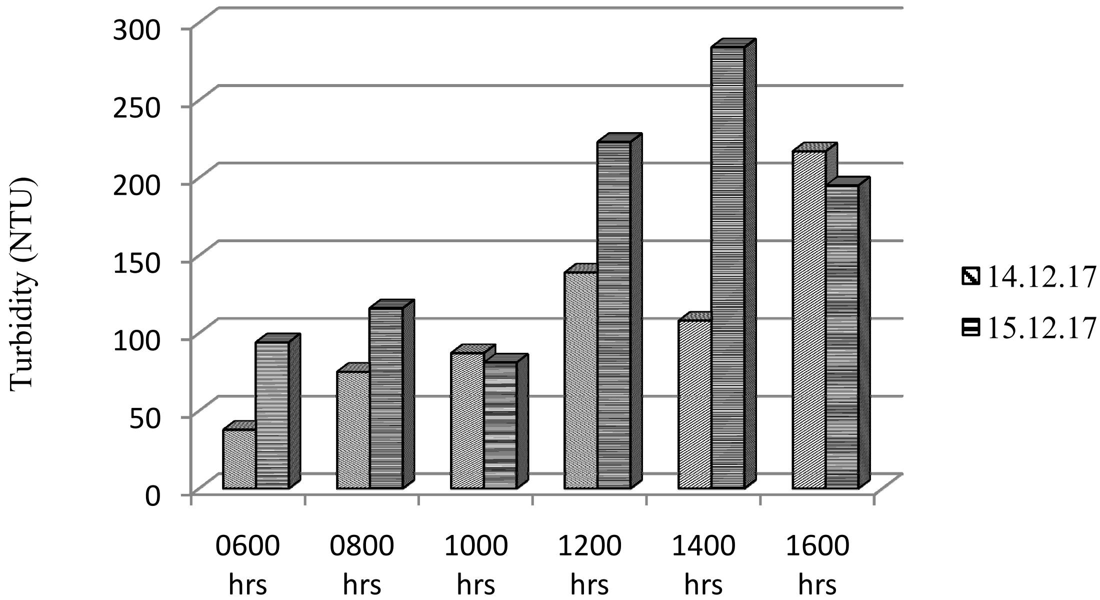

Fig 4.3: Variation of Turbidity of wastewater samples collected in December 2017

(iv) Electrical Conductivity (EC) and TDS

Figure 4.4 and Figure 4.5 show variation of Electrical Conductivity (EC) and TDS, respectively, of the samples collected in December 2017. As expected, variations of EC and TDS have been found to be similar. The EC values of the samples collected on the weekday (14th December) varied from 800 to 1055 μS/cm; while it varied from 730 to 856 μS/cm for samples collected on the weekend (15th December). The variation of EC over the day was not found to be significant. With a few exceptions, the EC values during the weekday were slightly higher than those recorded during the weekend.

The TDS values of samples collected during the weekday (14th December) varied from 426 to 505 mg/l; while they varied from 412 to 618 mg/l for samples collected on the weekend (15th December). As with EC, the variation of TDS values over the day was not very significant. The TDS values recorded during the weekday and weekend were found to be comparable.

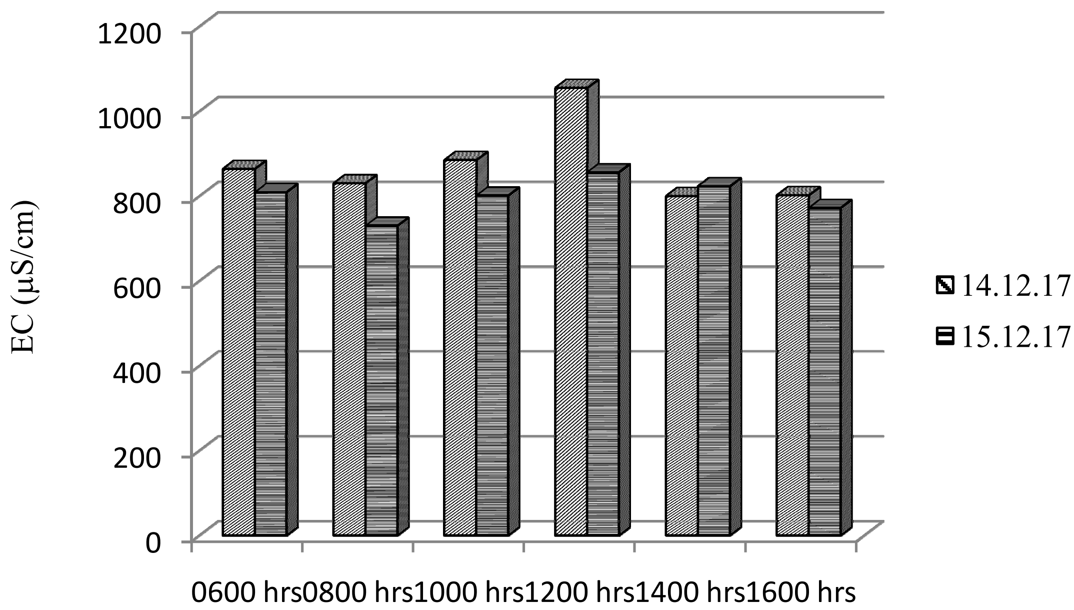

Fig 4.4: Variation of Electrical Conductivity (EC) of wastewater samples Collected in December 2017

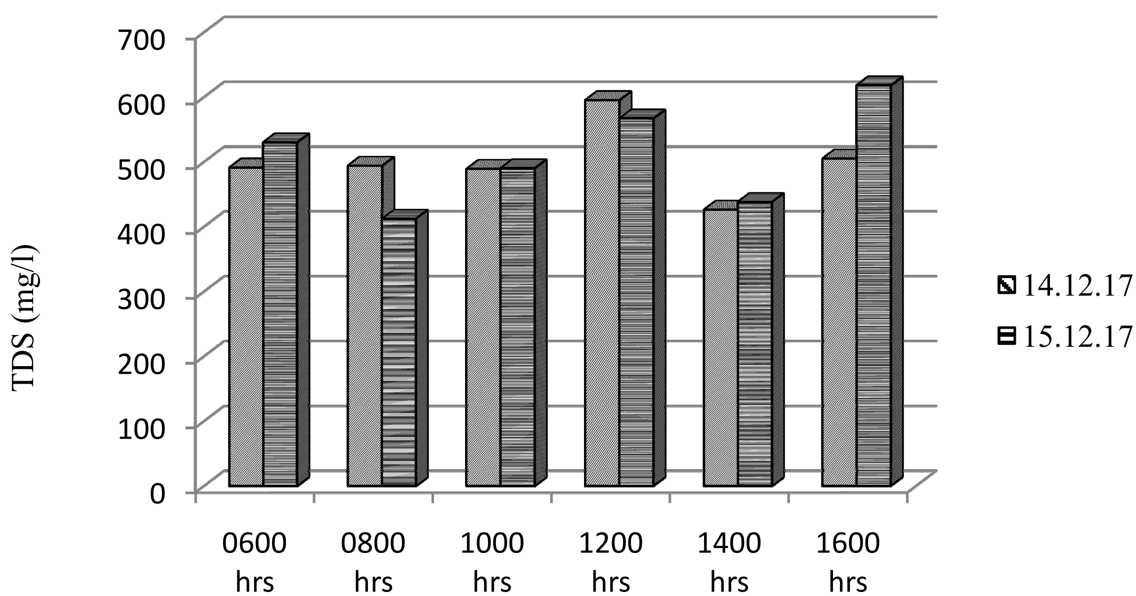

Fig 4.5: Variation of TDS of wastewater samples collected in December 2017

(v) Total Suspended Solids (TSS)

Total Suspended Solids (TSS) is one of the important parameters that need to be removed in a sewage treatment plant. Figure 4.6 shows variation of TSS concentration with time of the day for the samples collected in December 2017. Similar to the variation of Turbidity, TSS concentration of the wastewater samples shows an increasing trend with time of the day. Figure 4.6 (as well as Fig. 4.3) shows that suspended solids concentration in wastewater samples increases with passage of the day, as water use increases. As observed for Turbidity, TSS values recorded during the weekend were found to be higher in most cases, compared to those measured during the weekday.

On the weekday, the highest TSS value of 238 mg/l was measured for the sample collected at 1600 hours, while on the weekend (15th December), highest TSS value of 383 mg/l was measured for the sample collected at 1400 hours.

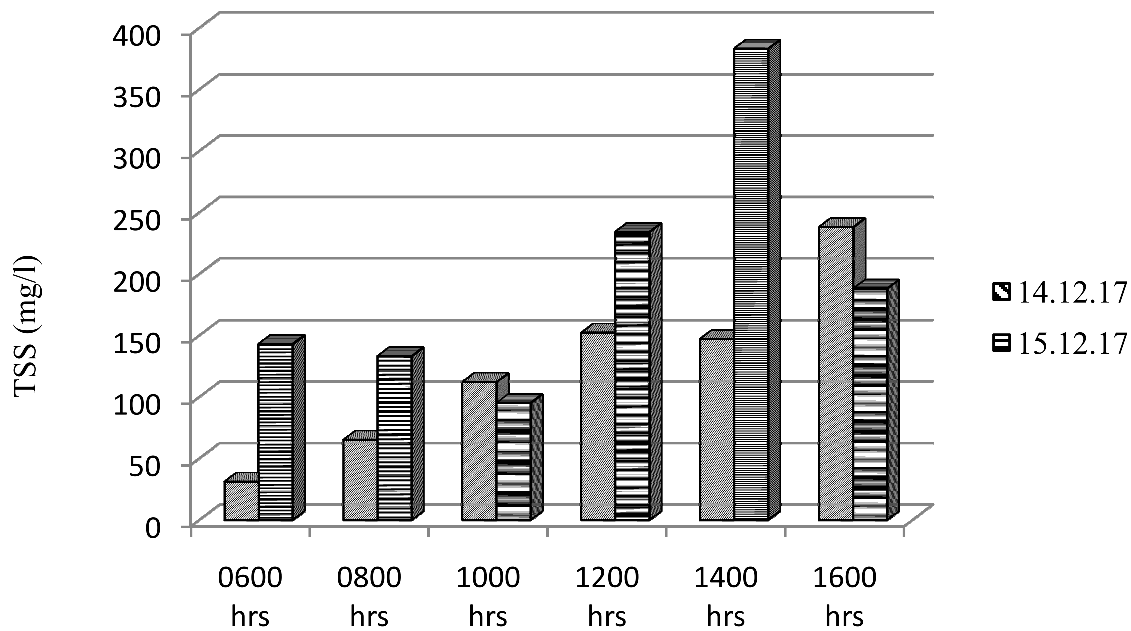

Fig 4.6: Variation of TSS of wastewater samples collected in December 2017

(vi) Alkalinity

Figure 4.7 shows variation of Alkalinity of combined wastewater samples collected in December 2017. The Alkalinity of the wastewater samples has been found to be relatively high, mostly above 250 mg/l as $CaCO_3$. On the weekday, Alkalinity varied from 289 to 386 mg/l as $CaCO_3$, while on weekend it varied from 252 to 350 mg/l as $CaCO_3$. Alkalinity values recorded on the weekday are in general slightly higher than those recorded for the samples collected on weekend. No strong trend was observed for the variation of Alkalinity with time of the day, and Alkalinity values did not vary significantly over the day.

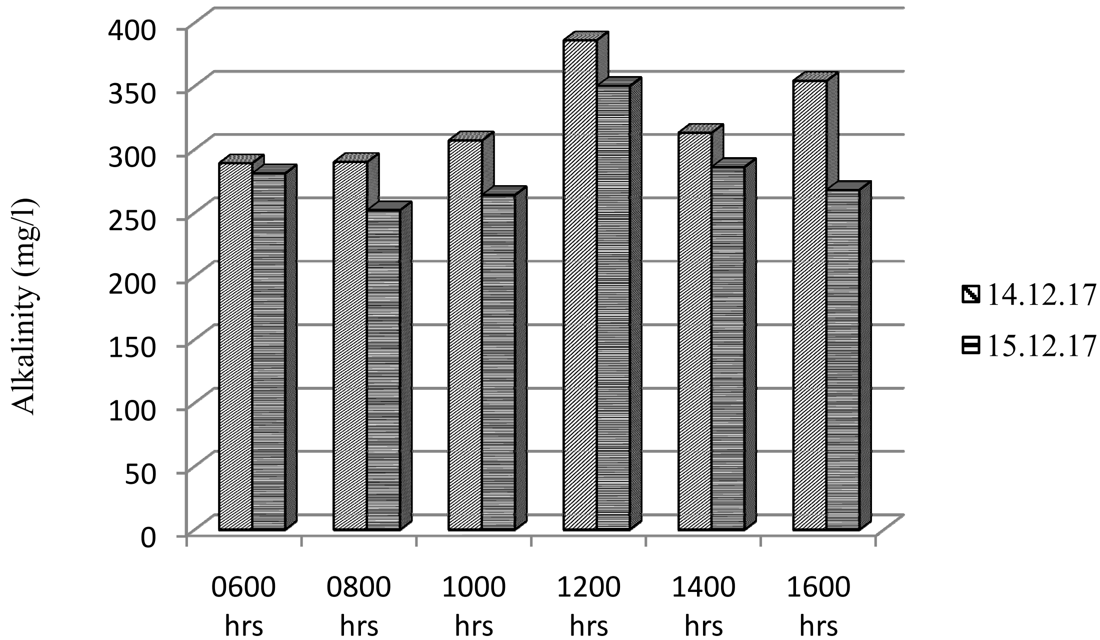

Fig 4.7: Variation of Alkalinity of wastewater samples collected in December 2017

(vii) Ammonia (NH_3-N) and Nitrate (NO_3-N)

Ammonia is one of the important parameters that need to be removed in a sewage treatment plant. Figure 4.8 shows variation of total ammonia for wastewater samples collected in December 2017. It shows very high concentration of ammonia, as expected for typical domestic sewage. On the weekday (14^{th} December), measured total ammonia concentration varied from 22.2 to 28 mg/l (as NH_3-N); while on weekend (15^{th} December) it varied from 17.63 to 24.2 mg/l. In all cases, values measured on weekday were higher than those measured on the weekend. Ammonia concentration appears to increase slightly as day progresses up to noon (1200 hours), and then decreases slightly.

Figure 4.9 shows variation of nitrate concentration. It shows that both on weekday and weekend, nitrate concentration increases with passage of the day (with one exception). In almost all cases nitrate concentration measured on weekend were higher than those measured on the weekday. On the weekday (14^{th} December), the highest nitrate concentration of 0.6 mg/l was found at 1600 hours; while on weekend, highest nitrate concentration of 0.9 mg/l was found at 1600 hours.

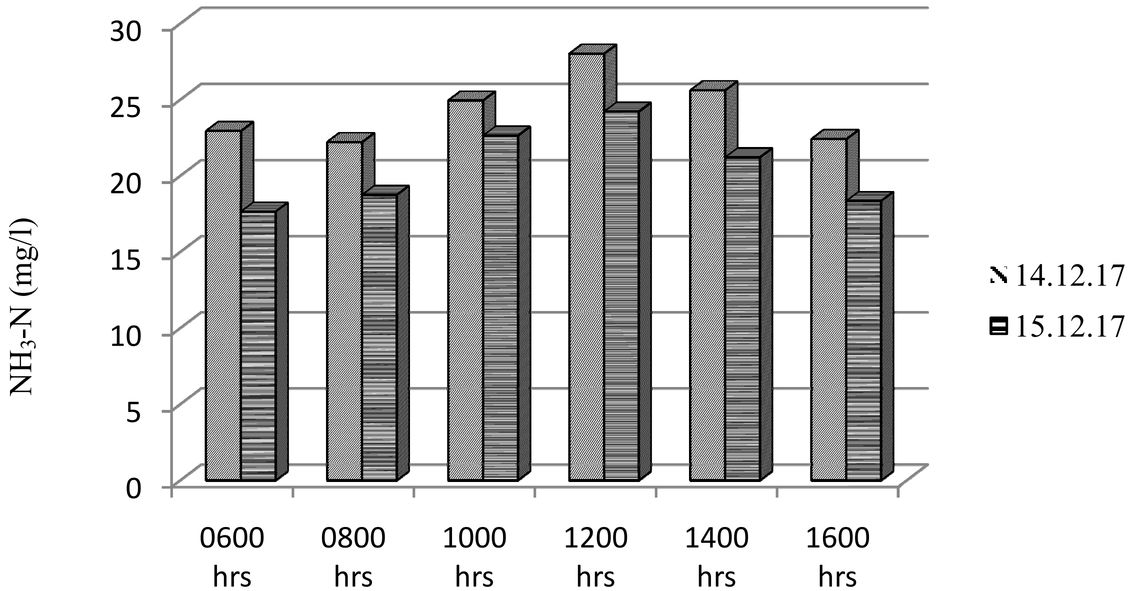

Fig 4.8: Variation of Total Ammonia of wastewater samples collected in December 2017

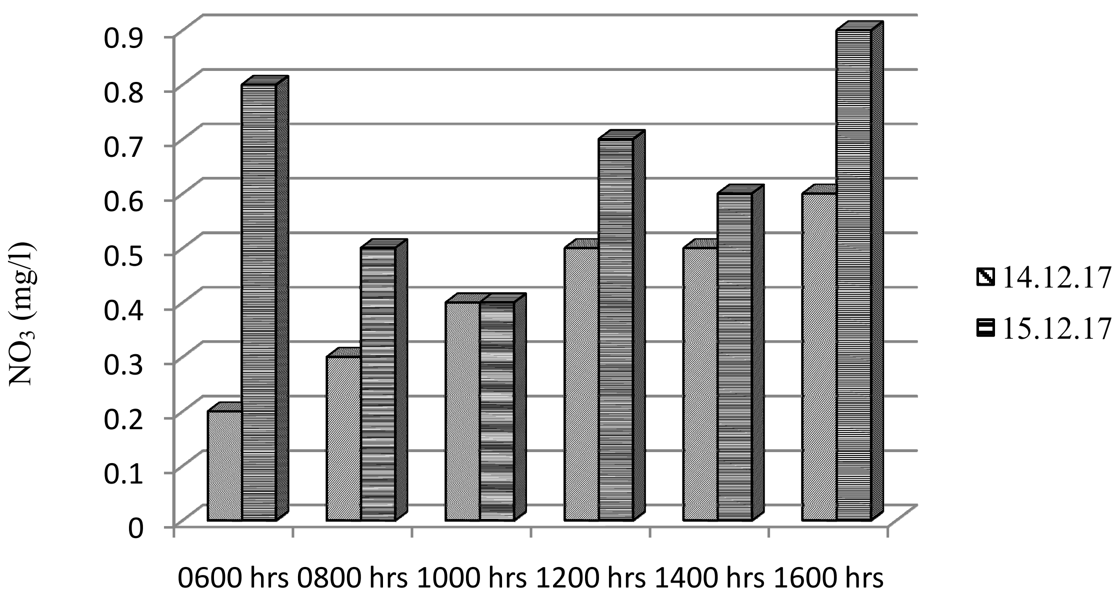

Fig 4.9: Variation of Nitrate of wastewater samples collected in December 2017

(viii) Phosphate (PO_4)

Phosphate is an important parameter that is targeted for removal in a sewage treatment plant. Figure 4.10 shows phosphate concentrations of the wastewater samples collected in December 2017. It shows significant variation of phosphate concentration over the day, on both weekday and weekend. In general, phosphate concentration has been found to be higher on the weekday, compared to those on the weekend. On weekday (14^{th} December), phosphate concentration varied from 5.32 to 7.9 mg/l, while on weekend, it varied from 1.425 to 8.85 mg/l. Phosphate concentration appear to increase around the mid-day.

