ANALYSIS OF WATER QUALITY INDEX OF HATIRJHEEL LAKE, DHAKA

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This Thesis Report Presented in Partial Fulfilment of the Requirements for the Degree of Bachelor of Science (B.Sc.) in Environmental Science and Disaster Management (ESDM)

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APPROVAL

This thesis report titled **"Analysis of water quality index of Hatirjheel Lake, Dhaka",** submitted by Syed Omayer Mustafa to the Department of Environmental Science and Disaster Management (ESDM), Daffodil International University (DIU), has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of Bachelor of Science (B.Sc.) in Environmental Science and Disaster Management (ESDM) and approved as to its style and contents. The presentation has been held on 15th March of 2021.

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DECLARATION

I hereby declare that this research project has been done by me under the supervision of **Dr. A. B. M. Kamal Pasha, D.Sc.** Associate Professor & Head, Department of Environmental Science and Disaster Management (ESDM), Daffodil International University (DIU). I also declare that neither this research project nor any part of this research project has been submitted elsewhere for the award of any degree.

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DEDICATION

To,

my loving parents

-Name-

-Name-

my younger brother

-Name-

my maternal grandmother and grandfather

-Name-

-Name-

my respected teachers

Dr. A. B. M. Kamal Pasha, DSc.

Md. Azharul Haque Chowdhury

Dr. Mahfuza Parveen, PhD

Mrs. Zannatul Ferdaus

Dr. Hasibur Rahman, PhD

and

to the loving memory of my beloved seniors, juniors, coordination officers and staffs from the ***Department of Environmental Science and Disaster Management (ESDM), Daffodil International University (DIU)*** *with whom I was spent a single second of my undergrad life.*

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ABSTRACT

The study was conducted to know the status of water quality of Hatirjheel lake in Dhaka city. There are nine water samples from different locations of this lake has been analyzed for various physiochemical parameters including pH, TDS, TSS, EC, DO, Free CO_2, Total Acidity, Total Alkalinity, Total Hardness, Ca^{2+} Hardness at dry season of 2021 (16^{th} January 2021). The mean ± SD of pH 6.80 ± 0.18, TDS 488.89 ± 41.67ppm, TSS 0.02 ± 0.010ppm, EC 558.89 ± 30.19 μS/cm, DO 4.12 ± 0.95mg/L, Total Acidity 385.78 ± 75.79 mg/L, Total Alkalinity 248 ± 1256.68 mg/L, Total Hardness 392 ± 35.72 mg/L, Ca^{2+} Hardness 122.44 ± 25.59 mg/L and they are compared to Bangladesh Standard (ECR, 1997) and WHO standard (WHO, 2004, WHO, 2011). The study found that the lower concentration of DO is below 6 mg/L which exceeds the Bangladesh standard (ECR, 97) in all of the water samples around the lake that severely harmed the aquatic organism and degrade their habitat. On the other hand, the concentration of f, free CO_2 is extremely high as the high concentration of CO_2 decrease the pH level of the water and it affects shallow-water marine organisms. Parameters such as pH varied from 6.5-7.05, EC varied from 510-600 μS/cm, TDS varied from 450-590ppm, TSS varied from 0-0.034ppm, Total Acidity varied from 224-500 mg/L, Total Alkalinity varied from 80-392 mg/L, Total Hardness varies from 348-452 mg/L, Ca^{2+} Hardness varied form 74-162 mg/L, Free CO2 varied form 730.4-1170.4 mg/L and DO varied from 2.7-5.5 mg/L. There are four positively strong significant relation found between pH and EC (r = 0.802), pH and Acidity (r =0.893), pH and Total Hardness (r = 0.879), EC and TDS (r = 0.814). Also, there are two positively moderate significant relationship found between pH and TDS (r = 0.702), EC and Total Hardness (r = 0.774). Although Hatirjheel plays a significant role in the drainage system of the storm water, many drainage discharges form the industrial area affects the water quality. In this consequence proper monitoring of the water quality of those discharge point should be implemented in order to prevent lake contamination.

TABLE OF CONTENTS

Contents **Page**

LIST OF TABLES

LIST OF FIGURES (IMAGE, MAP AND FLOW CHART)

LIST OF SYMBOLS AND ABBREVIATIONS

Symbol or Unit	Name of the symbols
'	Second
º	Minute
ºC	Degree Celsius
µS/cm	Micro Siemens Centimeter
mS/cm	Milli Siemens Centimeter
dS/cm	Deci Siemens Centimeter
mg/L	Milligram per Liter
ppt	Parts Per Thousand
ppm	Parts Per Million
m	Meter
m_2	Meter Square
km	Kilometer
sq.km	Square Kilometer

Abbreviation	Full Form of the Abbreviation
BIS	Bureau of Indian Standards
BSCIC	Bangladesh Small and Cottage Industries Corporation
BWDB	Bangladesh Water Development Board
DCC	Dhaka City Corporation
DIU	Daffodil International University
DO	Dissolved Oxygen
DOHS	Defense Officers Housing Society
EC	Electrical Conductivity

ECR	The Environment Conservation Rules
EDTA	Ethylenediaminetetraacetic Acid
ESDM	Environmental Science and Disaster Management
FAP	Floodplain Action Plan
HDPE	High Density Poly Ethelene
JICA	Japan International Corporation Agency
RAJUK	Rajdhani Unnayan Kartripakkha
SEAWA	South East Alberta Watershed Alliance
SPSS	Statistical Package for Social Science
TDS	Total Dissolved Solid
WASA	Water Supply and Sewerage Authority
WHO	World Health Organization
WQI	Water Quality Index