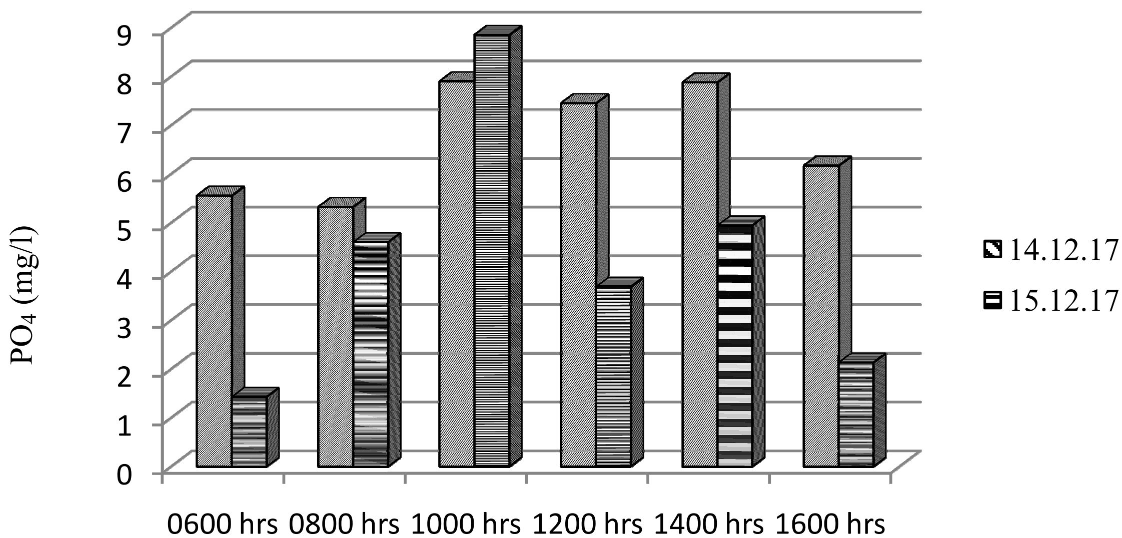

Fig 4.10: Variation of PO_4 of wastewater samples collected in December 2017

(ix) Organic Pollution: BOD_5 and COD

The most important objective of a sewage treatment plant is the removal of organic pollution, which is measured in terms of BOD_5 and COD. Figure 4.11 and 4.12 show variation of BOD_5 and COD, respectively of wastewater samples collected in December 2017. Both figures show that BOD_5 and COD of the wastewater increase as day progresses, and the peak concentration at about 1400 hours. Another important observation is that concentrations of both BOD_5 and COD are significantly higher (with a few exception) on the weekend, compared to the weekday. On the weekday, BOD_5 varied from 65 to 224 mg/l, while on weekend, it varied from 100 to 420 mg/l. Peak BOD_5 concentration on the weekend was found to be more than twice that found on weekday. On weekday, COD concentration varied from 172 to 579 mg/l, while on weekend it varied from 205 to 672 mg/l.

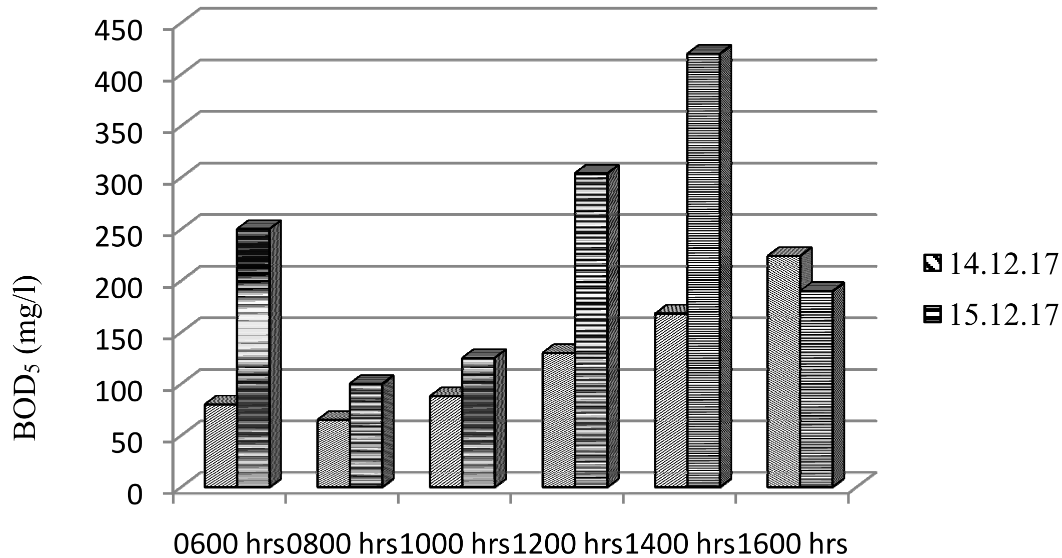

Fig 4.11: Variation of BOD_5 of wastewater samples collected in December 2017

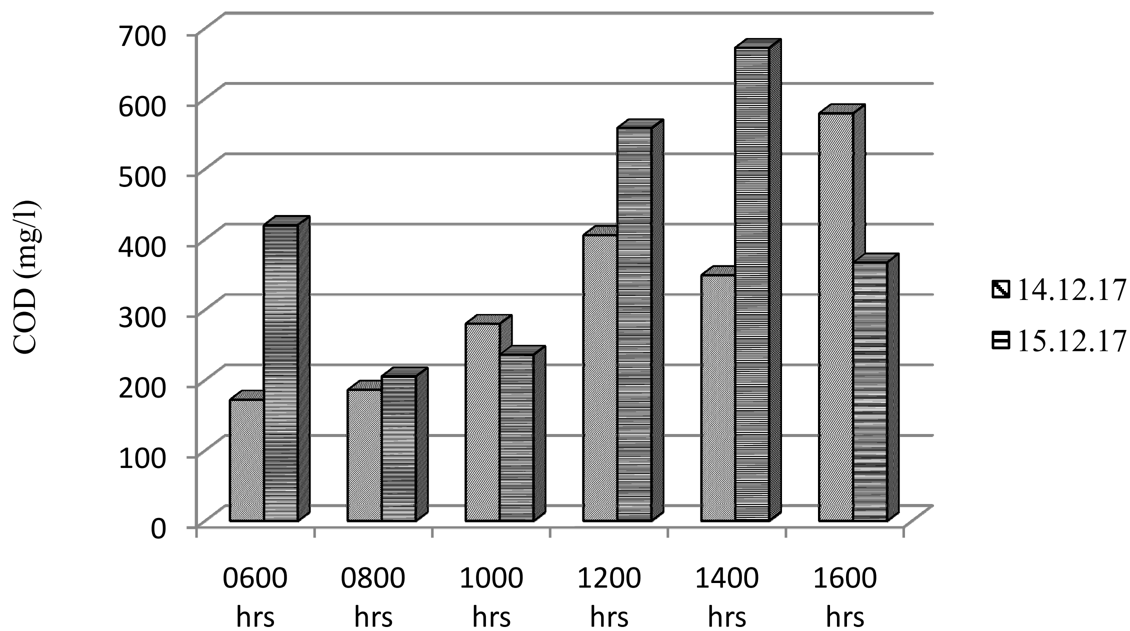

Fig 4.12: Variation of COD of wastewater samples collected in December 2017

Table 4.1 shows the BOD_5/COD ratio of wastewater samples collected in December 2017. Typical values for the ratio of BOD_5/COD for untreated municipal wastewater are usually in the range from 0.3 to 0.8. If the BOD/COD ratio for untreated wastewater is 0.5 or greater, the waste is considered to be easily treatable by biological means. Table 4.1 shows that the ratios of BOD_5/COD for the wastewater samples. It shows that the values are within the typical range of 0.3 to 0.8; in fact, most of the BOD_5/COD ratios are above 0.50. So the wastewater does not contain significant non-biodegradable waste and it can be easily treatable by biological means.

Table 4.1: BOD_5/COD ratio of wastewater samples collected in December 2017

Time	**BOD_5/COD Ratio**	
	14 December (weekday)	**15 December (weekend)**
0600	0.47	0.59
0800	0.35	0.49
1000	0.31	0.53
1200	0.32	0.54
1400	0.48	0.63
1600	0.39	0.52

4.2.2 Characteristics of wastewater collected from northern and southern sides of Hatirjheel in dry season

In this study, efforts were made to separately characterize wastewater coming from the northern and southern sides of Hatirjheel. This was done for a number of reasons. First of all, wastewater flowing along the main diversion sewer through the southern side of Hatirjheel primarily comes from areas of high residential concentration. These areas include Dhanmondi, Kathalbagan, Central Road, Eskaton, Modhubagh, etc. Wastewater from these areas enters into the main diversion sewer on the southern side of Hatirjheel through Special Sewage Diversion Structures (SSDS)-1, 2, 3, 4 and 5. On the other hand, wastewater flowing along the main diversion sewer on the northern side of Hatirjheel comes from Tejgaon, Badda, and Gulshan areas. Tejgaon and Badda areas have considerable industrial concentrations, which could have an influence on the characteristics of wastewater, which needs to be understood. Besides, once the renovation of Pagla STP, construction of Rayerbazar STP and associated sewerage network are complete, majority of domestic sewage that are now coming from the southern side of Hatirjheel would be diverted to these two STPs. Thus, wastewater/sewage flows in the main diversion sewer on the southern side of Hatirjheel would become negligible. Sewage flow from the northern side would dominate the overall flow. Thus, it is important to know the characteristics of wastewater coming from northern and southern sides of Hatirjheel separately.

This Section describes the characteristics of wastewater coming from northern and southern sides of Hatirjheel based on analysis of wastewater samples collected in December 2017 (dry season). Samples were collected on 14 December (weekday) and 15 December (weekend) at two different times 0800 hours and 1400 hours. No rainfall was recorded during the sampling time.

(i) pH

Figure 4.13 shows the variation of pH of the wastewater samples collected on 14th and 15th December 2017 from the northern and southern side of Hatirjheel at two different sampling times, in the morning (0800 hours) and in the afternoon (1400 hours). During weekday (14th December) in northern side pH varied from 7.12 to 7.36, and in southern side pH varied from 7.22 to 7.25. It shows that the variation of pH value over the day is not very significant. During the weekend (i.e., 15th December), in northern side pH varied from 7.12 to 7.36 and in southern side pH varied from 7.22 to 7.25. Thus, the variation of pH between the northern and southern sides is also not significant. In general, the pH values recorded during weekend are slightly lower than those recorded during the weekday.

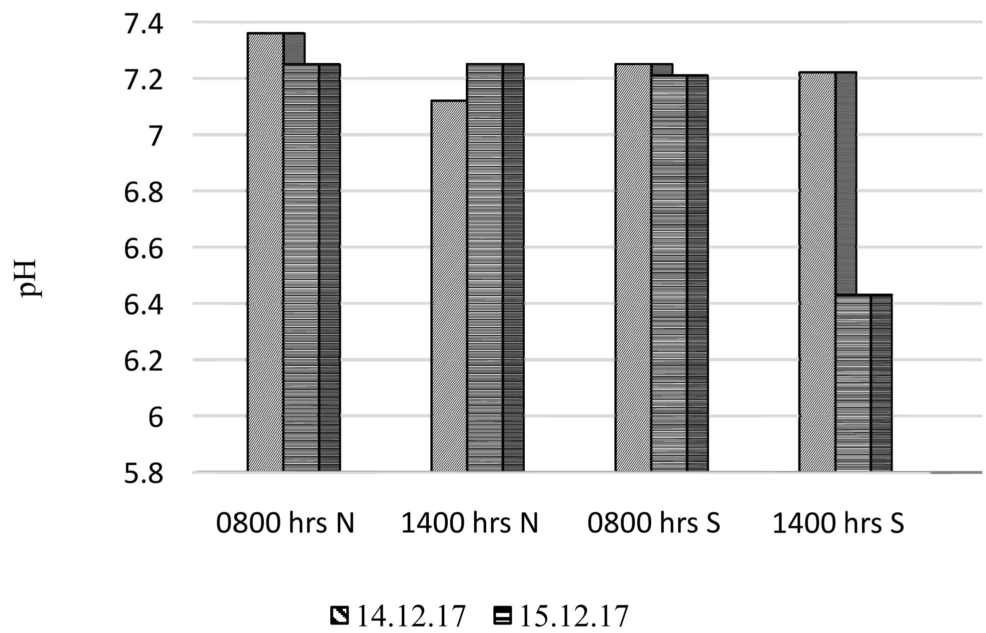

Fig 4.13: Variation of pH of wastewater samples collected in December 2017

(ii) Color

Figure 4.14 shows the variation of color of the wastewater samples collected on 14th and 15th December 2017. During weekday (14th December) in northern side color varied from 424 to 453 Pt.Co. unit and in southern side color varied from 230 to 285 Pt.Co. unit. It shows that the variation of colour value over the day is not very significant. During the weekend (i.e., 15th December) in northern side color varied from 299 to 336 Pt.Co. unit and in southern side colour varied from 212 to 830 Pt.Co. unit. Except for the very high color value (830 Pt.-Co. Unit), color of wastewater sample from northern side is found to be higher than southern side.

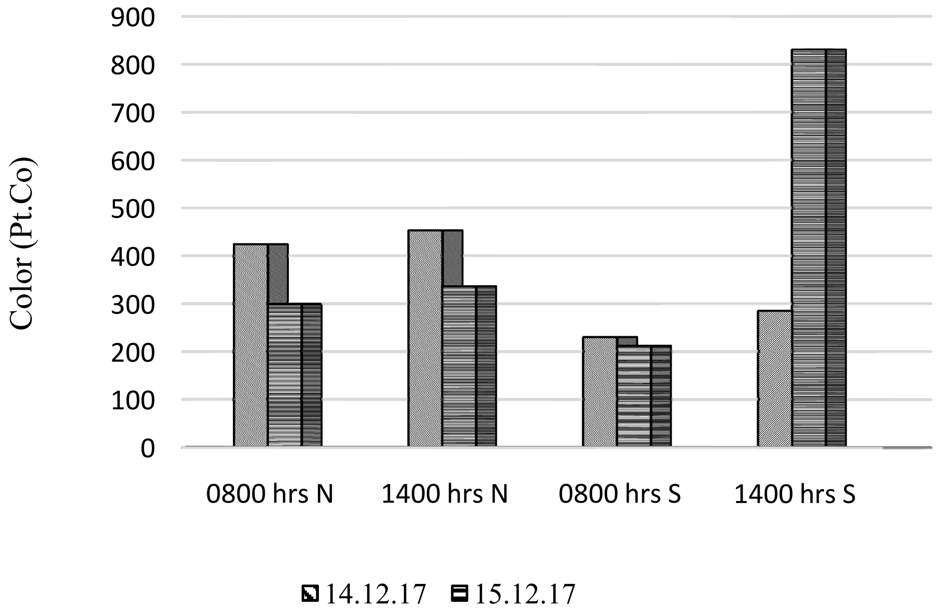

Fig 4.14: Variation of Color of wastewater samples collected in December 2017

(iii) Turbidity

Figure 4.15 shows turbidity of wastewater samples flowing along main diversion sewers on the northern and southern sides of Hatirjheel. It shows that at 1400 hours, turbidity of wastewater is slightly higher both at northern and southern side than 0800 hrs; however, in the afternoon (1400 hours), turbidity in the northern sides becomes slightly higher, especially on weekend (15 December). The highest turbidity of 283 NTU of wastewater sample was recorded at northern side on 15 December.

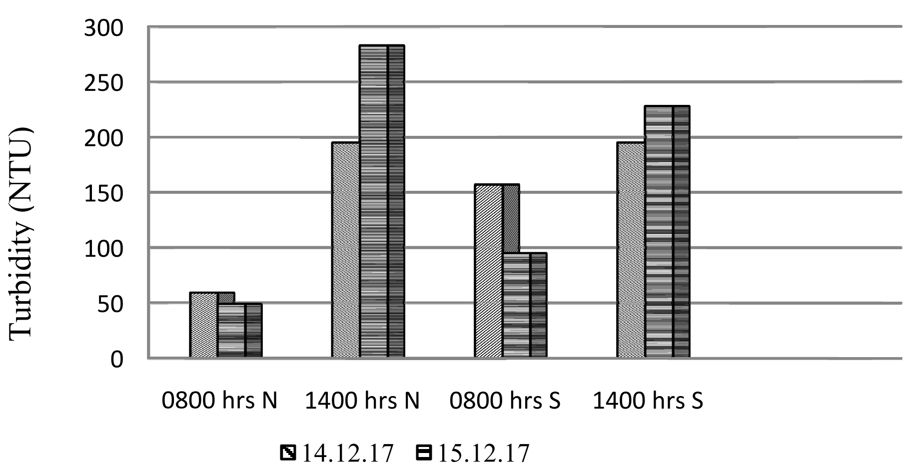

Fig 4.15: Variation of Turbidity of wastewater samples collected in December 2017

(iv) Electrical Conductivity (EC) and TDS

Figure 4.16 and Figure 4.17 show variation of Electrical Conductivity (EC) and TDS, respectively, of the samples collected in December 2017 from northern and southern side. As expected, variations of EC and TDS have been found to be similar. The EC values of the samples collected from northern side varied from 851 to 1096 μS/cm; while it varied from 640 to 786 μS/cm from southern side. It shows EC of samples from northern side is slide higher than that of southern side. Again TDS also shows similar variation.