CHAPTER 01: INTRODUCTION

1.1 Background

Since water is essential for all life, it is a unique resource that continuously cycles between the land and the atmosphere. The same water is used for crop and animal processing, as well as being available to the general public and marine and terrestrial habitats. Water supplies are a major environmental concern that is being researched by a diverse group of experts, including hydrologists, engineers, ecologists, geologists, and geomorphologists. According to environmental estimates, water sources should make up about 10% of a city's total area in order for it to operate properly, as the presence of water bodies reduces sound and air pollution. The main sources of water in Bangladesh are surface waters in rivers, reservoirs, lakes, canals and ponds, and groundwater in shallow and deep aquifers (Ahmed and Rahman, 2005). Dhaka is situated in the country's geographic center. It is located in the Ganges and Brahmaputra rivers' great deltaic area. The city is in the monsoon climate region, with an annual average temperature of 25 degrees Celsius (77 degrees Fahrenheit) and monthly mean temperatures ranging from 18 degrees Celsius (64 degrees Fahrenheit) in August to 25 degrees Celsius (77 degrees Fahrenheit) in January. Between May and September, nearly 80% of the annual average rainfall of 1854 mm (73 in) falls. A lake is a smaller body of water than a canal or a river. In an area, a lake is thought to be a reservoir for drain water, though some lakes are kept free of drain connections. Lake water is used for a variety of purposes, including irrigation, aquaculture, and livestock. a body of water.(Razzak, 2013)

The Hatirjheel and Gulshan Lakes have long been in demand by city dwellers seeking physical and mental nourishment. Rapid urbanization, combined with encroachment, has resulted in the depletion of surface water catchments, as well as siltation and contamination from residential, industrial, and agricultural waste, as well as eutrophication. These are the world's major problems in protecting and controlling water supplies (4). In (5) While the release of these harmful contaminants has decreased, their levels in fish and other aquatic species have actually increased because they remain in the ecosystem and accumulate in fish over long periods of time, according to research from the United States' Great Lakes and other important lakes. Bangladesh, luckily, has sufficient freshwater reserves due to its geographic location. However, due to overcrowding, ignorance, and a lack of legal compliance, only a small percentage of her water bodies maintain good water quality and biodiversity. To assess the water quality of some lakes in and around Dhaka, a number of investigations have been carried out. The Hatirjheel and Gulshan lakes have been reduced to a drain and are no longer pleasing to the eye. In contrast to the surrounding landscapes and climate, both lakes often produce high levels of pollution. To find a solution to water pollution, it is important to evaluate the water quality of Hatirjheel and Gulshan lakes.

Within the Dhaka metropolitan area, Haitrjheel is a prominent depression. The lake, which covers 302 acres in the Tejgaon, Moghmazar, and Rampura regions, has played an important role in preserving the area's only drainage system. Every day, a significant number of tourists visit the open stage for cultural activities, as well as a number of lovely bridges and roads. The capital's lack of adequate entertainment venues is exacerbating the problem. On weekends, Tile Lake and the surrounding area become very crowded. Residents in the region also say that sewage liquid waste is pumped into the lake. Garbage and human waste have turned the lake's water green.(Miah et al., 2017)

1.2 Problem Statement

Hatirjheel Lake, in the heart of Dhaka, is an important part of the city's drainage system. It was previously linked to the Banani, Dhanmondi, and Gulshan Lakes, as well as the Begun Bari Khal at the Rampura Bridge. As a result, the environmental conditions of these lakes have a major impact on city dwellers and their surroundings. Different forms of urban waste are trapped in each lake. Excessive waste water is destroying the lake ecosystem system. As a result, there are more increases in biodiversity. Birds, aquatic plants, and other species have disappeared from the lake. Solid waste is becoming a major issue. In the lake bed, a dense layer of solid waste sediments is forming. As a result, plants that grow in a lake's bed that provide food for fish and other living organisms are no longer viable. The reverse scenario, on the other hand, is still being pursued. In lake water, excess nitrogen and phosphorous from waste will build up. As a result, rooted aquatic plants and algae can develop quickly, resulting in an algal bloom that can cause navigation problems in lake water, as well as other environmental issues.(Tariquzzaman et al., 2016)

1.3 Justification of the Study

A research has been done on the water quality of Hatirjheel where the pH ranged from 6.7 to 7.1, color ranged from 25 to 50 pt.-Co units, turbidity ranged from 0 to 13 NTU, CO2 ranged from 35 to 60 mg/l, alkalinity ranged from 90 to 345 mg/l, hardness ranged from 150 to 300 mg/l, chloride ranged from 0.5 to 1.0 mg/l, BOD ranged from 0.0 to 10 mg/l (Alam MS). Natural waters should not be overloaded with organic or inorganic nutrients, or with poisonous, noxious, or esthetically objectionable contaminants, in order to maintain water quality. They should not become disease transmission vehicles due to fecal contamination, and their oxygenation, temperature, salinity, turbidity, or pH should not be substantially altered. (SEAWA. 2009.). Since water contamination is a natural occurrence, its environmental impact must be carefully researched and monitored on a regular basis. As a result, the current study was conducted to assess the microbial content of Hatirjheel's water.

The main objective of this study is to,

- Assess the water quality of Hatirjheel Lake.
- Study variations of water quality of different point of sources of the lake.
- To identify the major parameters influencing the improvements of the environmental condition of water.
- To identify pollution sources (Present and expected (including domestic, industrial.