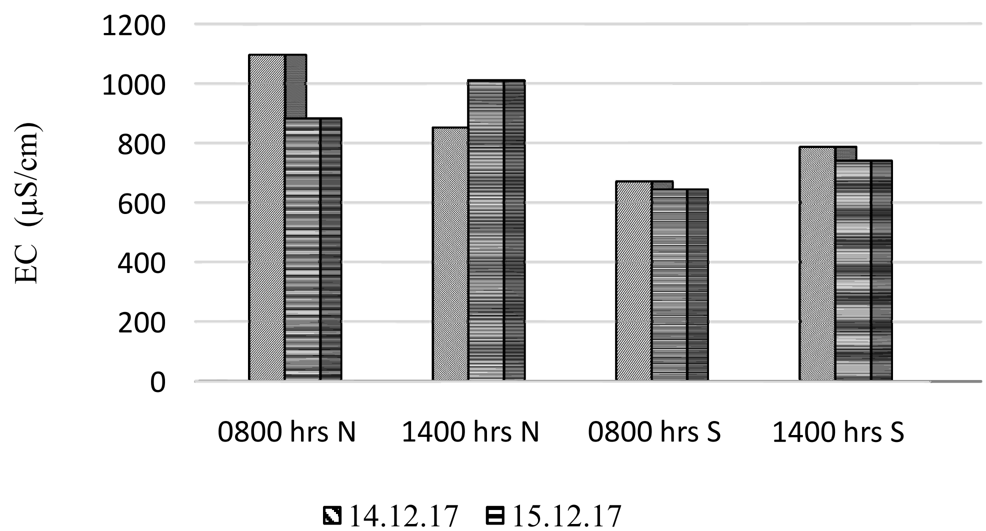

Fig 4.16: Variation of EC of wastewater samples collected in December 2017

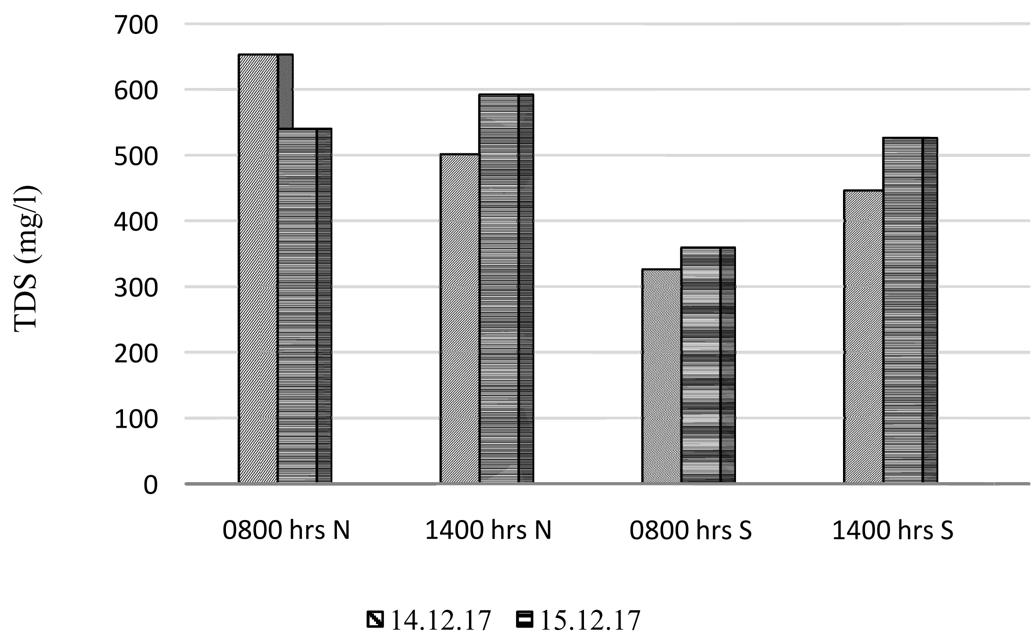

Fig 4.17: Variation of TDS of wastewater samples collected in December

(v) Total Suspended Solids (TSS)

Figure 4.18 shows variation of TSS for wastewater coming from northern and southern sides of Hatirjheel. The variation of TSS has been found to be similar to that observed for turbidity (see Fig. 4.15), as expected. The highest TSS of 363 mg/l was found for wastewater coming from northern side at 1400 hours on 15 December.

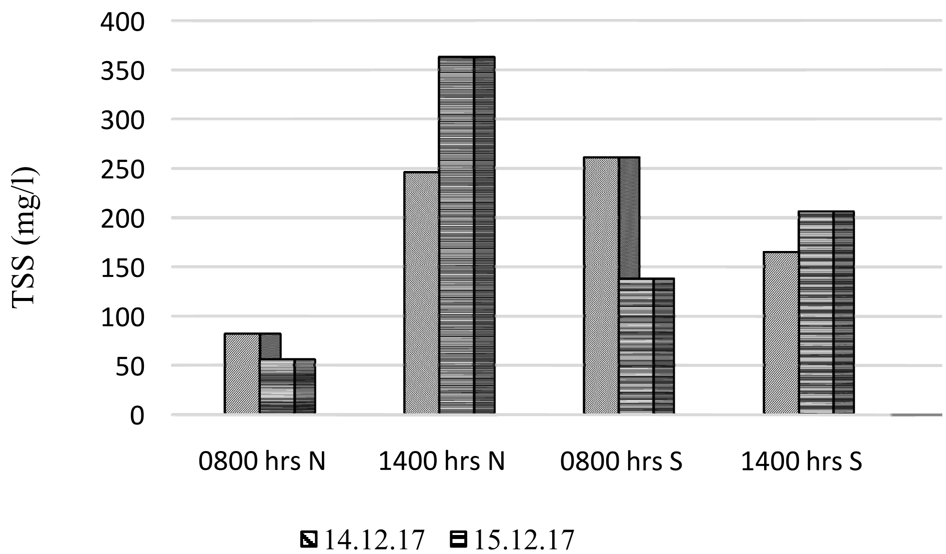

Fig4.18: Variation of TSS of wastewater samples collected in December 2017

(vi) Alkalinity

Figure 4.19 shows variation of Alkalinity of combined wastewater samples coming from northern and southern side collected in December 2017. The Alkalinity of the samples collected from northern side varied from 294 to 388 mg/l; while it varied from 241 to 291 mg/l from southern side. It shows Alkalinity of samples from northern side is slide higher than that of southern side.

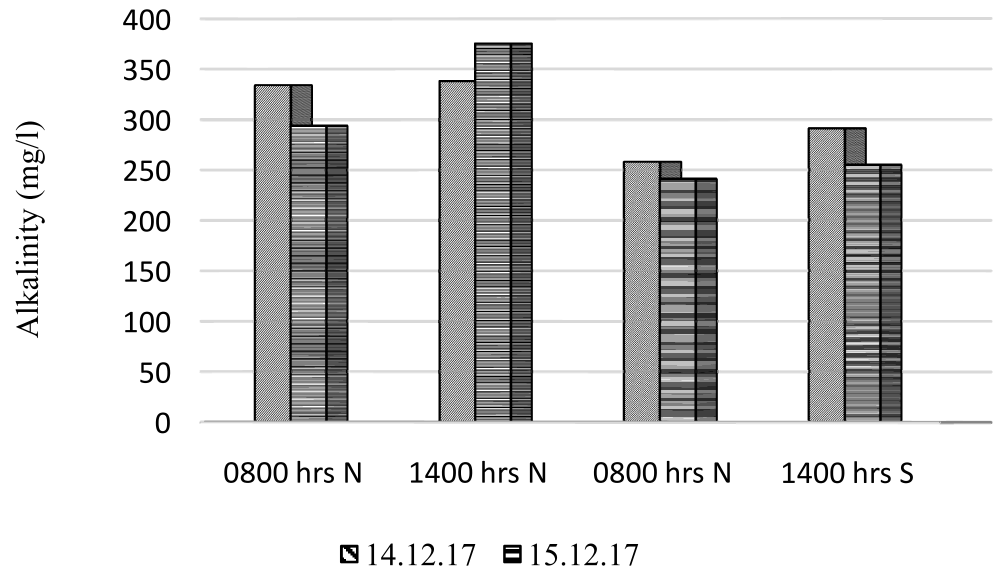

Fig 4.19: Variation of Alkalinity of wastewater samples collected in December 2017

(vii) Ammonia (NH_3-N) and Nitrate (NO_3-N)

Figure 4.20 and Figure 4.21 show variation of Ammonia (NH3-N) and Nitrate (NO_3-N), respectively, of the samples collected in December 2017 from northern and southern side. The NH_3-N values of the samples collected from northern side varied from 20.83 to 25.1 mg/l; while it varied from 17.1 to 29.3 mg/l from southern side. It shows average NH_3-N of samples from northern side is slightly higher than that of southern side. Again NO_3-N also shows similar variation.

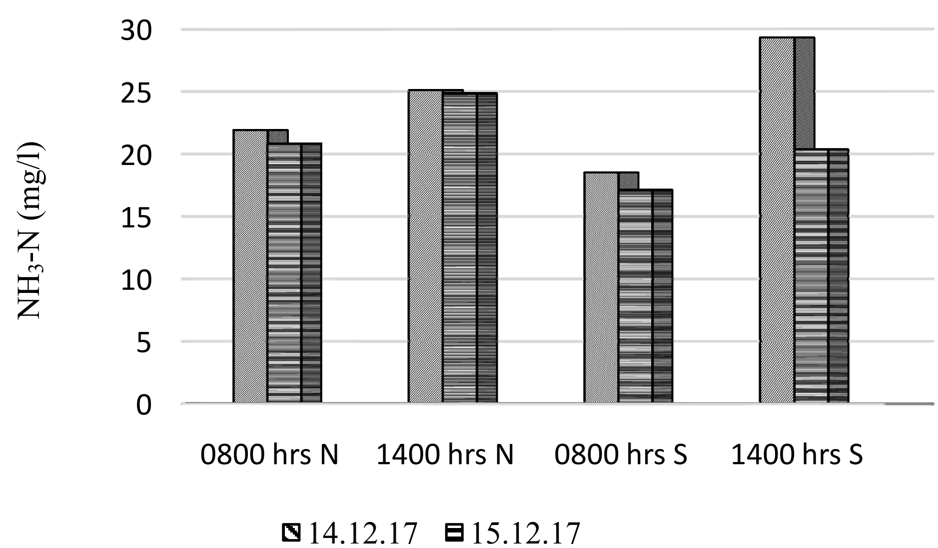

Fig 4.20: Variation of Ammonia of wastewater samples collected in December 2017

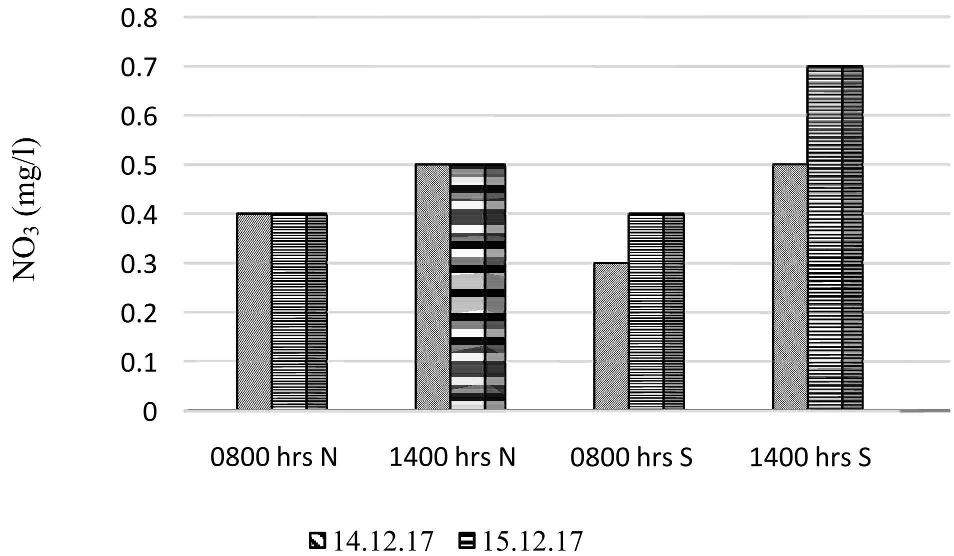

Fig 4.21: Variation of Nitrate of wastewater samples collected in December 2017

(viii) Phosphate (PO_4)

Figure 4.19 shows variation of Phosphate of combined wastewater samples coming from northern and southern side collected in December 2017. The phosphate concentration of the samples collected from northern side varied from 5.44 to 8.0 mg/l; while it varied from 4.425 to 7.565 mg/l from southern side. It shows Phosphate of samples from northern side is slide higher than that of southern side.

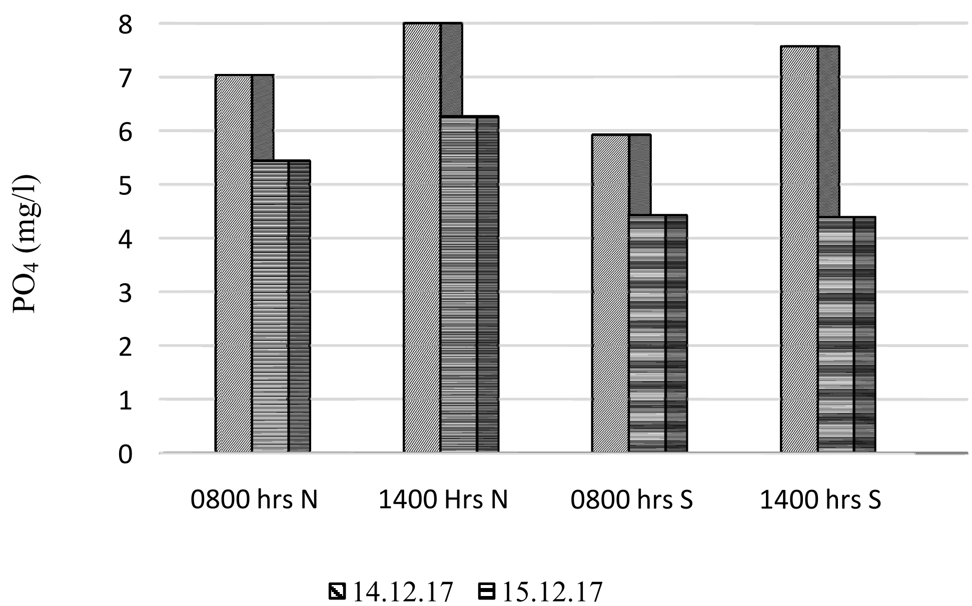

Fig 4.22: Variation of Phosphate of wastewater samples collected in December 2017

(ix) Organic pollution: BOD_5 and COD

The most important objective of a sewage treatment plant is the removal of organic pollution, which is measured in terms of BOD_5 and COD. Figure 4.23 and Figure 4.24 show variation of BOD_5 and COD respectively, of the samples collected in December 2017 from northern and southern side. As expected, variations of BOD_5 and COD have been found to be similar. The BOD_5 values of the samples collected from northern side varied from 90 to 224 mg/l; while it varied from 112 to 320 mg/l from southern side. The average BOD_5 of samples from northern side is slightly lower than that of southern side. Again COD values of the samples collected from northern side varied from 191 to 481 mg/l; while it varied from 201 to 614 mg/l from southern side. The average COD of samples from northern side is also slightly lower than that of southern side.

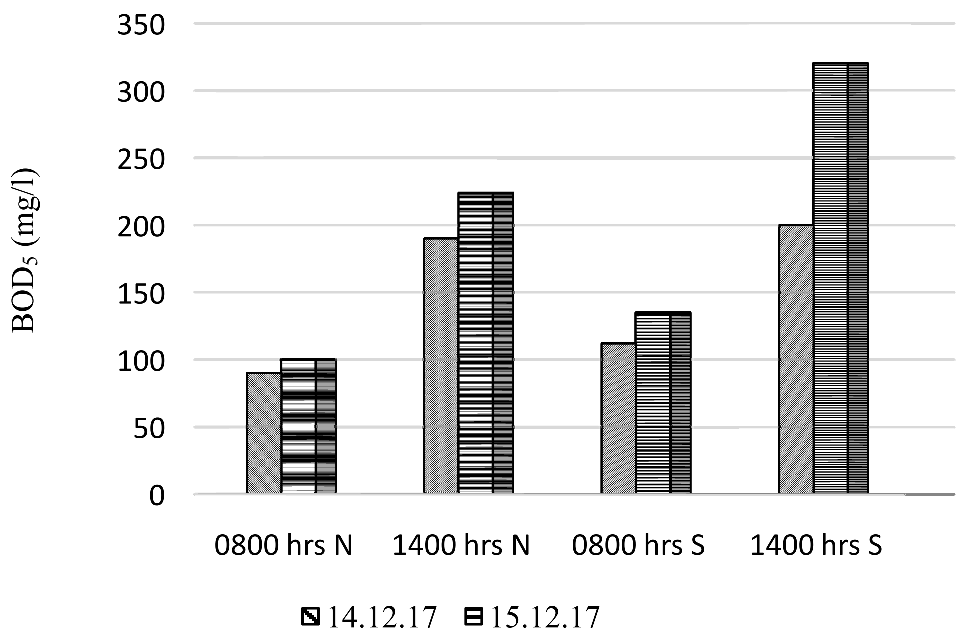

Fig 4.23: Variation of BOD_5 of wastewater samples collected in December 2017

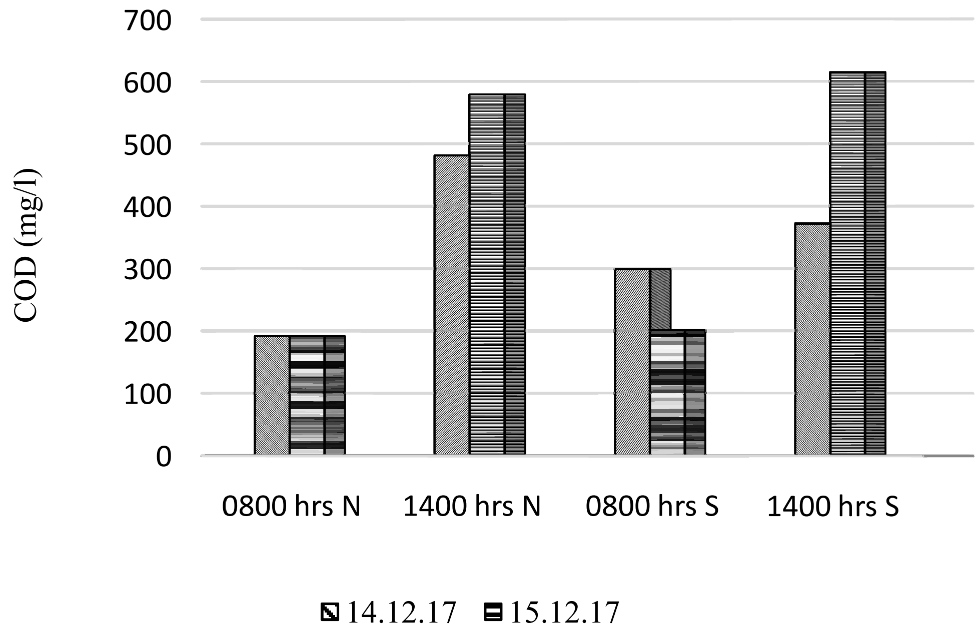

Fig 4.24: Variation of COD of wastewater samples collected in December 2017

4.2.3 Comparison of wastewater characteristics

Table 4.2 shows comparison of characteristics of combined wastewater and wastewater coming from northern and southern sides of Hatirjheel, with respect to some important parameters.

Table 4.2: Comparison of characteristics of combined wastewater and wastewater coming from southern and northern sides of Hatirjheel

Parameter	Date and Time	Combined Wastewater	Wastewater-Northern Side	Wastewater-Southern Side
Turbidity (NTU)	14-12-17; 1400	108	195	195
	15-12-17; 1400	284	283	228
TSS (mg/l)	14-12-17; 1400	147	246	165
	15-12-17; 1400	383	363	206
Ammonia (mg/l as NH_3-N)	14-12-17; 1400	25.6	25.1	29.3
	15-12-17; 1400	21.2	24.85	20.35
Phosphate (mg/l)	14-12-17; 1400	7.86	8.0	7.57
	15-12-17; 1400	4.94	6.27	4.39
BOD_5 (mg/l)	14-12-17; 1400	168	190	200
	15-12-17; 1400	420	224	320
COD (mg/l)	14-12-17; 1400	349	481	372
	15-12-17; 1400	672	579	614
BOD_5/COD Ratio	14-12-17; 1400	0.48	0.40	0.53
	15-12-17; 1400	0.625	0.39	0.52

Table 4.2 shows that in the wastewater sample of December 2017, the value of Turbidity, TSS, Ammonia and Phosphate are little higher in the wastewater sample coming from northern side of main diversion sewer system than that of southern side. On the other hand, the value of BOD_5, COD in the wastewater sample coming from northern side is slightly lower than the southern side. The BOD_5/COD ratio of wastewater coming from the northern side is slightly lower than that coming from the southern side, possibly indicating relatively higher contribution of industrial sewage from the northern side of Hatirjheel. However, as BOD_5/COD ratios are within the typical range of 0.3 to 0.8, it appears that the wastewater does not contain significant non-biodegradable waste and it could be easily treatable by biological means. So the nature of wastewater will not vary significantly when Pagla catchment will be separated from Dasherkandi sewerage catchment, as discussed in Section 4.6.