CHAPTER 02: LITARATURE REVIEW

2.1 Tectonic Structure of Dhaka City Controlling the Natural Drainage Pattern

Dhaka City is a landscape of unique geomorphological characteristics. From the geomorphologic and tectonic setting, it has been observed that, the city is an integral part of the Madhupur Tract, which is an uplifted horst block in the Bengal Basin (Map 1.1). The prominent faults and lineaments controlling the natural drainage of the city have been described in the following section.

Table 1: Faults in Dhaka City with the Khals & Rivers following their Track

Name of the Faults	Khals/Rivers flowing along the Faults	Location of the faults	Direction of the Faults
Tongi Fault (F1) (AIam, 1988)	Tongi Khal	Tongi-Uttara, Uttar Khan area in the Northern border of the city	East-West Direction and down thrown to the south.
Balu Fault (F2) (WASA1991)	Balu river	In the eastern fringe area of Dhaka City, covering the Dhakshin Khan, Merul, Joarshahara , Meradia, etc.	In the North-South direction, and down thrown to the east, up thrown to the west.
Turag Fault (F3) (WASA, 1991)	Turag river	In the North west limit of the city, comprising the Mirpur Zoo, Gabtoli, Nawaberbagh, etc.	In the North-South direction, down thrown to the west, & up thrown to east.
Baunia Fault (F4)	Along the abandoned channel in the west Uttara	In the north-west part of Uttara, up to the northern part of the Cantonment parallel to the L 3	In North-South direction, down thrown to the west, up thrown to east.
Begunbari Fault (F5)	Begunbari Khal	In middle part of the city along the east-west direction	In the East-West direction, & down-thrown to the south.

Pagla Fault (F6)	Along the depression	In the southern part of the city	In East-West direction & down-thrown to the south.

Source: FAP 8-A & 8-B, 1990 / WASA, 1991/ GSB, 1991

The city has no evidence of surface folding, although the area had been raised almost at the central region (5.0 Meters & above) due to some faulting and differential movement in the fault-blocks. The corresponding northern and eastern blocks are the up-thrown and the southern and western blocks are the down-thrown parts of the fault-blocks. The surface of the city is cress-crossed by numerous N-S, E-W, NE-SW, and NW-SE trending faults and lineaments. The faults are the result of vertical movement, while lateral movement is also reported. The rivers, khals, and other natural drainage traversing Dhaka city surface, follow the course of these faults and lineaments. Five major faults and six lineaments are identified in Dhaka city (Table 1.1, 1.2 and Map 1.2).

Among the five major faults only two (F1 & F5) of them are aligned in east-west direction, while the other three are trended in north-south direction. The only south-west aligned lineament is the L2 and L7 is trended in east-west direction, while the other lineaments are in north-south direction. Nevertheless, all these above mentioned geological and tectonic features control the hydrological and drainage situation of Dhaka city, and control the city's growth, land use, and land value pattern as well. The following section is an attempt to understand the drainage pattern of Dhaka City.

Table 2: Lineaments in Dhaka City with the Khals & Rivers following their track

Name of the Lineaments	**Khal /River Flowing along the Lineaments**	**Location of the Lineaments**	**Direction of the Lineaments**
Lineament (L1)	Along the edge of depression	From Khilkhet-Jatrabari	Trending towards North-South
Lineament (L2)	Along the Behnai Khal	Dakshin Khan area in north-east part of the city	Trending towards South-West
Lineament (L3)	Along Mirpur khal	From Tongi upto Kallyanpur	Trending towards North- South
Lineament (L4)	Along Diabari khal	In Pallabi area in north part of the city	Trending towards North- South

Lineament (L5)	Along the Degan khal	Branch of Turag river in the west part of Uttara	Trending towards N.E. - S.W.
Lineament (L6)	The river Buriganga	In the western part of Buriganga near Lalbagh area.	Trending in the N.W.-S.E. direction.
Lineament (L7)	Tongi Khal	Along Tongi khal in Tongi-Uttara-Uttar Khan area in the northern limit of the city	Trending East-West direction
Lineament (L8)	Old natural levee along Hazaribagh Khal	From Kallyanpur to Hazaribagh area in the south-eastern part of the city	Trending almost North-South direction

Source: FAP 8-A & 8-B, 1990 / WASA, 1991

2.2 Drainage Network and Spatial Distribution of the Rivers, Khals and other Water bodies in Dhaka City

Approximately 30-35 khals or natural drainage, summarizing up almost 437 km in length (JICA, 1991) together with the four major rivers like-the Buriganga, the Turag, the Balu, and the Tongi, etc. bordering the city with their smaller branches has crisscrossed the whole city. These rivers and khals play a very vital role in an urbanized area, as they are used as natural water ways for transportation, communication and storm-water and rain-water drainage. Thus, the water ways, from the very beginning of the city's establishment, had a great impact upon the geomorphological as well as socio-economic structure of the city. Undesirably, the unplanned and unstructured city development due to irrational human interference to construct urban structures by the process of land accretion and earth filling, most parts of the rivers, khals, and jheels are filled up or clogged up at present. The consequences of the maltreatment of the inner-city water bodies show the signs of damages done to the city like, water logging, urban flooding, obstructions in smooth movement of the city people etc. Hence, the consequences of damaging the water bodies, and wetlands, along with the volume of loss already done, have to be measured with profound significance. Therefore, it is obvious that the major inner-city khals, jheels and the bordering rivers have a significant hydrological importance for the city's balanced growth.

The spatial distribution and the degrading situation of these four rivers surrounding Dhaka city, along with the khals and jheels has been describe below and two maps (Map no 1.1 &1.2) showing the geomorphic and tectonic structures controlling the drainage of Dhaka city, has been illustrated in the following sections.

2.3 Rivers Bordering Dhaka City

The four medium size rivers girdling the city, and flowing through he faults and lineaments, have been described in the following section.

2.3.1 The Buriganga River

The river Buriganga, one of the bifurcated branches of river Dhaleshwari, borders the city in the south-west and western side. The river is almost straight in drainage pattern, branching off from the Dhaleshwari a little below Savar, which is also a section of the combined drainage system of Brahmaputra- Jumuna - Padma rivers. The main sources of water flow in Buriganga are the Dhaleswari in the north and south and Turag in the west. Following the fault no. F6, the length of this river is 17 km (Rahman, A Karim, I994), depth is 3.05 to 4.57 m (Snell, 1962), and it reaches a depth of 6m and above in monsoon period. The width of the river fluctuates between 330 m to 200 m varying according to the dry and wet season (FAP 8A, 1991). The river inundates the southwestern fringe area of Dhaka City with flood in wet season. The river is the main water way and also the main inland river port (Shadarghat) and did not lose its importance still now as the main center of city development and economic activities.

2.3.2 The Turag River

The Turag river is on the western side of the city, recently been dragged into Jamuna River system, by the invasion of the Lowhajang river in Tangail. The river is active throughout the year. This fully meandering river consist a number of sand bars and point bars. The water of the river Turag falls into the river Buriganga, and Tongi khal. Following the fault no. F3, the depth varies from 6.6m to 10 m in dry and wet seasons respectively. The width is 17m in day season and 80 m in wet season (B. W.D.B., 1989).

Table 3: Characteristics of the Four Major Rivers around Dhaka City

Rivers	Strength (M)	Width (M)	

	Min	Max	Wet Season	Dry Season	Length (Km)
Buriganga	2.8	6.0	330	200	17
Turag	6.6	10.6	80	17	30
Tongi	0.5	2.5	100	60	14.4
Balu	0.5	3.5	100	70	27.6

Source: B. W.D.B. 1989, FAP 8A, 1991

The water of the river Turag falls into the river Buriganga, and Tongi khal. The depth varies from 6.6m to 10m in dry and wet seasons respectively. The width is 17m in day season and 80 m in wet season (B.W.D.B., 1989).

2.3.3 The Balu River

This river plays an important role as the lower branch of it was the Dolai River, which branched off from the Balu river near Derma and fell into the river Buriganga, while passing through the then main city area of Dhaka near Mill barrack. This river follows the fault n F2. The Dolai lost its depth, length, and width to be turned into Dolai khal gradually. The main Balu river branched off from the Lakhya near Demra in the south. The river runs mainly through the extensive swamps of Bill Belai and other low-lying areas in the eastern fringe and suburb area of Dhaka City.