4.3 Characteristics of Wastewater: Summer

In order to assess characteristics of combined sewage-storm water flow during wet season, combined wastewater samples were collected during May 2017 (Summer/early monsoon) and August 2017 (during peak monsoon). This Section describes the characteristics of wastewater in May 2017. As described in Chapter 3, combined wastewater samples were collected on 12th May (Friday, weekend) and 14th May (Sunday, weekday). On each day, samples were collected at 0600, 0800, 1000, 1200, 1400 & 1600 hrs. No rainfall was recorded during the sampling time. This Section presents the variation of different parameters of combined flow during the summer/early wet season.

(i) pH

Figure 4.25 shows variation of pH of the wastewater samples collected on 12th and 14th May 2017 at different sampling times. On the weekday (14th May), pH varied from 6.60 to 7.13. It shows that the variation of pH value over the day is not very significant. During the weekend (i.e., 12th May), pH value varied from 6.91 to 7.04; the variation of pH over the day was not very significant. In general, the pH values recorded during weekend are slightly lower than those recorded during the weekday in morning time but little higher in the afternoon.

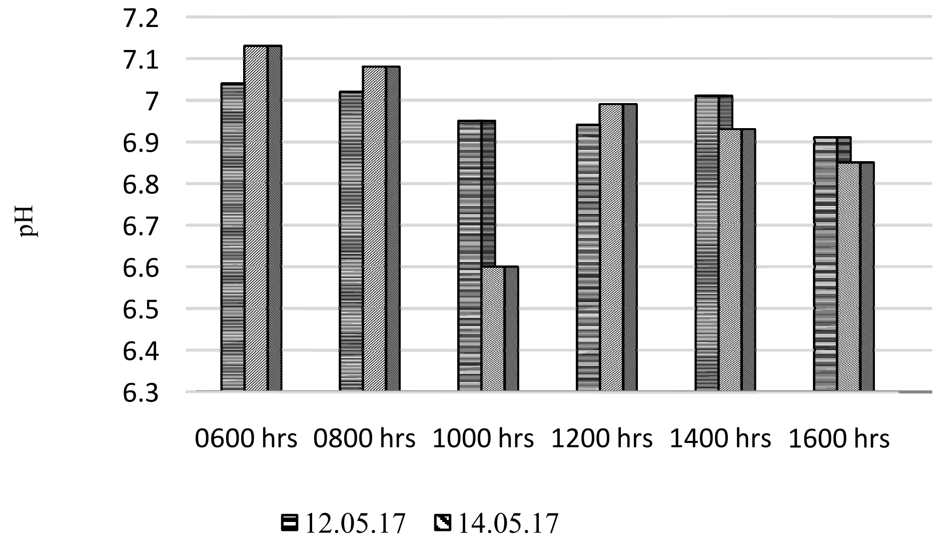

Fig 4.25: Variation of p^H of wastewater samples collected in May 2017

(ii) Color

Figure 4.26 shows the variation of color of the wastewater samples collected in May 2017. On the weekday (14^{th} May), color value varied from 273 to 339 Pt-Co unit. No particular trend was observed in the variation of color with time. During the weekend (12^{th} May), color varied from 181 to 340 Pt.Co. unit; in this case also no particular trend was observed for variation of color with time of the day. Relatively high concentration of color was recorded during the weekday (compared to weekend).

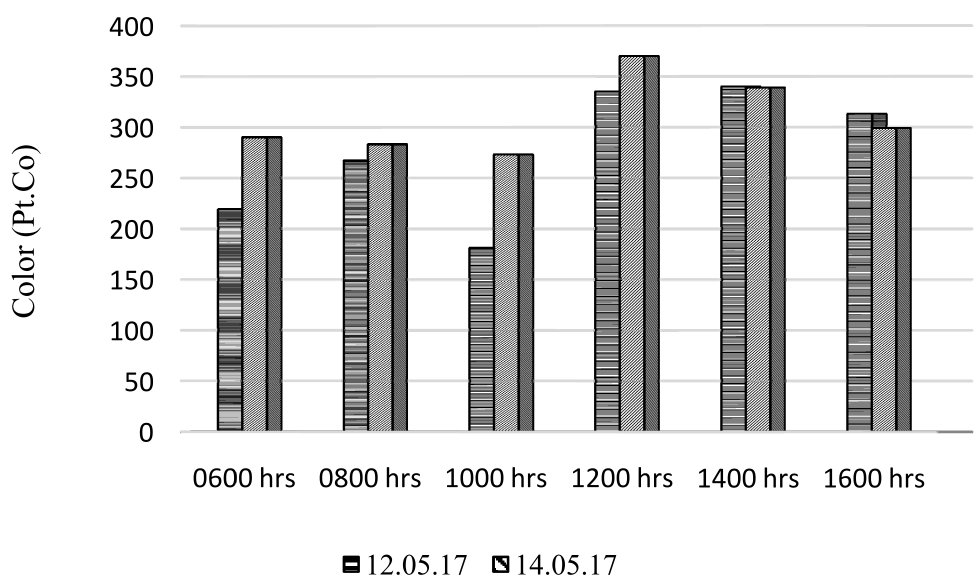

Fig 4.26: Variation of color of wastewater samples collected in May 2017

(iii) Turbidity

Figure 4.27 shows variation of Turbidity of wastewater samples collected in May 2017. Figure 4.3 shows a clear trend of the variation of Turbidity with time of the day; Turbidity of wastewater samples increases as the day progresses. This suggests Turbidity increases as water use increases with progress of the day. During the weekday (14 May), Turbidity varied from 58.6 to 170 NTU; the lowest Turbidity of 58.6 NTU was recorded at 0800 hours, while the highest Turbidity of 170 NTU was recorded at 1400 hours. On the weekday (12 May), Turbidity varied from 89 to 241 NTU; highest Turbidity of 241 NTU was recorded at 1400 hours. In general, Turbidity values during the weekend were found to be slight higher compared to those during the weekday.

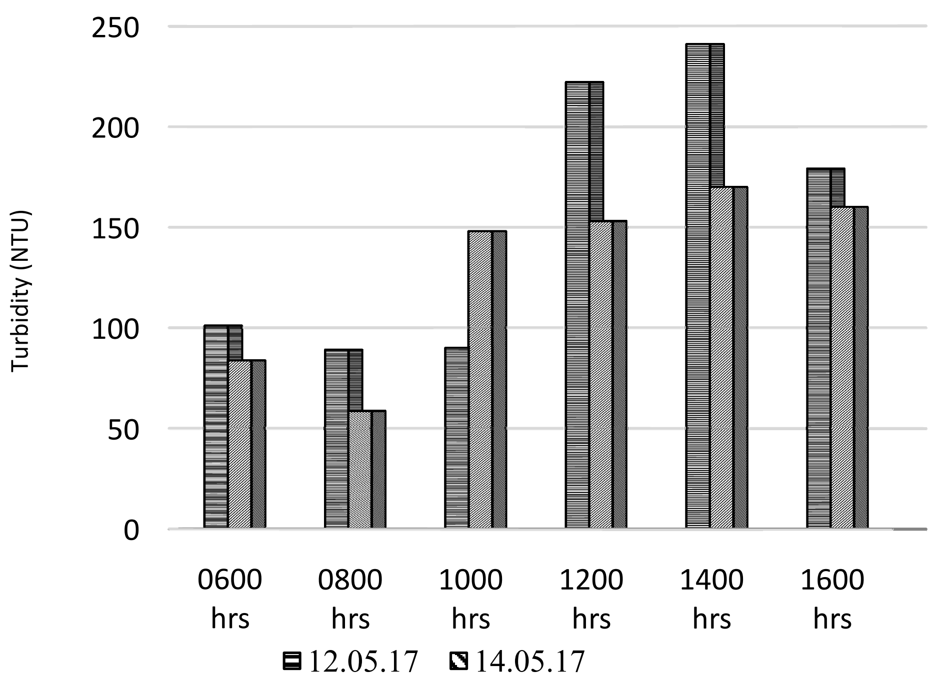

Fig 4.27: Variation of Turbidity of wastewater samples collected in May 2017

(iv) Electrical Conductivity (EC) and TDS

Figure 4.28 and Figure 4.29 show variation of Electrical Conductivity (EC) and TDS, respectively, of the samples collected in May 2017. As expected, variations of EC and TDS have been found to be almost similar. The EC values of the samples collected on the weekday (14 May) varied from 708 to 997 μS/cm; while it varied from 624 to 720 μS/cm for samples collected on the weekend. The variation of EC over the day was not found to be significant.

The TDS values of samples collected during the weekday (14 May) varied from 415 to 612 mg/l; while they varied from 374 to 418 mg/l for samples collected on the weekend (12 May). As with EC, the variation of TDS values over the day was not very significant.

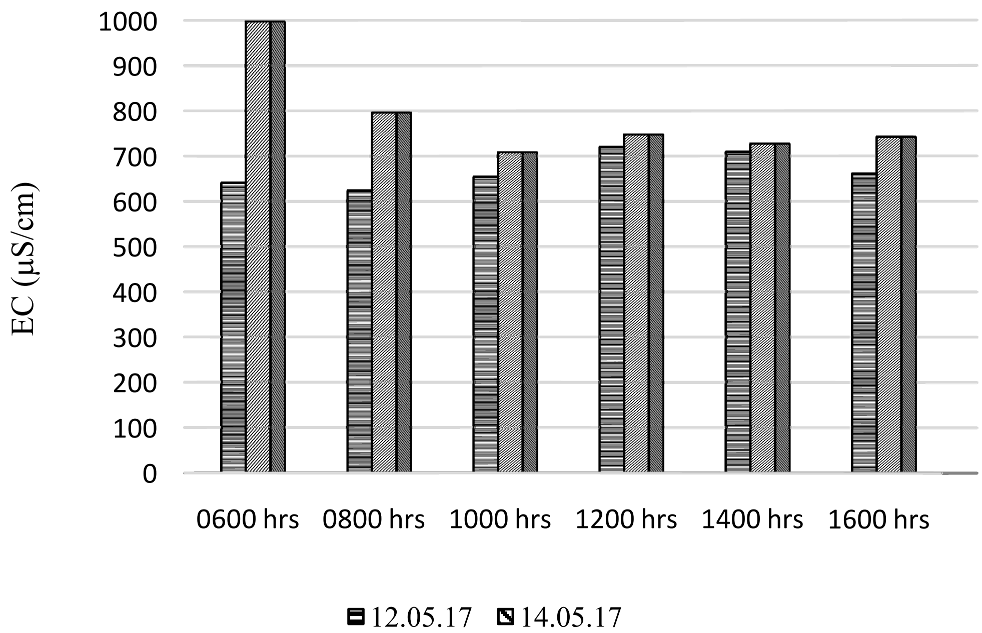

Fig 4.28: Variation of EC of wastewater samples collected in May 2017

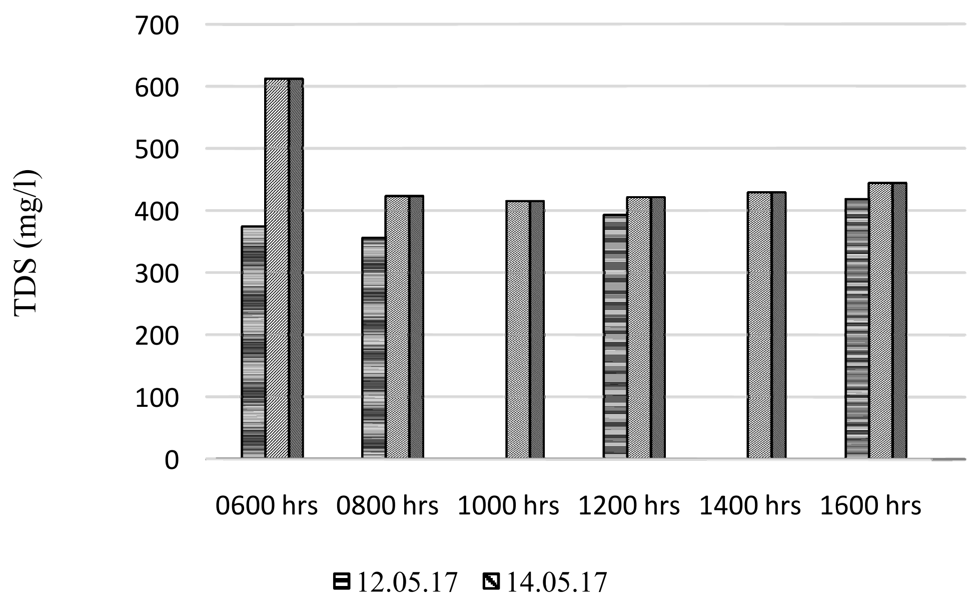

Fig 4.29: Variation of TDS of wastewater samples collected in May 2017

(v) Total Suspended Solids (TSS)

Figure 4.30 shows variation of TSS concentration with time of the day for the samples collected in May 2017. Here suspended solids concentration in wastewater samples shows irregular nature as the day progress. On the weekday, the highest TSS value of 162 mg/l was measured for the sample collected at 1200 hours, while on the weekend (12 May), highest TSS value of 655 mg/l was measured for the sample collected at 1400 hours.

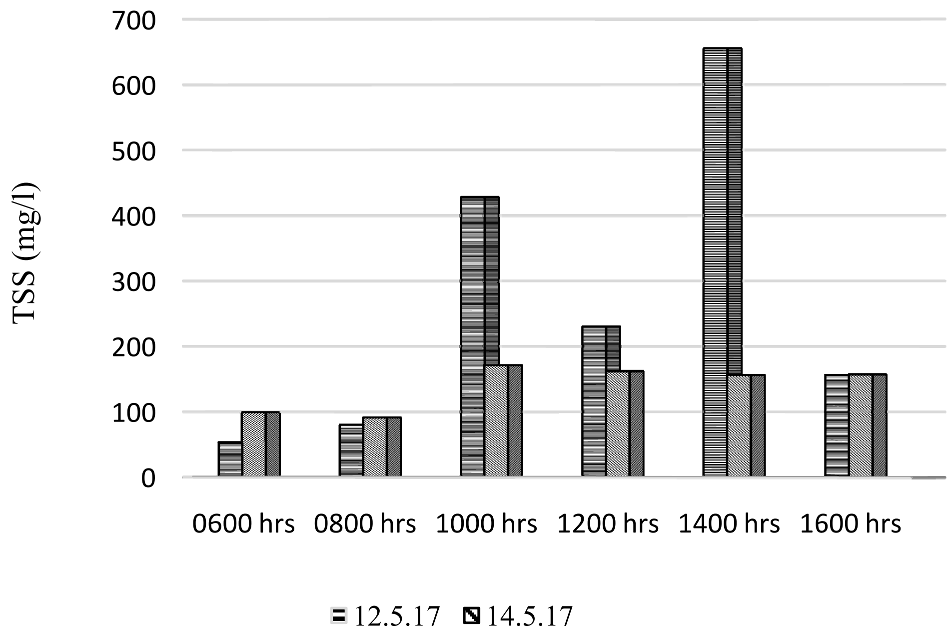

Fig 4.30: Variation of TSS of wastewater samples collected in May 2017

(vi) Alkalinity

Figure 4.31 shows variation of Alkalinity of combined wastewater samples collected in May 2017.On the weekday, Alkalinity varied from 244 to 292 mg/l as $CaCO_3$, while on weekend it varied from 243 to 281 mg/l as $CaCO_3$. No strong trend was observed for the variation of Alkalinity with time of the day, and Alkalinity values did not vary significantly over the day.

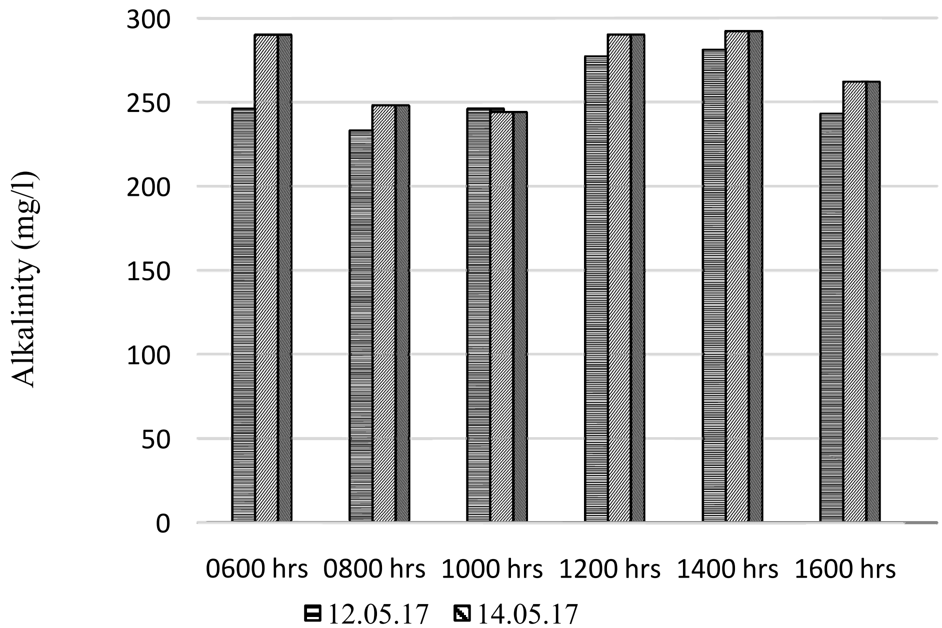

Fig 4.31: Variation of Alkalinity of wastewater samples collected in May 2017

(vii) Ammonia (NH_3-N) and Nitrate (NO_3-N)

Figure 4.32 shows variation of total ammonia for wastewater samples collected in May 2017. It shows very high concentration of ammonia, as expected for typical domestic sewage. On the weekday (14 May), measured total ammonia concentration varied from 19.125 to 26.375 mg/l (as NH_3-N); while on weekend (12 May) it varied from 18.425 to 25.975 mg/l. In all cases, values measured on weekday were higher than those measured on the weekend. Ammonia concentration appears to increase slightly as day progresses up to noon (1200 hours), then decreases slightly. This variation is similar to dry season as most likely due to no rainfall.

Figure 4.33 shows variation of nitrate concentration. It shows that both on weekday and weekend, nitrate concentration increases with passage of the day (with one exception). In almost all cases nitrate concentration measured on weekday were higher than those measured on the weekend. On the weekday (14 December), the highest nitrate concentration of 0.7 mg/l was found at 1400 hours; while on weekend, highest nitrate concentration of 0.5 mg/l was found at 0800 and 1400 hours.