Figure 2.1 A: Characteristics of the Four Major rivers in Dhaka City

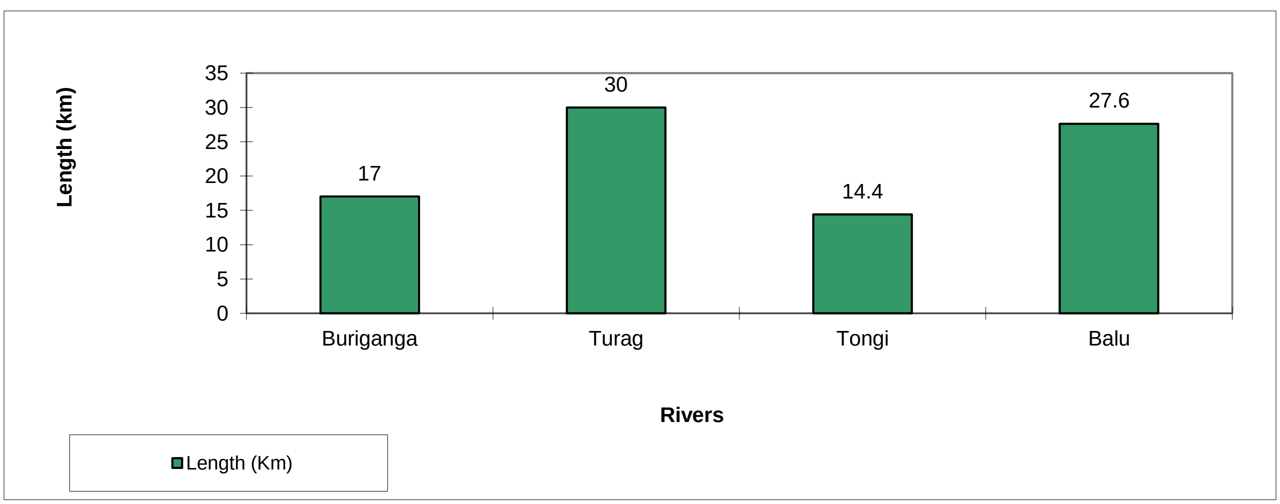
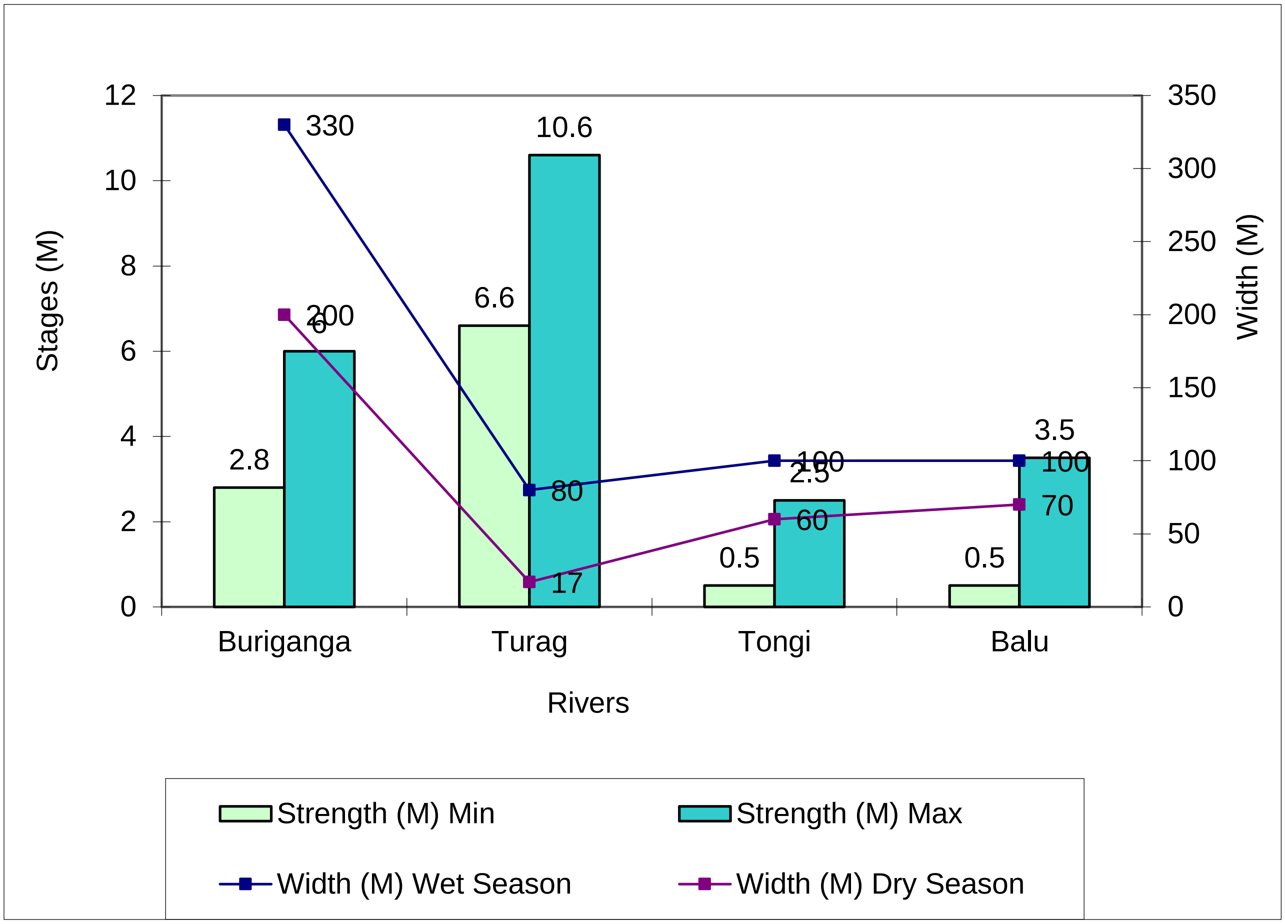


Figure 2.1 B: Stages and Seasonal Characteristics of four Major Rivers in Dhaka City



Source: BWDB, 1989, FAP 8A, 1991

2.3.4 Tongi River/ Khal

The Tongi river/ khal demarcating the northern boundary of Dhaka city flows in the east-west direction, and is controlled by the Tongi fault. The river Turag, while joining the main two rivers of east and west feeds the Balu river, and Tongi khal respectively. It was a river in the past and lost its width and depth to turn into a khal through the span of time. The present length of this khal is 14.4m, and the width is 60 m, with the minimum stage of 0.5m and a maximum stage of 2.5m with the width 100 m. (B.W.D.B., 1989). The khal is the main drainage of the northern part of the city.

Figure 2.3 Distribution of the Tectonic Faults in Dhaka City (1998)

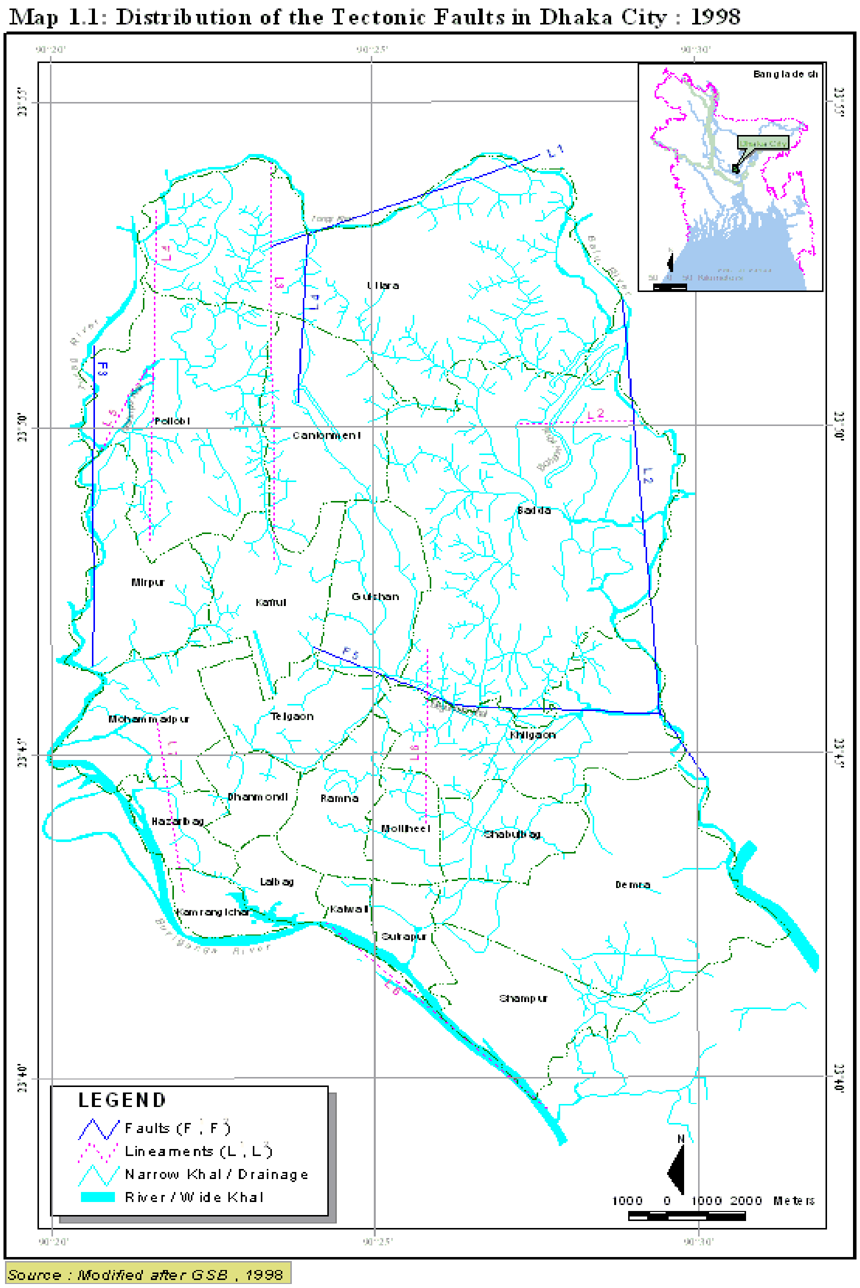
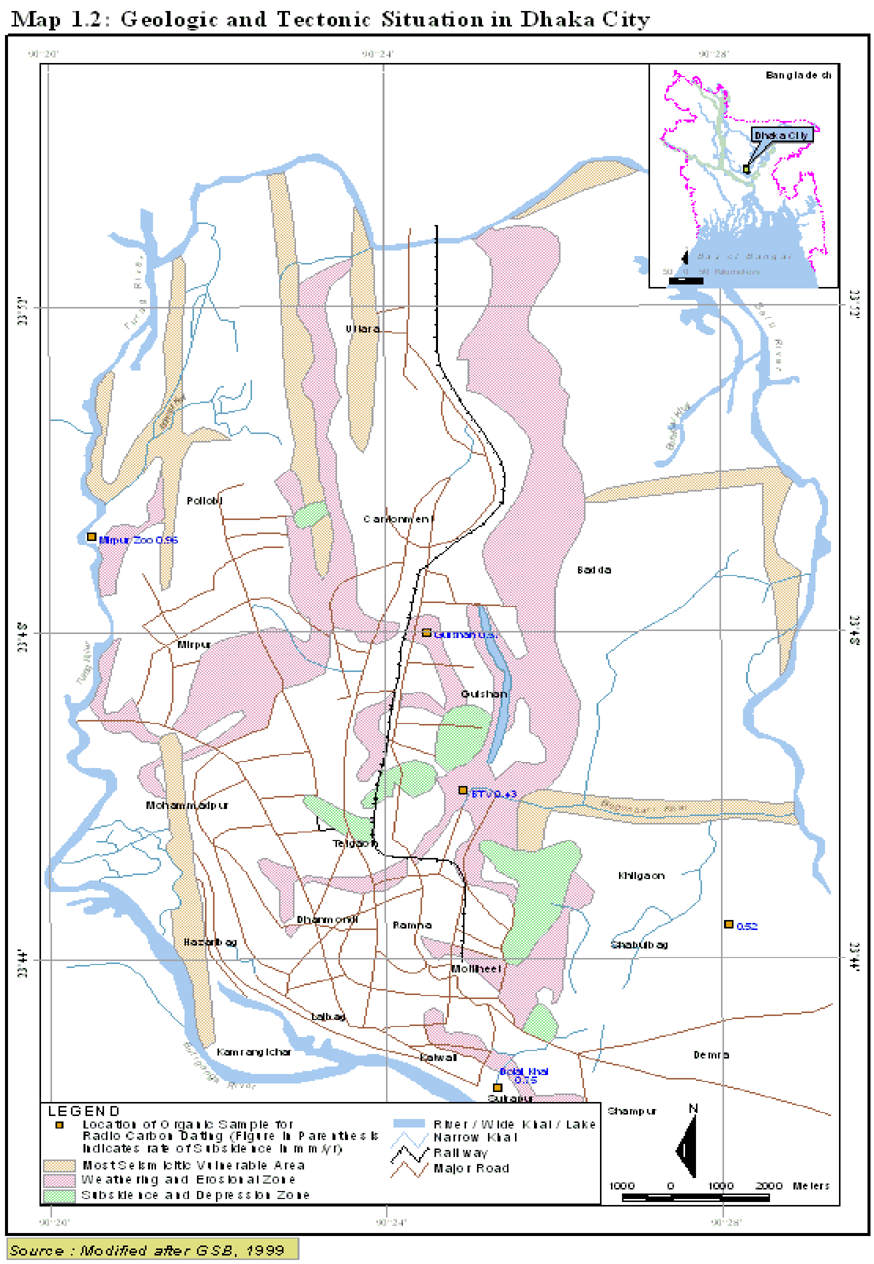