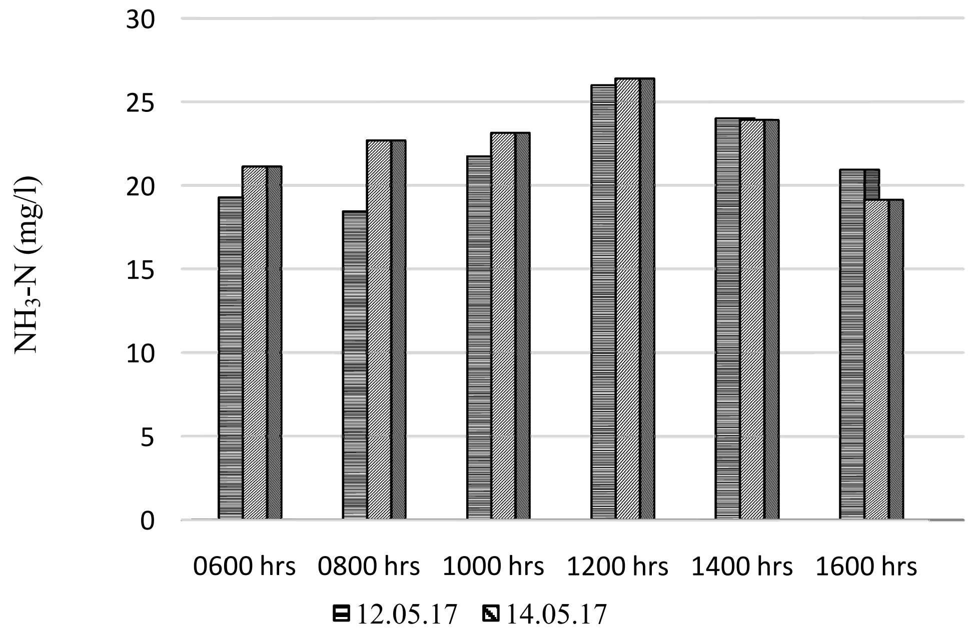

Fig 4.32: Variation of NH_3-N of wastewater samples collected in May 2017

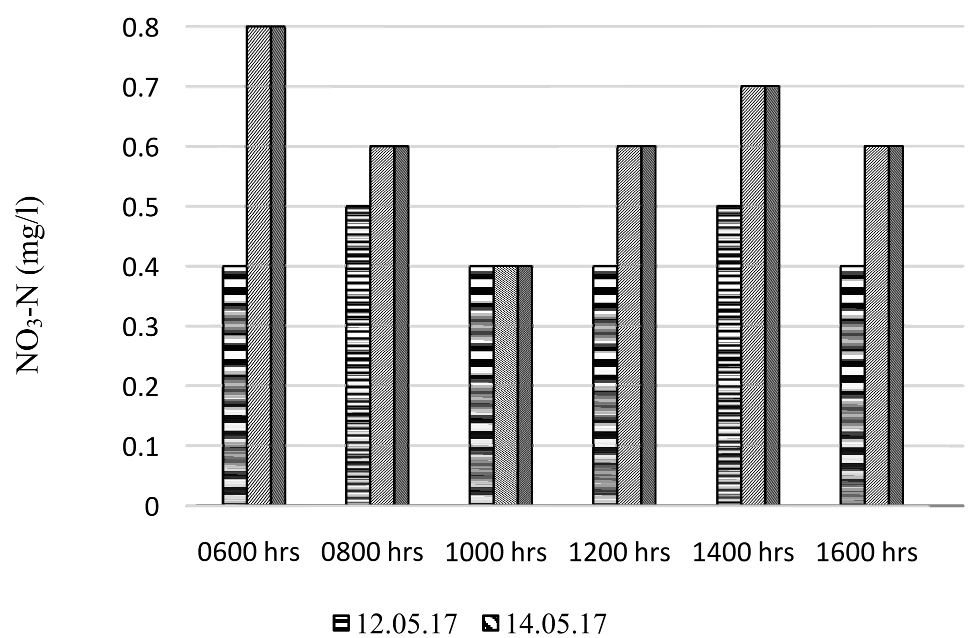

Fig 4.33: Variation of NO_3-N of wastewater samples collected in May 2017

(viii) Phosphate (PO_4)

Figure 4.34 shows phosphate concentrations of the wastewater samples collected in May 2017. It shows significant variation of phosphate concentration over the day, on both weekday and weekend. In general, phosphate concentration has been found to be higher in the weekday, compared to those on the weekend. On weekday (14th May), phosphate concentration varied from 5.54 to 10.2 mg/l, while on weekend, it varied from 4.69 to 7.13 mg/l. Phosphate concentration appear to increase around the mid-day. This variation is similar to the trend found in the dry season, possibly because there was no rainfall during the sampling period in summer.

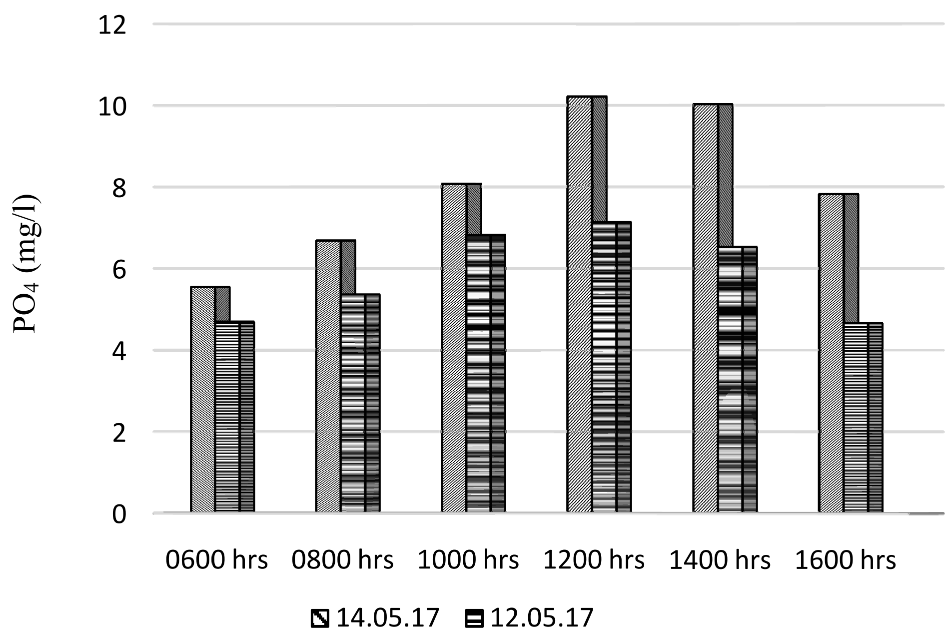

Fig 4.34: Variation of PO_4 of wastewater samples collected in May 2017

(ix) Organic pollution: BOD_5 and COD

Figure 4.35 and 4.36 show variation of BOD_5 and COD, respectively of wastewater samples collected in May 2017. Both figures show that BOD_5 and COD of the wastewater increase as day progresses, and the peak concentration at about 1400 hours. Another important observation is that concentrations of both BOD_5 and COD are slightly higher (with a few exception) on the weekend, compared to the weekday. On the weekday, BOD_5 varied from 120 to 224 mg/l, while on weekend, it varied from 136 to 288 mg/l. On weekday, COD concentration varied from 244 to 393 mg/l, while on weekend it varied from 269 to 559 mg/l. Here the variation of BOD_5 and COD is similar to that of dry season, possibly due to no rainfall.

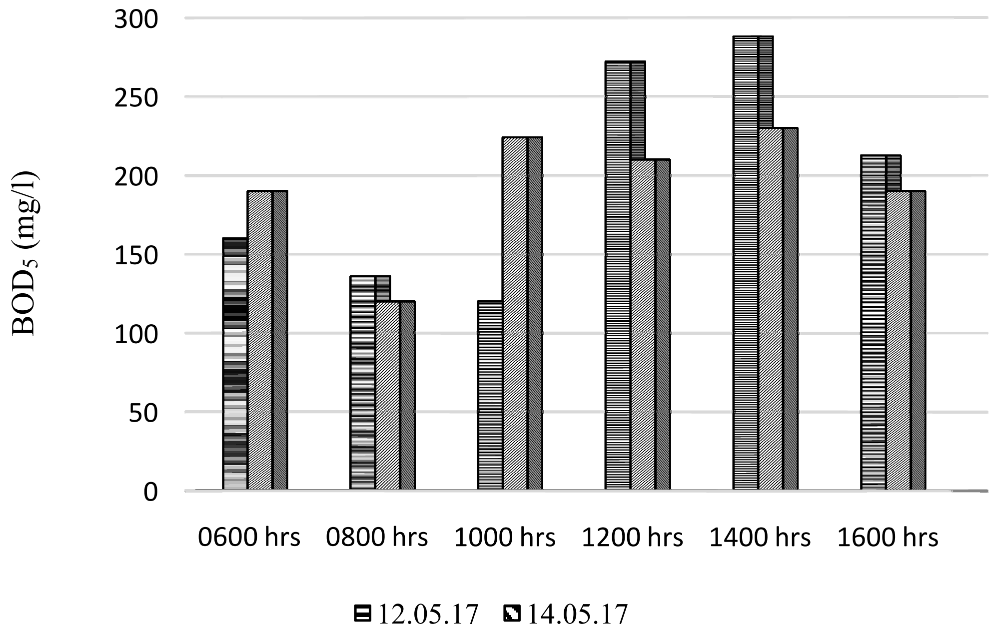

Fig 4.35: Variation of BOD_5 of wastewater samples collected in May 2017

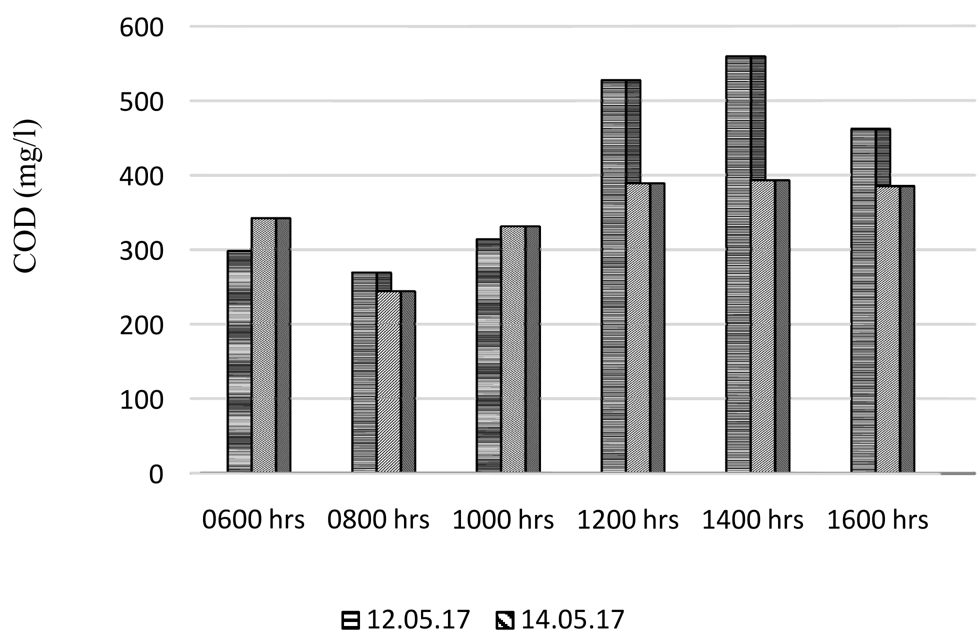

Fig 4.36: Variation of COD of wastewater samples collected in May 2017

4.4 Characteristics of Wastewater: Wet Season

In order to assess characteristics of combined sewage-storm water flow during wet season, combined wastewater samples were collected on 11^{th} and 12^{th} August 2017 (during peak monsoon). Table 4.3 below shows the rainfall data of Dhaka city recorded in August 2017. As per the Bangladesh Meteorological Department (BMD) the average rainfall of August in Dhaka city is 306.5 mm; rainfall recorded on 11^{th} and 12^{th} August were 28.5 mm and 34 mm, respectively. This Section describes the characteristics of wastewater in August 2017 during peak monsoon.

Table 4.3: Rainfall data of Dhaka city in August 2017 (Source: BWDB)

Date	**Precipitation (in mm)**	**Date**	**Precipitation (in mm)**	**Date**	**Precipitation (in mm)**
01 Aug 17	0	**12 Aug 17**	**34**	23 Aug 17	70
02 Aug 17	16	13 Aug 17	25.5	24 Aug 17	3
03 Aug 17	69	14 Aug 17	17	25 Aug 17	0
04 Aug 17	0	15 Aug 17	0	26 Aug 17	3.5
05 Aug 17	0	16 Aug 17	1	27 Aug 17	32
06 Aug 17	4.5	17 Aug 17	9	28 Aug 17	0
07 Aug 17	9	18 Aug 17	0	29 Aug 17	0
08 Aug 17	0	19 Aug 17	0	30 Aug 17	0
09 Aug 17	0	20 Aug 17	0	31 Aug 17	0
10 Aug 17	0	21 Aug 17	0		
11 Aug 17	**28.5**	22 Aug 17	81		

As described in Chapter 3, combined wastewater samples were collected on 11 August (Friday) and 12^{th} August (Saturday). On each day, samples were collected at 0600, 0800, 1000, 1200, 1400 & 1600 hrs. As per the precipitation record shown in above table, rainfall recorded on 11 and 12 August 2017 were 28.5 mm and 34 mm respectively. As the amount of rainfall is directly proportional to the amount of storm discharge considering the terrain, formation and surface runoff coefficient of that area and runoff from urban areas as a result of rainfall is generally higher than those from rural areas due to many impervious surfaces viz., roofs of houses, paved roads, parking lots etc in the urban areas, so surely this would have an impact on combined wastewater samples. This Section presents that impact on the variation of different parameters of combined wastewater flow during the peak wet season.

(i) pH

Figure 4.37 shows variation of pH of the wastewater samples collected on 11th and 12th August 2017 at different sampling times. On the weekday (as Saturday, 12th August), pH varied from 7.23 to 7.62 during the sampling period. It shows that the variation of pH value over the day is not very significant. During the weekend (i.e., 11th August), pH value varied from 6.14 to 7.18; the variation of pH over the day was little significant. In general, the p^H values recorded during weekend are slightly lower than those recorded during the weekday.

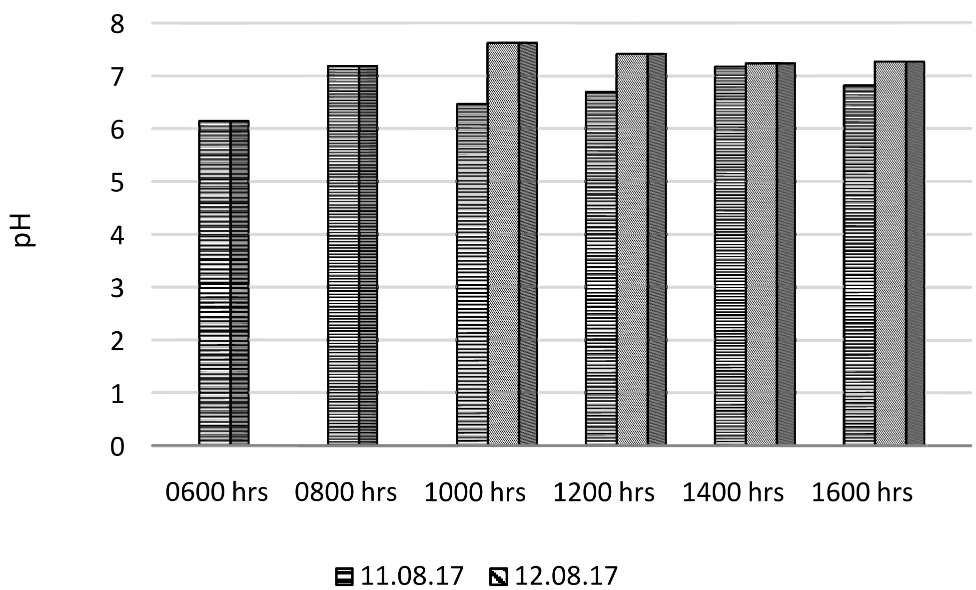

Fig 4.37: Variation of pH of wastewater samples collected in August 2017

(ii) Color

Figure 4.38 shows the variation of color of the wastewater samples collected in August 2017. On Saturday (12th August), color value varied from 185 to 265 Pt-Co unit. No particular trend was observed in the variation of color with time. During weekend (11th August), color varied from 163 to 502 Pt.Co. unit; in this case also no particular trend was observed for variation of color with time of the day.

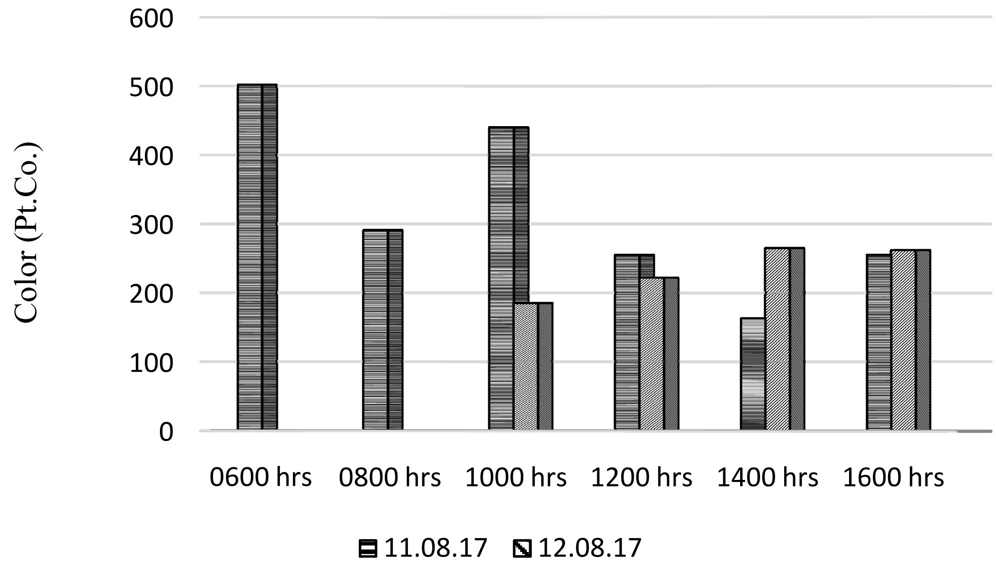

Fig 4.38: Variation of color of wastewater samples collected in August 2017

(iii) Turbidity

Figure 4.39 shows variation of Turbidity of wastewater samples collected in August 2017. Figure 4.3 shows no trend of the variation of Turbidity with time of the day as the day progresses. It is because of the intense rainfall during those two days as the wastewater became diluted by rain water. During weekend (12th August), Turbidity varied from 91 to 228 NTU; the lowest Turbidity of 91 NTU was recorded at 0800 hours, while the highest Turbidity of 228 NTU was recorded at 1000 hours. On Saturday (12th August), Turbidity varied from116 to 132NTU; highest Turbidity of 132 NTU was recorded at 1200 hours..