Figure 2.4 Geologic and Tectonic situation in Dhaka City



2.4 Encroachment of Khals and Jheels in Dhaka City and the consequent geo-environmental degradation

In this section, emphasis has been given upon the water-logging and the associated problems as the major environmental degradation phenomena. While doing so, the impact of water logging upon the geomorphological and tectonic structure has been taken into account as well. The adverse effect upon the socio-economic structure of the city is also discussed consequently. According to urban experts, encroachment on natural water reservoirs is the main reason for water logging. The water logging is accelerated by the lack of cleaning activities of the box–culverts constructed over the khals and water bodies. The water logging caused by the earth filling in the water bodies is described below.

2.4.1 Dolai Khal

Dolai khal was the most important khal in the history of Dhaka. N.K Bhattashali described the course of Dolai khal very precisely as he realized the strategic importance of the khal at that time. Its length was 5 km (JICA,1991). Branching out from the Balu river near Demra, the Dolai Khal flew towards the south-west navigating through the old Dhaka separating the northern part of the city from the southern part and to meet the river Buriganga near Mill Barak. It maintained good connection with the Buriganga, the Balu, and the Tongi Khal through its once major branch-the Begunbari Khal, while flowing through the Tejgaon, Dhammondi and Gushan area. Dolai khal had many minute radiating branches in the past. The low-lying areas around it took the shape of a big pond in rainy season. The urban structures began to develop after 1950 by filling up this khal and recently this khal is almost entirely filled up and occupied by the city developers.

2.4.2 Begunbari Khal

The almost extinct portion of the ancient river Pandur,the Begunbari khal was named as the Neri Khal by the famous geographer Rennel. Connecting the river Balu with the river Turag, the khal once navigated in and the length of this khal is around 3,857m, and the area is 237.76 acres. At least six khals- Paribagh khal, Dhanmondi Khal, Rajarbagh Khal, Kathalbagan Khal, Bashabo Khal, and Mahakhali Khal etc. were connected with the Begunbari khal at Pantha Kunja in a near past. None of the khals now exist for the construction of the box culverts and clogging up of the khal by earth filling for urban constructions. Branching off in western direction, it connected the Balu river with Buriganga river through Dhanmondi khal in the past. This western course of this khal has turned stagnant as the khal has become totally covered with the Kazi Nazrul Islam Avenue due to the construction of the road from Karwan Bazar to Dhanmondi via Panthapath. However, the water-logged areas of the Rayerbazar, and Madhubazar proves the existence of the khal in the western part of the city in the past. On the other hand, another branch of the Begunbari khal known as Gulshan khal had connection with the Tongi khal. The construction of the roads like Tongi Diversion Road, Rampura D.I.T Road, Kuril Bishwa Road, have blocked the eastern flow of the khal. This khal once played a very important role as the major discharge source of water in the eastern part of Dhaka City. Recently, nearly all parts of this khal are now filled up for urban construction, leaving behind water logged areas along with drainage & discharge problem for the future. The restoration of this khal is very essential and inevitable for the the city and the country in the broader context. Therefore, proper initiatives should be taken to re-excavate, and re-organize network of the khal to make it navigable again and to turn it into an attractive tourist point.

2.4.3 Segunbagicha Khal

One of the main branches of Dolai khal, the Segunbagicha khal started from the Tanti bazar area to fall into the Jirani khal. According to WASA, this khal is also known as Segunbagicha-Arambagh khal. This khal is almost 4.19 km. in length. A review committee for the inundation problem of Dhaka city found out that there were three cluster canals or khals in Segunbagicha, Kallyanpur, and Begunbari, each having four to six branches. The Segunbagicha cluster khals netted the old Dhaka and Gulistan area with its branches-Dolai khal, Segunbagicha khal, Arambagh khal, Gopibagh khal, Gandaria khal and Jirani khal. Unfortunately, only a 300 feet length of the khal is now found open near the Gopibagh rail gate. This cluster khal with its branches played a very important role as a busy water way and storm water drainage way for the central and southern part of the city in the old days. In recent times, only 812-meter length of this khal can be seen as a lake inside the Ramna Green area. Encroachment on Segunbagicha khal at Maniknagar and Manda causes water logging in the business areas like Shantinagar, Inner Circular Road, Arambagh, Fakirer pool, Zero Point, Motijheel, Dilkusha and Sayedabad. However, major encroachment on Jirani Khal and Shahjahanpur Khal has caused drainage problems in Malibagh, Mouchak and Shantinagar areas.The unplanned box culverts constructed over the khal by WASA has reduced the width of it into 14 to16 feet only. As a result, the most important business areas of the city like Paltan, Kakrail, Shantinagar, Fakirapul, and Motijheel experiences severe water logging even in a little rainfall. On the other hand, the khal flowing between the Kamalapur and Jirani khal has become a garbage dump which ultimately caused water logging. However, construction of wider box-culverts and roads beside the khal could make it more navigable to some extent. The main khals still now remaining are described in the subsequent section and their length is shown in table 1.1 & Fig. 1.1.