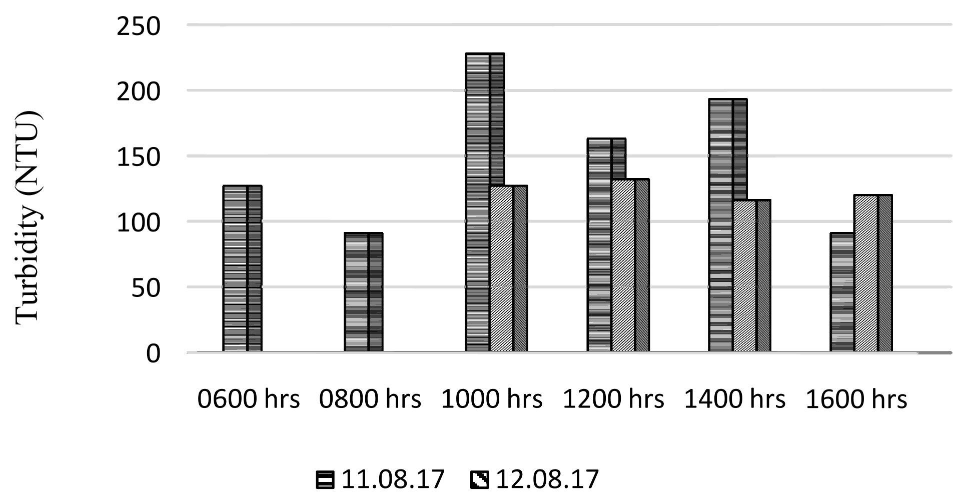

Fig 4.39: Variation of Turbidity of wastewater samples collected in August 2017

(iv) Electrical Conductivity (EC) and TDS

Figure 4.40 and Figure 4.41 show variation of Electrical Conductivity (EC) and TDS, respectively, of the samples collected in August 2017. As expected, variations of EC and TDS have been found to be similar. The EC values of the samples collected on the Saturday (12thAugust) varied from 184 to 485 µS/cm; while it varied from 359 to 717 µS/cm for samples collected on the weekend. Figure 4.40 shows no trend of the variation of EC with time of the day as the day progresses due to heavy rainfall during those days. The TDS values of samples collected during the Saturday (12th August) varied from 133 to 272 mg/l; while they varied from 184 to 363 mg/l for samples collected on the weekend (11th August).

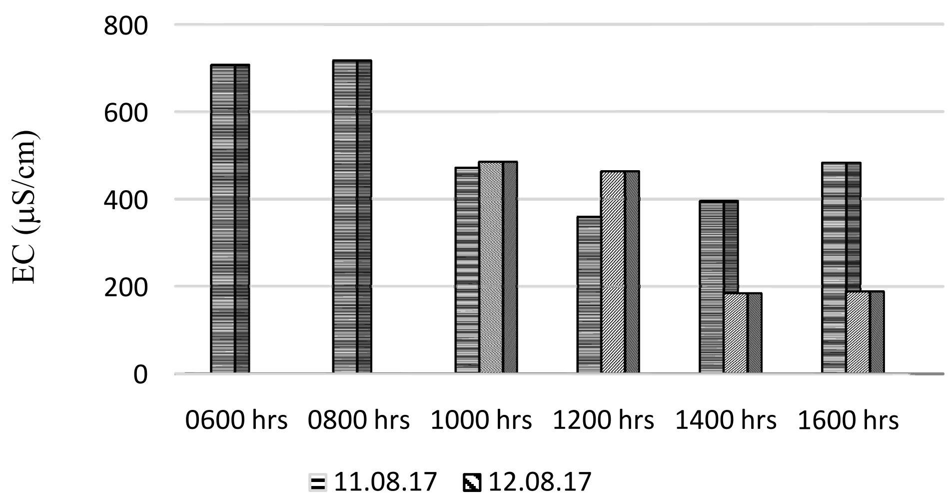

Fig 4.40: Variation of EC of wastewater samples collected in August 2017

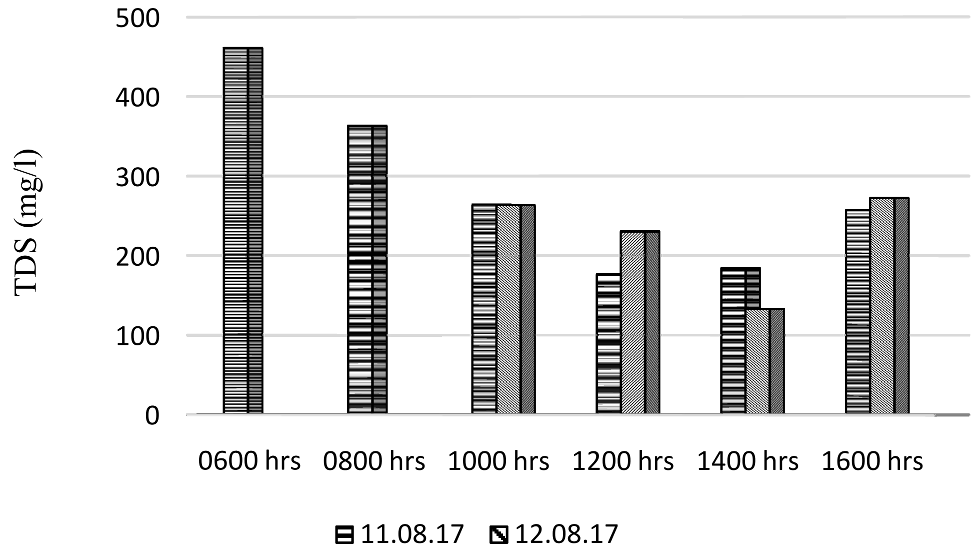

Fig 4.41: Variation of TDS of wastewater samples collected in August 2017

(v) Total Suspended Solids (TSS)

Figure 4.42 shows variation of TSS concentration with time of the day for the samples collected in August 2017. No particular trend was observed with the variation of Turbidity with time of the day. It is possibly because of the heavy rainfall which diluted the wastewater sample. On Saturday, the highest TSS value of 195 mg/l was measured for the sample collected at 1400 hours, while on the weekend (12^{th} August), highest TSS value of 491 mg/l was measured for the sample collected at 1000 hours.

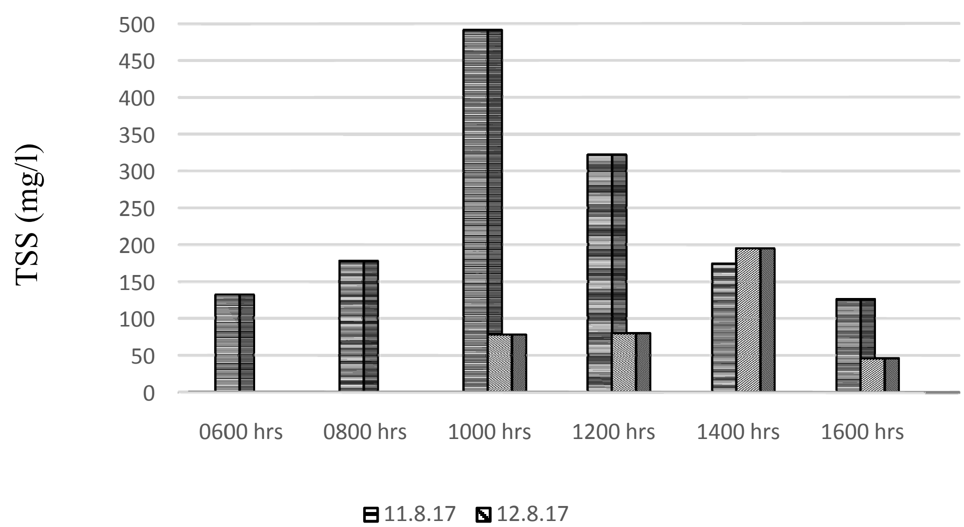

Fig 4.42: Variation of TSS of wastewater samples collected in August 2017

(vi) Alkalinity

Figure 4.43 shows variation of Alkalinity of combined wastewater samples collected in August 2017. The Alkalinity of the wastewater samples has been found to be relatively low, mostly below 200 mg/l as $CaCO_3$. On the Saturday, Alkalinity varied from 132 to 150 mg/l as $CaCO_3$, while on weekend it varied from 133 to 510 mg/l as $CaCO_3$. No strong trend was observed for the variation of Alkalinity with time of the day and highest value of 510 mg/l was recorded at 0600 hrs in the weekend (11 August) unusually due to heavy rainfall during day time.

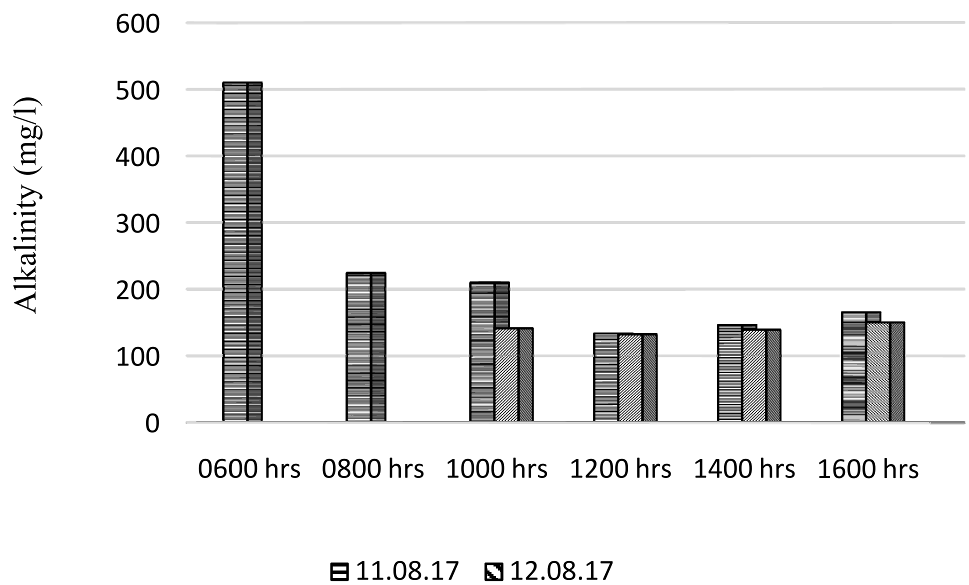

Fig 4.43: Variation of Alkalinity of wastewater samples collected in August 2017

(vii) Ammonia (NH_3-N) and Nitrate (NO_3-N)

Figure 4.44 shows variation of total ammonia for wastewater samples collected in August 2017. On the Saturday (12^{th} August), measured total ammonia concentration varied from 7.225 to 9.2 mg/l (as NH_3-N); while on weekend (11^{th} August) it varied from 9.3 to 14.575 mg/l. In all cases, values measured on weekend were higher than those measured on the weekday. No pattern was observed in the value of ammonia as the day progressed, as observed during the dry season; this is possibly due to heavy rainfall during the sampling time.

Figure 4.45 shows variation of nitrate concentration. It shows that both on weekday and weekend, nitrate concentration is very low after 0600 hrs; possibly due to significant dilution by rainwater. On the Saturday (12^{th} August), the highest nitrate concentration of 0.5mg/l was found at 1200 and 1400 hrs; while on weekend, highest nitrate concentration of 1.6 mg/l was found at 0600 hours.

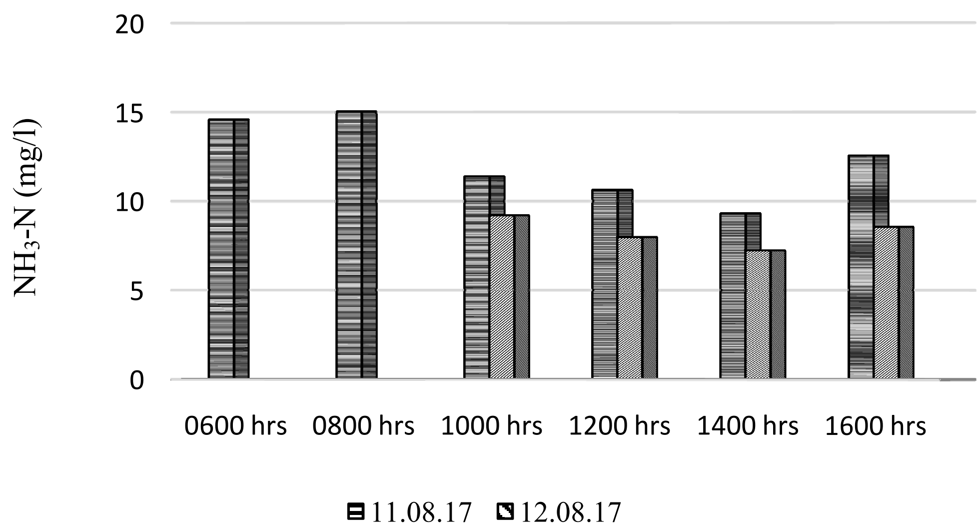

Fig 4.44: Variation of NH_3-N of wastewater samples collected in August 2017

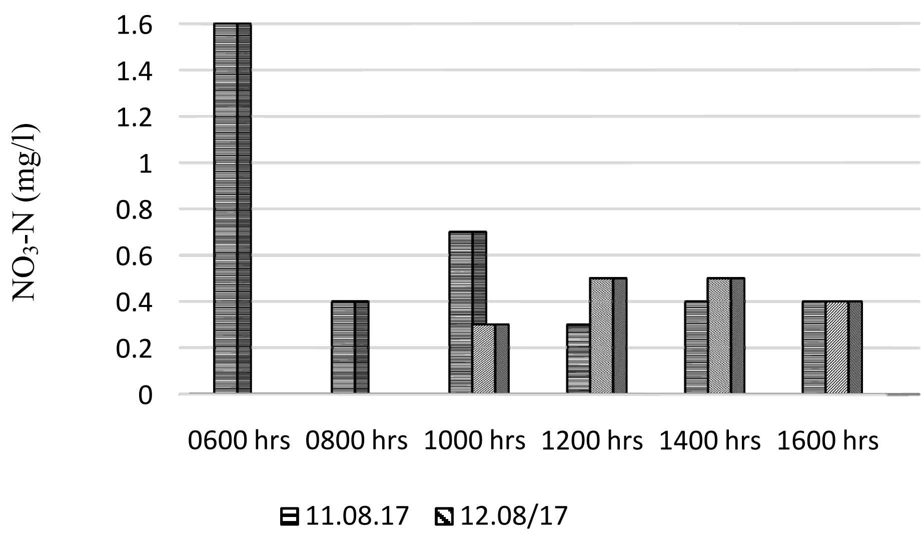

Fig 4.45: Variation of NO_3-N of wastewater samples collected in August 2017

(viii) Phosphate (PO_4)

Figure 4.46 shows phosphate concentrations of the wastewater samples collected in August 2017. It shows no significant variation of phosphate concentration over the day, on both weekday and weekend. In general, phosphate concentration has been found to be higher on the weekday, compared to those on the weekend. On Saturday (12^{th}August), phosphate concentration varied from 3.83 to 4.51 mg/l, while on weekend (11^{th}August), it varied from 2.72 to 4.96 mg/l. As noted earlier, rainfall appears to have significant effect on wastewater composition.

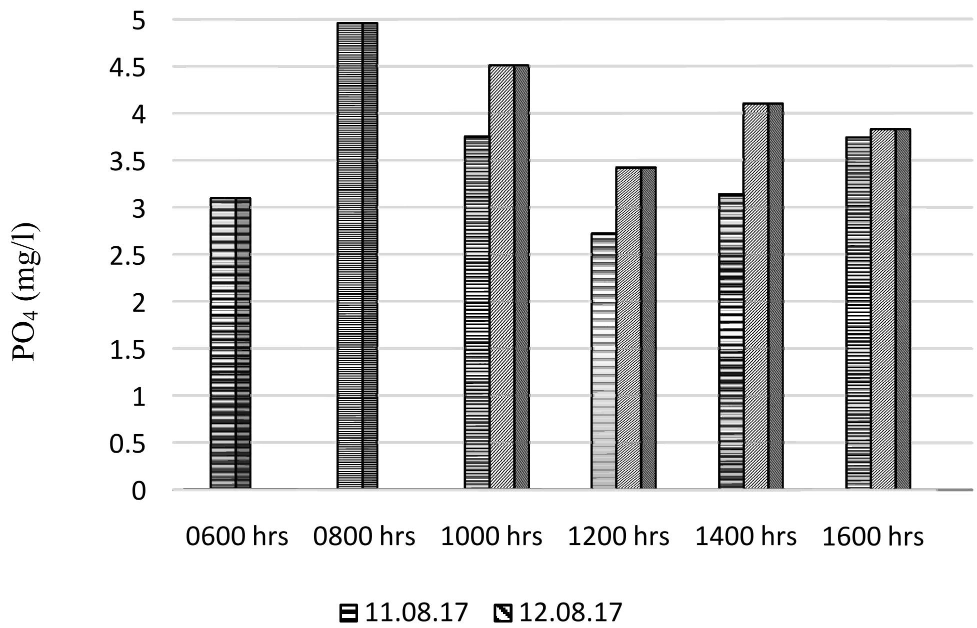

Fig 4.46: Variation of PO_4 of wastewater samples collected in August 2017

(ix) Organic pollution: BOD_5 and COD

Figure 4.47 and 4.48 show variation of BOD_5 and COD, respectively of wastewater samples collected in August 2017. Both figures showed no pattern of values of BOD_5 and COD as day progresses, as observed during the dry season. On Saturday (12 August), BOD_5 concentration varied from 96 to 120 mg/l, while on weekend it varied from 105 to 320 mg/l, and the peak concentration was found at 0600 hrs. During dry season, BOD_5 and COD increased as the day progressed, while during the wet season (especially on 11^{th} August 2018), both BOD_5 and COD decreased with time due to dilution with rainwater. On Saturday (12 August), COD concentration varied from 155 to 188 mg/l, while on weekend it varied from 235 to 599 mg/l and pick concentration was found at 1600 hrs

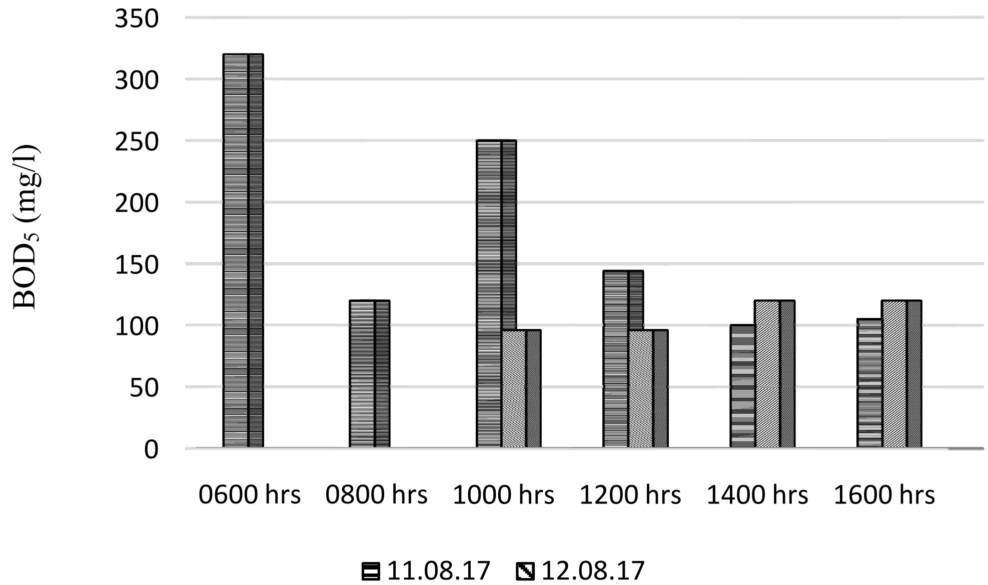

Fig 4.47: Variation of BOD$_5$ of wastewater samples collected in August 2017

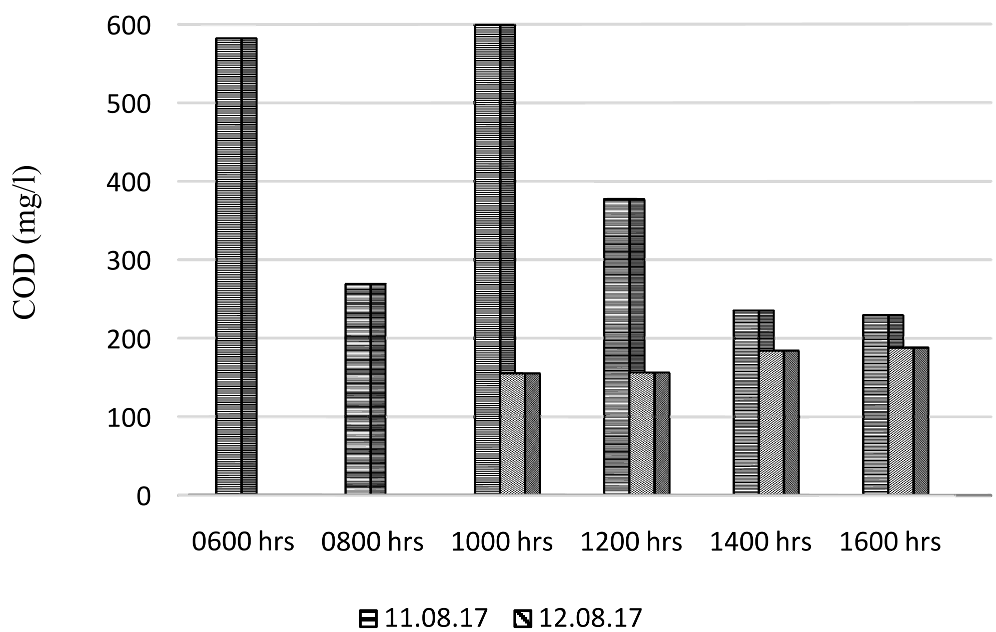

Figure 4.48: Variation of COD of wastewater samples collected in August 2017

4.5 Comparison of Seasonal Characteristics of Wastewater and Implications on Dasherkandi STP

Data presented in preceding Sections suggest that the trend of variation of combined wastewater characteristics is more or less similar for dry season and summer (early wet season), when there was no/low rainfall. During both these periods peak/higher concentrations of important parameters (e.g., TSS, ammonia, phosphate, BOD_5, COD) were reached in the afternoon, mostly at around 1400 hours. During the sampling period in peak wet season in August 2017, wastewater characteristics varied primarily due to variation in rainfall. For comparison of key characteristics of wastewater in different sampling periods, concentrations of the parameters for samples collected at 1400 hours on weekend was compared. Table 4.3 shows comparison of characteristics of key wastewater parameter (from sewage treatment perspective). This table shows significant variation in wastewater characteristics in different seasons/sampling periods.

4.5.1 Comparison of seasonal characteristics of wastewater

Table 4.3 shows a comparison of characteristics of wastewater in dry season (December), summer (May) and wet season (August). Table 4.3 shows that the wastewater parameters varied significantly with season. As expected, concentrations of all the parameters have been found to be higher during the dry season and summer (when there was little rainfall). In the wet season, concentrations of the parameters decreased significantly due to dilution by rainwater; the extent of dilution would depend on intensity of rainfall. Table 4.4 shows that BOD_5 concentration recorded in December 2017 (dry season) is over four times higher than that found for sample collected in August 2017during heavy rainfall. The COD and Ammonia concentrations in December were found to be over two times higher than those recorded in August 2017.

Table 4.4: Comparison of characteristics of combined wastewater flowing through the main diversion sewer system of Hatirjheel in different seasons.

Parameter (unit)	**Concentration for samples collected at 1400 hours on weekend**		
	Dry Season (Dec.)	**Summer (May)**	**Wet Season (August)**
Turbidity (NTU)	284	241	193
TSS (mg/l)	383	655	174
Ammonia (mg/l)	**21.2**	**24**	**9.3**
Phosphate (mg/l)	4.94	6.53	3.14
BOD_5 (mg/l)	**420**	**288**	**100**
COD (mg/l)	**672**	**559**	**235**

4.5.2 Implications of variations in wastewater quality on Dasherkandi STP

Combined wastewater quality monitoring was carried out from May 2017 to December 2017. Samples were collected from the main diversion sewer system near Rampura bridge and from northern and southern sides of main diversion sewer system in three seasons of dry (December), summer (May) and wet (August). Samples were collected every alternative working and holiday in each season and six different times of a day. This section presents the implication of variations in combined wastewater characteristics of Hatirjheel main diversion sewer system for Dasherkandi STP.

The variation of BOD_5 and COD of combined wastewater of Hatirjheel main diversion sewer system with three seasons is shown in following Fig 4.49. It shows that the organic pollution is maximum in dry season (BOD_5 is 420 mg/l and COD is 672 mg/l at 1400 hours on a weekend) and lowest in wet season (BOD_5 is 100 mg/l and COD is 235 mg/l at 1400 hours on a weekend).

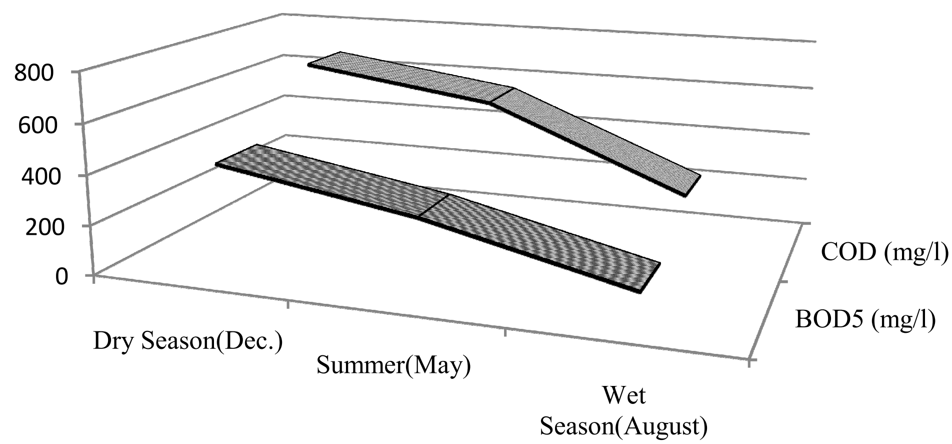

Fig. 4.49: Variation of BOD_5 and COD of combined wastewater from main diversion sewer system in three seasons.

The variation of NH_3-N and PO_4 of combined wastewater of Hatirjheel main diversion sewer system with three seasons is shown in following Fig 4.50. It shows that the ammonia and other nutrients are maximum in summer season (NH_3-N is 24 mg/l and PO_4 is 6.53 mg/l) and lowest in wet season (NH_3-N is 9.3 mg/l and PO_4 is 3.14 mg/l).

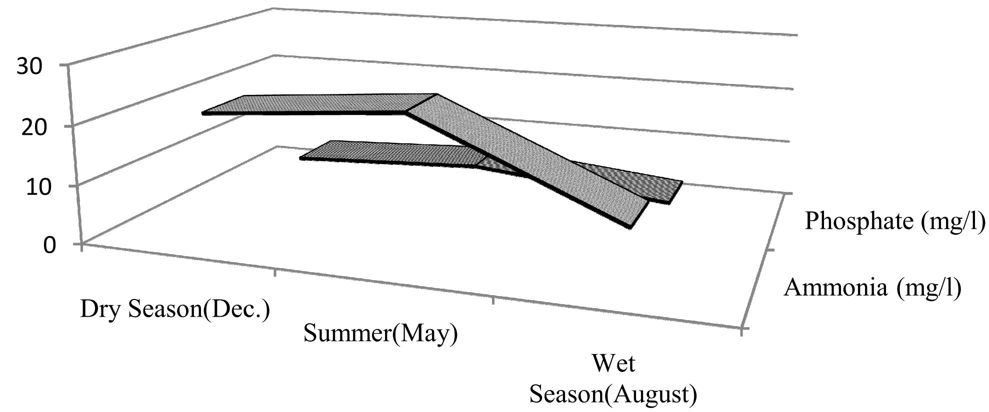

Fig. 4.50: Variation of NH_3-N and PO_4 of combined wastewater from main diversion sewer system in three seasons.

The variation of Turbidity and TSS of combined wastewater of Hatirjheel main diversion sewer system with three seasons is shown in following Fig 4.51. It shows that the solids-Turbidity and TSS are maximum in summer season (Turbidity is 655 NTU and TSS is 241 mg/l) and lowest in wet season (Turbidity is 193 NTU and TSS is 174 mg/l).

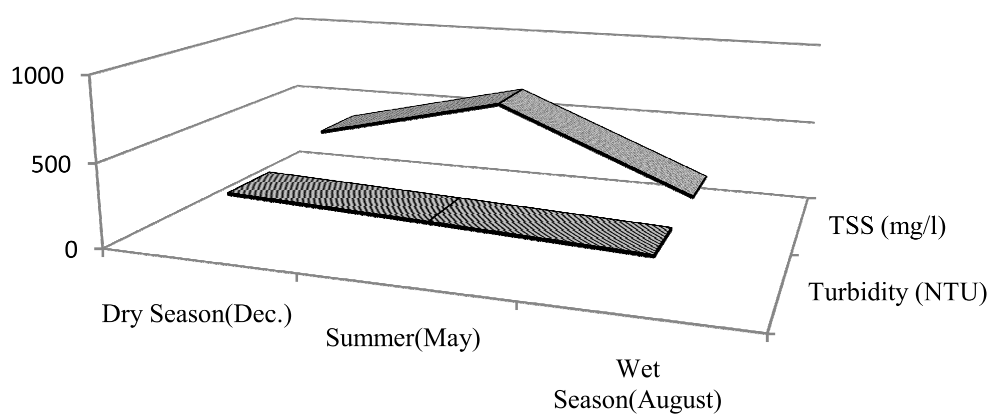

Fig. 4.51: Variation of average Turbidity with TSS in three seasons in the main diversion sewer system

Under the current situation, combined wastewater from main diversion sewer of Hatirjheel would be lifted at the Rampura sewage lifting station and sewage would be transported to Dasherkandi STP. Thus, the flow/discharge of sewage at Dasherkandi STP is not likely to vary significantly with season. On the other hand, depending on rainfall situation, organic load could vary by a factor of four. As a result, the operational parameters (e.g., detention time at the aeration tanks, and secondary clarifiers) at the Dasherkandi needs to be adjusted to optimize the treatment process.

4.6 Impact of Future Developments on Operation of Dasherkandi STP

As discussed earlier, the combined wastewater flows from the main diversion sewers of Hatirjheel would be carried to the under-construction Dasherkandi STP (using a pumping station to be built at Rampura) for treatment. While the Dasherkandi STP is being constructed to serve domestic wastewater generated in Dasherkandi (or Dhaka East) catchment, no sewerage system/network has so far been developed for carrying wastewater generated from Dasherkandi catchment to the Dasherkandi STP; in fact, development of sewerage network for Dasherkandi catchment is still at the planning stage. Under this situation, Dasherkandi STP would receive wastewater from the main diversion sewer system of Hatirjheel. However, the main diversion sewer system of Hatirjheel receives wastewater from three different catchments-Dhaka South (Pagla), Dhaka East (Dasherkandi) and Rayerbazar catchments. Therefore, until the sewerage system for Dasherkandi catchment is developed, Dasherkandi STP would treat sewage from these three catchments. However, Dhaka WASA is also planning renovation/construction of sewerage system and sewage treatment plant in Dhaka South (Pagla) and Rayerbazar catchments. These projects could significantly impact operation of the Dasherkandi STP, which needs to be carefully evaluated for ensuring proper operation of the Dasherdandi STP.

This Section presents an assessment of operational situation of Dasherkandi STP under the following conditions:

(a) Present situation;
(b) After renovation of Pagla Sewage Treatment Plant and associated sewerage system;
(c) After construction of Rayerbazar Sewage Treatment Plant and associated sewerage system; and
(d) After development of sewerage network for Dasherkandi catchment.

4.6.1 Operation under present situation

Under the present situation, combined wastewater flows from the main diversion sewers of Hatirjheel would be carried to the under-construction Dasherkandi STP (using a pumping station to be built at Rampura) for treatment. The main diversion sewers of Hatirjheel receive storm waster-sewage from 9 Special Sewage Diversion Structures (SSDS). The main diversion sewer along the southern periphery of Hatirjheel receives storm water-sewage from SSDS-1, 2, 3, 4 and 5; while main diversion sewer along the northern periphery receives storm water-sewage from SSDS-7, 8, 9 and 10. It should be noted that storm water-sewage from SSDS-6 and SSDS-11 are discharged directly into the Begunbari khal system and does not come into the main diversion sewer system. As noted earlier, these SSDS receive storm water-sewage from three different sewerage catchments – Dhaka South (Pagla) catchment, Dhaka East (Dasherkandi) catchment, and Rayerbazar catchment. Figure 4.52 shows sewerage catchments according to DWASA Master Plan (DWASA, 2013).Table 4.5 shows sewerage catchment and catchment area under each of the 9 SSDS contributing to the main diversion sewer.

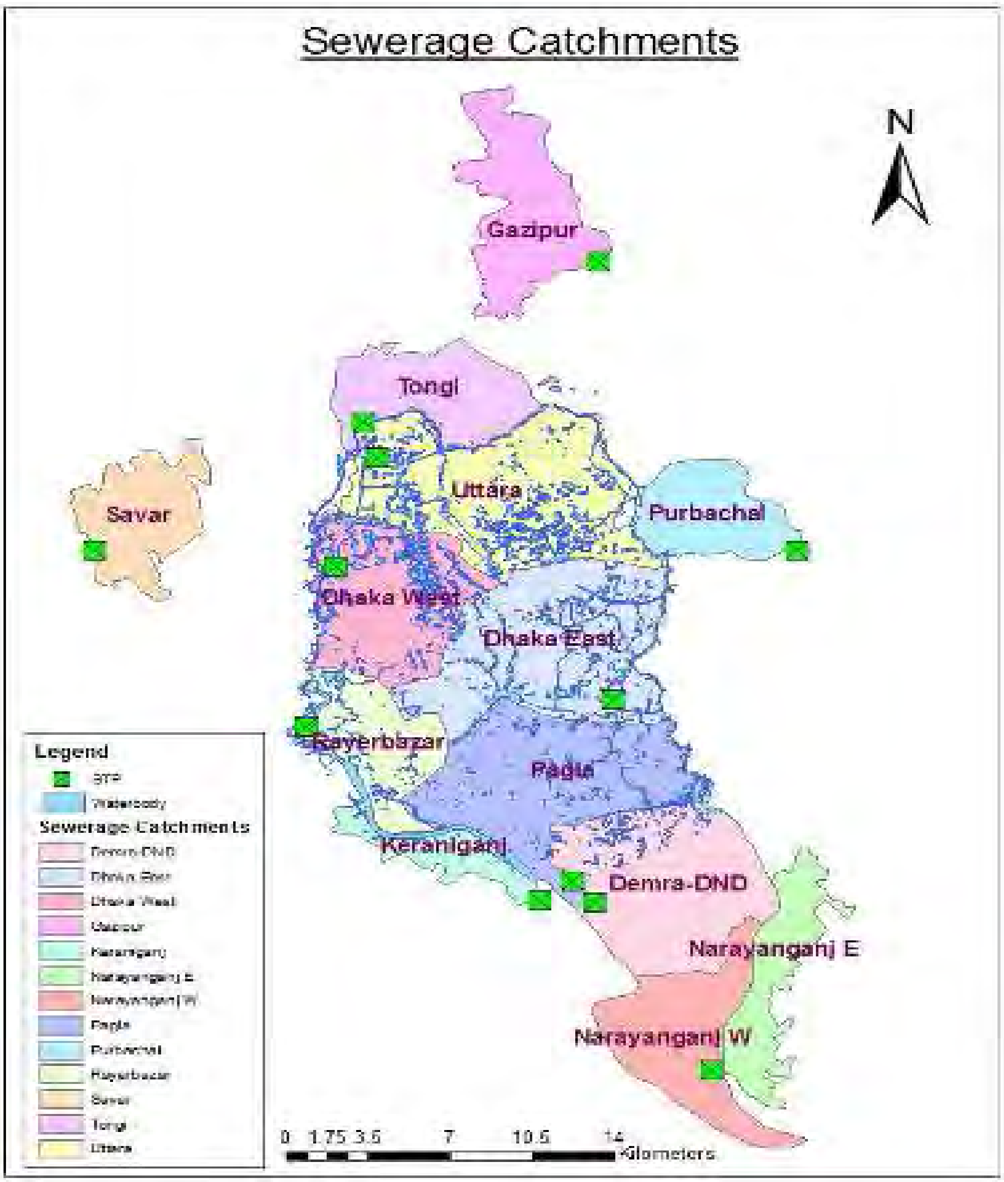

Fig 4.52: Sewerage catchments according to DWASA Master Plan (DWASA, 2013)

Table 4.5: Sewerage catchment and catchment areas under the SSDS contributing flow to the main diversion sewer of Hatirjheel

Main Diversion Sewer	SSDS Contributing Flow (storm water-sewage)	Catchment Area (km^2)	Sewerage Catchments
Along Southern Side of Hatirjheel	SSDS-1	6.75	Rayerbazar catchment: 4.80 km^2 Pagla catchment: 1.56 km^2 Dasherkandi catchment: 0.39 km^2
	SSDS-2	1.90	Entire area under Pagla catchment
	SSDS-3	1.30	Entire area under Pagla catchment
	SSDS-4	0.20	Entire area under Pagla catchment
	SSDS-5	0.30	Entire area under Pagla catchment
	Sub-total (catchment area for southern side of Hatirjheel)	10.45	Rayerbazar catchment: 4.80 km^2 Pagla catchment: 5.26 km^2 Dasherkandi catchment: 0.39 km^2
Along Northern Side of Hatirjheel	SSDS-7	1.60	Entire area under Dasherkandi catchment
	SSDS-8	0.40	Entire area under Dasherkandi catchment
	SSDS-9	0.40	Entire area under Dasherkandi catchment
	SSDS-10	4.87	Entire area under Dasherkandi catchment
	Sub-total (catchment area for northern side of Hatirjheel)	7.27	Entire area (7.27) under Dasherkandi catchment

Thus, the main diversion sewer system along the southern periphery of Hatirjheel receives storm water-sewage from a total catchment area of about 10.45 km^2; of this, only 0.39 km^2 falls under Dasherkandi catchment. Thus, of the total catchment area contributing flow to the southern part of main diversion sewer, Rayerbazar catchment (4.80 km^2) accounts for about 46% of the area, Pagla catchment (5.26 km^2) for about 50% of the area, while Dasherkandi catchment accounts for about 4% of the area. On the other hand, the entire area (7.27 km^2) contributing flows to the main diversion sewer on the northern side of Hatirjheel falls under Dasherdandi catchment.

Thus, of the total catchment area of 17.72 km^2 that contributes to the combined flow (both storm water and sewage) of main diversion sewer system, 7.66 km^2 (or 43.2%) falls under Dasherkandi catchment, 4.80 km^2 (or 27.1%) falls under Rayerbazar catchment, and 5.26 km^2 (or 29.7%) falls under Pagla catchment. Therefore, under the present situation, Dasherkandi STP would receive flows (storm water and sewage) from a catchment area of about 17.72 km^2, of which only 43.2% falls under Dasherdandi catchment.

4.6.2 Operation after renovation of Pagla STP and sewerage System

Preparatory works for the renovation of Pagla STP and associated sewerage system is already underway, and these works are likely to be completed before development of sewerage system for Dasherkandi catchment areas. Therefore, Dasherkandi STP would continue to receive wastewater from the main diversion sewer system of Hatirjheel. But development of Pagla STP and sewerage system would bring about some changes in the quality and quantity of flow in the main diversion sewer system, flowing along the southern side of Hatirjheel.

After completion of renovation works of Pagla STP and sewerage system, the southern main diversion sewer of Hatirjheel would continue to receive storm water discharge from 10.45 km^2 area (through storm drainage network); but it will receive sewage from an area of about 5.19 km^2, due to diversion of sewage from 5.26 km^2 area under Pagla catchment to Pagla STP (through a separate sanitary sewer network). This would result in even more dilution of sewage during the wet season; in this situation sewage generated within an area of 5.19 km^2 would be mixed with storm water generated in 10.45 km^2 area. This would cause even more variation in the characteristics of combined sewage (that would be transported to Dasherkandi SPT) between dry season and wet season. Since dilution of sewage by rainwater would depend on rainfall intensity, the characteristics of the combined sewage would change with changes in rainfall intensity during the wet season. The operators at the Dasherkandi STP need to take care of this variation by adjusting operational parameters, e.g., detention time in activated sludge process and so on.

During dry season, after the completion of Pagla renovation works, the "southern main diversion sewer" would receive less sewage, as sewage generated in Pagla catchment would be carried out Pagla STP. Thus, dry weather flow of sewage to Dasherkandi would decrease significantly.

4.6.3 Operation after implementation of Rayerbazar STP and sewerage system

Work of Rayerbazar STP and sewerage system is yet to start. But eventually DWASA will implement this STP and operation of this STP and associated sewerage system is likely to have significant impact on the characteristics of sewage flowing into Dasherkandi STP.

After implementation of Rayerbazar STP and sewerage system, sewage generated 4.80 km^2 area (under Rayerbazar catchment) would be diverted to Rayerbazar STP through a separate sanitary sewer network. Thus the main diversion sewer on the southern side of Hatirjheel would receive sewage from only 0.39 km^2area, while it would continue to receive storm water from 10.45 km^2 areas. Thus, during wet season, sewage generated in only 0.39 km^2 area would be mixed with storm water generated in 10.45 km^2 area. In other words, under this situation, the main diversion sewer on the southern side of Hatirjheel would carry "primarily storm water" during the wet season. This "primarily storm water" would then be mixed with storm water-sewage mixture coming through the "northern main diversion sewer" and transported to Dasherkandi STP for treatment.

This appears to be a highly unacceptable situation; in this situation the Dasherkandi STP would be forced to treat a huge flow of "storm water" that should actually be discharged into open water bodies. Depending on the characteristics of flow along the northern main diversion sewer, DWASA should take a decision whether this flow would be carried to Dasherkandi STP for treatment or discharged into Hatirjheel through the overflow structures of the SSDS.

If Rayerbazar STP is implemented before development of Dasherkandi sewerage system, the sewage flow to Dasherkandi STP during dry season would significantly reduce, as sewage generated in both Pagla and Rayerbazar catchments (that now comes into the southern main diversion sewer of Hatirjheel) would be carried to the respective STPs.

4.6.4 Operation after development of Dasherkandi sewerage system

Under the present arrangement, a sewage lifting station at Rampura would pump wastewater received from the main diversion sewers of Hatirjheel to the Dasherkandi STP. As discussed earlier, the main diversion sewer on the southern side of Hatirjheel currently carry sewage generated primarily in Rayerbazar and Pagla catchments. Once sewerage system and STP would be developed in these (i.e., Rayerbazar and Pagla) catchments, this part of the main diversion sewer would carry very little domestic sewage during dry season, and would carry primarily storm water during the wet season. Thus, it can be assumed that under this situation the "southern main diversion sewer" would not contribute any significant sewage to the Dasherkandi STP.

The separate sanitary sewer network to be developed for Dasherkandi catchment is likely to utilize the main diversion sewer along the northern side of Hatirjheel to carry sewage up to the Rampura lifting station (from where it would be fed to Dasherkandi STP). But the northern main diversion sewer of Hatirjheel consists of twin 1830 mm concrete sewers (at the downstream end), which limits the quantity of sewage that could be carried through this system. The maximum capacity of twin 1830 mm concrete sewers is about 200,000 m^3/day; whereas the capacity of Dasherkandi STP is 500,000 m^3/day. Therefore, additional sewage (generated within Dasherkandi catchment) needs to be carried to the Dasherkandi STP through other sanitary sewer network to be developed for this catchment. In this situation, it is likely that the Rampura sewage lifting station would be under-utilized (lifting only sewage received from northern side). During design of Dasherkandi sewerage network, efforts should therefore be made to make sure that the existing facilities (e.g., the Rampura sewage lifting station) are optimally used for conveyance of sewage to Dasherkandi STP.

CHAPTER 5

CONCLUSIONS AND SUGGESTIONS

5.1 Introduction

At present Hatirjheel serves very important hydrological functions of draining and detaining storm water from a large area like Dhaka east, Rayerbazar and Pagla catchment of Dhaka city. Its main diversion sewer system carries primarily domestic sewage during dry season, and mixture of storm water and domestic sewage during wet season as there is virtually no operational sanitary sewer network in the city. The combined wastewater of main diversion sewer system of Hatirjheel would be transported to the under-construction Dasherkandi STP for treatment. This research work provides an assessment of the quality of the combined wastewater during dry, summer and wet seasons. It also provides assessment of the characteristics of wastewater from northern and southern sides of Hatirjheel. This study presents an assessment of the implication of variable wastewater characteristics of diversion sewer system, and ongoing and future projects of DWASA on the operation of the Dasherkandi STP.

This Chapter presents the major conclusions from the present study. It also presents recommendations for future work.

5.2 Conclusions

Major conclusions that are obtained from this study are as follows:

a. During the dry season and summer, when there is little rainfall, the characteristics of combined sewage of Hatirjheel main diversion sever varies significantly with the time of the day. Concentration of most of the parameters, particularly Turbidity, TSS, Ammonia, Phosphate, BOD_5 and COD, increases at the day progresses, and reaches their peak values at around 1400 hours.

b. During the dry season and summer, when there is little rainfall, concentrations of Turbidity, TSS, BOD_5 and COD appears to be slightly higher during the weekend, compared to weekdays; while concentration of ammonia and phosphate appear to be slightly lower during the weekend, compared to weekdays.

c. BOD_5/COD ratio of combined wastewater during dry season varied from 0.49 to 0.63, indicating that the wastewater does not contain significant non-biodegradable waste and it could be easily treatable by biological means.

d. The characteristics of wastewater coming from northern and southern sides of the main diversion sewer are comparable, although the organic load coming from the southern side appears to be slightly higher. The BOD_5/COD ratio of wastewater coming from the northern side is slightly lower than that coming from the southern side, indicating relatively higher contribution of industrial sewage from the northern side of Hatirjheel.

e. The characteristics of combined wastewater changes significantly during the wet season due to dilution with rainwater. The peak BOD_5 concentration (420 mg/l) recorded in December 2017 (dry season) has been found to be over four times higher than that of the sample collected in August 2017 during heavy rainfall. The COD (672 mg/l) and Ammonia (21.2 mg/l) concentrations in December (dry season) were found to be over two times higher than those recorded in August 2017 (wet season).

f. Depending on rainfall situation, pollution load at Dasherkandi STP would vary significantly; the BOD load could vary by a factor of four. As a result, the operational parameters (e.g., detention time at the aeration tanks, and secondary clarifiers) at the Dasherkandi needs to be adjusted to optimize the treatment process.

g. The flow coming through the "southern main diversion sewer of Hatirjheel" carries sewage mainly from Pagla and Rayerbazar catchments. After implementation of sewerage system (including STP) at these two catchments, the "southern main diversion sewer of Hatirjheel" would carry primarily storm water during wet season; this would cause even more dilution of sewage during wet season.

5.3 Suggestions

Major suggestions are as follows:

a. In the study, flow/discharge through the main diversion sewer could not be measured due to unavailability of suitable measuring devices. In future studies, effort should be made to measure flow rate through the main diversion sewer system as a function of the time of the day, in order to get better estimate of pollution load.

b. During wet season, the characteristics of flow through the main diversion sewer vary with rainfall intensity. In future studies, efforts should be made to quantity the characteristics of wet season flow with rainfall intensity.

c. Studies should be undertaken to understand characteristic of sewage to be treated at the Dasherkandi STP after implementation of Pagla STP and sewerage system renovation works.

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APPENDIX

SEWAGE QUALITY PARAMETERS FOR SAMPLES COLLECTED ON 12 & 14 MAY 2017

pH:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
12.05.17	7.04	7.02	6.95	6.94	7.01	6.91	6.95	6.6	7.13	0.14
14.05.17	7.13	7.08	6.60	6.99	6.93	6.85				

Turbidity:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
12.05.17	101	89	90	222	241	179	141.3	58.6	241	57.53
14.05.17	83.4	58.6	148	153	170	160				

Alkalinity:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max	STDEV
12.05.17	246	233	246	277	281	243	262.6	233	584	21.91
14.05.17	290	248	244	290	292	262				

COD:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
12.05.17	298	269	314	527	559	462	376.08	244	559	98.261
14.05.17	342	244	331	389	393	385				

BOD_5 :

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
12.05.17	160	136	120	272	288	212.5	196.04	120	288	54.91
14.05.17	190	120	224	210	230	190				

NH_3-N:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	140 0 hrs	1600 hrs	Avg	Min.	Max.	STD EV
12.05.17	19.27	18.4	21.7	25.9	24	20.92	22.22	18.42	52.75	2.59
14.05.17	21.12	22.6	23.1	26.3	23.9	19.12				

EC:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
12.05.17	641	624	654	720	709	661	727.17	624	997	98.49
14.05.17	997	796	708	747	727	742				

Temperature:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
12.05.17	29.4	29.6	30.2	30.4	30.4	30.6	30.1	29.4	30.4	0.42
14.05.17	30.5	30.4	30.4	30.3	30.4	29.5				

NO_3:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
12.05.17	0.4	0.5	0.4	0.4	0.5	0.4	0.53	0.4	0.7	0.135
14.05.17	0.8	0.6	0.4	0.6	0.7	0.6				

TSS:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
12.05.17	53	80	428	230	655	156	201.5	53	655	172.72
14.05.17	99	91	171	162	136	157				

TDS:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
12.05.17	374	356	34	393	41	418	363.3	34	612	164.76
14.05.17	612	423	415	421	429	444				

PO_4:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
12.05.17	4.69	5.36	6.82	7.13	6.53	4.66	6.96	4.66	10.2	3.68
14.05.17	5.54	6.68	8.07	10.2	10.02	7.82				

Color:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
12.05.17	219	267	181	335	340	313	287.1	181	370	56.92
14.05.17	290	283	273	370						

SEWAGE QUALITY PARAMETERS FOR SAMPLES COLLECTED ON 11 & 12 AUG 2017

pH:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
11.08.17	6.14	7.18	6.46	6.69	7.17	6.81	6.99	6.14	7.62	0.92
12.08.17	-	-	7.62	7.41	7.23	7.26				

Turbidity:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
11.08.17	127	91	228	163	193	91	138.8	91	228	131.33
12.08.17	-	-	127	132	116	120				

Alkalinity:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
11.08.17	510	224	210	133	146	165	195	132	510	460.88
12.08.17	-	-	141	132	139	150				

COD:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
11.08.17	582	269	599	377	235	229	297.4	155	599	167.59
12.08.17	-	-	155	156	184	188				

BOD_5:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
11.08.17	320	120	250	144	100	105	147.1	96	320	75.95
12.08.17	-	-	96	96	120	120				

NH_3-N:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
11.08.17	14.5	15.0	11.37	10.62	9.3	12.5	10.6	7.22	15.0	2.71
12.08.17	-	-	9.2	7.975	7.22	8.55				

EC:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
11.08.17	707	717	471	359	395	483	445.2	184	717	179.73
12.08.17	-	-	485	463	184	188				

Temperature:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
11.08.17	27.8	27.6	27.5	27.4	27.3	27.1	27.48	27.1	27.8	0.23
12.08.17	-	-	27.6	27.8	27.4	27.3				

NO_3:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
11.08.17	1.6	0.4	0.7	0.3	0.4	0.4	0.55	0.3	1.6	0.39
12.08.17	-	-	0.3	0.5	0.5	0.4				

TSS:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
11.08.17	132	178	491	322	174	126	182.2	46	491	133.62
12.08.17	-	-	78	80	195	46				

TDS:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
11.08.17	461	363	264	176	184	257	260.3	133	461	94.90
12.08.17	-	-	263	230	133	272				

PO_4:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
11.08.17	3.1	4.96	3.75	2.72	3.14	3.74	3.727	2.72	4.96	0.68
12.08.17	-	-	4.51	3.42	4.10	3.83				

Color:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
11.08.17	502	291	440	255	163	255	284	163	502	106.83
12.08.17	-	-	185	222	265	262				

SEWAGE QUALITY PARAMETERS FOR SAMPLES COLLECTED ON 14 & 15 DEC 2017

pH:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
14.12.17	7.38	7.41	7.35	7.25	7.34	7.11	7.04	6.15	7.41	0.42
15.12.17	6.49	7.13	7.32	6.55	6.15	7.01				

Turbidity:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
14.12.17	37.7	75	87	139	108	217	138.06	37.7	284	74.61
15.12.17	94	116	81	223	284	195				

Alkalinity:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
14.12.17	289	290	307	386	313	354	309.94	252	303.33	40.79
15.12.17	281	252	264	350	286	268				

COD:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
14.12.17	172	186	280	406	349	579	369.17	172	672	165.37
15.12.17	420	205	236	558	672	367				

BOD_5:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
14.12.17	80	65	88	130	168	224	178.67	65	420	106.02
15.12.17	250	100	125	304	420	190				

NH_3-N:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
14.12.17	22.93	22.2	24.93	28	25.6	22.4	22.40	17.63	28	3.10
15.12.17	17.63	18.73	22.63	24.2	21.2	18.33				

EC:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
14.12.17	864	830	885	1055	800	802	835.58	730	1055	80.62
15.12.17	809	730	801	856	823	772				

Temperature:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
14.12.17	23.1	21.1	23.2	23.3	22.7	22.9	22.71	21.1	23.3	0.57
15.12.17	23	22.7	22.6	22.5	22.6	22.8				

NO_3:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
14.12.17	0.2	0.3	0.4	0.5	0.5	0.6	0.53	0.2	0.9	0.20
15.12.17	0.8	0.5	0.4	0.7	0.6	0.9				

TSS:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
14.12.17	31	65	112	152	147	238	160.08	31	383	93.19
15.12.17	143	133	95	234	383	188				

TDS:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
14.12.17	491	494	489	595	426	505	504.58	412	618	64.32
15.12.17	530	412	490	567	438	618				

PO_4:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
14.12.17	5.555	5.32	7.9	7.45	7.875	6.17	5.49	1.43	8.85	2.32
15.12.17	1.425	4.6	8.85	3.685	4.94	2.13				

Color:

Date	0600 hrs	0800 hrs	1000 hrs	1200 hrs	1400 hrs	1600 hrs	Avg	Min.	Max.	STDEV
14.12.17	341	283	300	380	325	398	369.92	256	565	106.21
15.12.17	535	259	256	487	310	565				

SEWAGE QUALITY PARAMETERS FOR SAMPLES COLLECTED ON 14 & 15 DEC 2017 FROM NORTHERN AND SOUTHERN SIDES OF MAIN DIVERSION SEWER

pH:

	0800 hrs 14.12.17	1400 hrs 14.12.17	0800 hrs 15.12.17	1400 hrs 15.12.17	Avg	Min.	Max.	STDEV
North	7.36	7.12	7.25	7.25	7.25	7.12	7.36	0.098
South	7.25	7.22	7.21	6.43	7.03	6.43	7.25	0.399

Turbidity:

	0800 hrs 14.12.17	1400 hrs 14.12.17	0800 hrs 15.12.17	1400 hrs 15.12.17	Avg	Min.	Max.	STDEV
North	59	195	49	283	147	49	283	112,76
South	157	195	95	228	169	95	228	67.09

Alkalinity:

	0800 hrs 14.12.17	1400 hrs 14.12.17	0800 hrs 15.12.17	1400 hrs 15.12.17	Avg	Min.	Max.	STDEV
North	334	388	294	375	348	294	388	42.59
South	258	291	241	255	261	241	291	21.17

COD:

	0800 hrs 14.12.17	1400 hrs 14.12.17	0800 hrs 15.12.1 7	1400 hrs 15.12.17	Avg	Min.	Max.	STDEV
North	191	481	191	579	361	191	481	199.77
South	299	372	201	614	372	201	614	176.19

BOD_5:

	0800 hrs 14.12.17	1400 hrs 14.12.17	0800 hrs 15.12.17	1400 hrs 15.12.17	Avg	Min .	Max.	STDEV
North	90	190	100	224	151	90	224	66.26
South	112	200	135	320	192	112	320	93.27

NH3-N:

	0800 hrs 14.12.17	1400 hrs 14.12.17	0800 hrs 15.12.1 7	1400 hrs 15.12.17	Avg	Min.	Max.	STDEV
North	21.9	25.1	20.83	24.85	23.17	20.83	24.85	2.13
South	18.5	29.3	17.1	20.35	21.31	17.1	20.35	5.49

EC:

	0800 hrs 14.12.1 7	1400 hrs 14.12.17	0800 hrs 15.12.17	1400 hrs 15.12.17	Avg	Min .	Max.	STDEV
North	1096	851	882	1010	960	851	1096	113.96
South	670	786	643	740	710	670	786	65.23

Temperature:

	0800 hrs 14.12.17	1400 hrs 14.12.17	0800 hrs 15.12.17	1400 hrs 15.12.17	Avg	Min.	Max.	STDEV
North	23.3	22.7	22.0	23.1	22.78	22.0	23.3	0.573
South	22.7	22.8	23	22.8	22.83	22.7	23	0.126

NO_3:

	0800 hrs 14.12.17	1400 hrs 14.12.17	0800 hrs 15.12.17	1400 hrs 15.12.17	Avg	Min.	Max.	STDEV
North	.4	.5	.4	.5	.45	.4	.5	.058
South	.3	.5	.4	.7	.475	.3	.7	.170

TSS:

	0800 hrs 14.12.17	1400 hrs 14.12.17	0800 hrs 15.12.17	1400 hrs 15.12.17	Avg	Min.	Max.	STDEV
North	82	246	56	363	187	56	363	144.50
South	261	165	138	206	193	138	261	53.54

TDS:

	0800 hrs 14.12.17	1400 hrs 14.12.17	0800 hrs 15.12.17	1400 hrs 15.12.17	Avg	Min.	Max.	STDEV
North	653	501	540	592	572	501	653	65.89
South	326	446	359	526	414	326	526	90.07

PO_4:

	0800 hrs 14.12.17	1400 hrs 14.12.17	0800 hrs 15.12.17	1400 hrs 15.12.17	Avg	Min.	Max.	STDEV
North	7.035	8.0	5.44	6.265	6.685	5.44	8.0	1.09
South	5.92	7.565	4.425	4.39	5.575	4.425	7.57	1.51

Color:

	0800 hrs 14.12.17	1400 hrs 14.12.17	0800 hrs 15.12.17	1400 hrs 15.12.17	Avg	Min.	Max.	STDEV
North	424	453	299	336	378	299	453	72.45
South	230	285	212	830	389	212	830	295.47