Table 4: Name and Length of the Khals in Dhaka City

Name of the Khals	Length (km)	Name of the Khals	Length(m)
Dolai Khal	**5.0**	**Kathalbagan Khal**	**.26**
Gopibag Khal	**.39**	**West Rajabazar Khal**	**.13**
Segunbagicha Khal	**4**	**Khilgaon-Basabo Khal**	**2**
Paribag Khal	**.66**	**Mohakhali Khal**	**4**
Begunbari Khal	**4**	**Kallyanpur khal**	**4**
Dhanmondi Khal	3	**Ibrahimpur Khal**	**2**
Gulshan -Banani Lake	4		

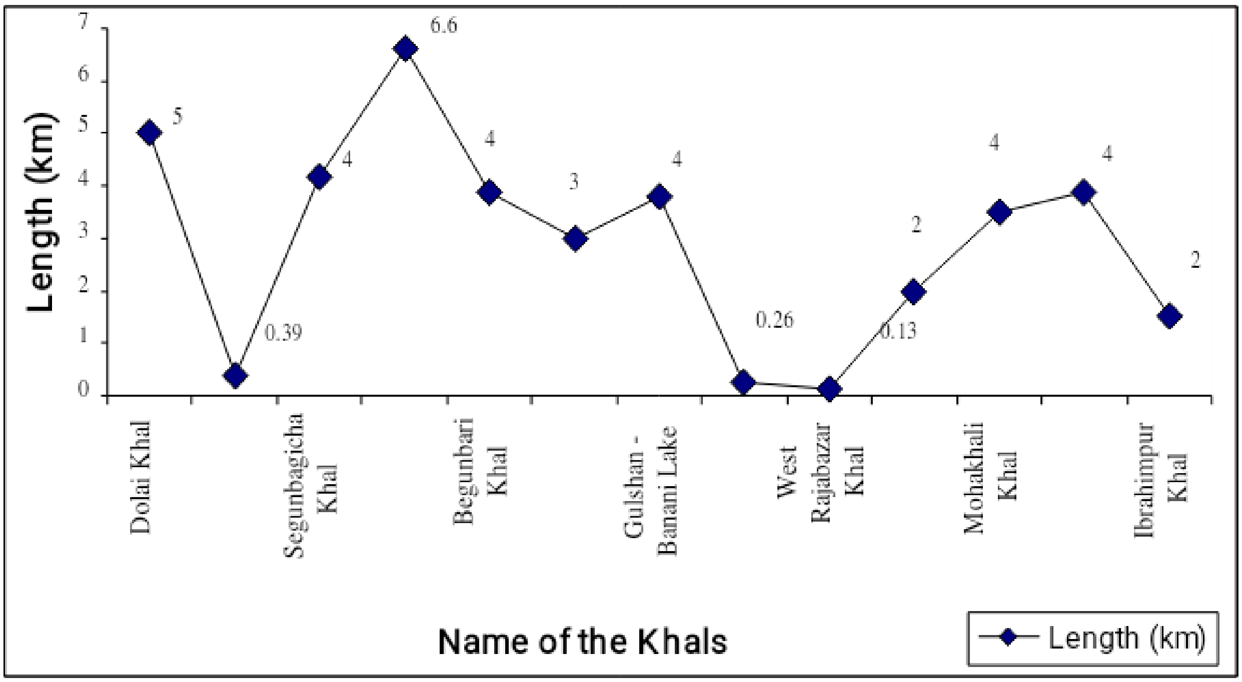
Source: Different Secondary Data Sources

2.4.4 Dhanmondi Khal

Dhanmondi khal which is now known as Dhanmondi lake, also a branch of the Begunbari khal was previously connected to the Turag river through Katashur khal in the western part of Dhaka city. The lake is one of the prominent depressions between the borders of the low lands and high-level plateau in the northern part of Dhaka city. The elevation of this area is 3-6 meter. The khal starts from Jigatola in the south-western part of the city, extending up to the Mohammadpur-Lalmatia area in the north, Satmashjid in the west, BDR Gate in the south, Kalabagan area in the east. Located almost at a strategically important position, this khal was a natural depression connected to the ancient Karwan Bazar river with the alignment along Begunbari khal-Green Road-Kalabagan-Dhanmondi lake up to the Turag in the west. It also shows some trellis pattern together with the dendritic pattern in its drainage network. Though this khal has been cut through by the construction of the Mirpur road, the length of this khal is 3 km, width 35-100 m with a mean depth of 4.77m, comprising an area of 110 acres. The only outlet of the khal for the heavy rain water drainage is near Shukrabad area. This lake was initially used both for drainage of rainwater and as a center of recreation for the residents of the Dhanmondi residential area, which was established in 1956 with an area of 240 acres. The lake comprises around 16% of the total residential area. The lake was started to be used for waste disposal by the end of the 1996, the khal turned into one of the worst polluted water bodies in the country.

However, in 1998, a 100-million-BDT project was taken up by the D.C.C. to renovate and restore its natural environment with a view to make the lake a pollution free recreation zone. Map 1.2 shows the existing Khals in Dhaka City.

Fig. 2.5: Length (km) of the Khals in Dhaka City



Source: Different Secondary Data Sources

2.4.5 Gulshan – Banani Lake/Khal

The Gulshan-Banani lake or khal is approximately 3.8 km in length, stretching in a north-south alignment across the Gulshan, Banani, and Baridhara area in the north-eastern part of the city. Only around two decades back, Gulshan lake system directly drained into the Hatir jheel in the south-west and in the Balu river in the east, through the Rampura Khal. This lake system was once connected to Dhanmondi lake system through the Begunbari khal. The lake system has been occupied in an extensive scale by the illegal land grabbers. On the other hand, the water has become fully contaminated with toxicity and has become totally unusable.

2.4.6 Other Lakes or Khals in Dhaka City

In Dhaka city, there were numerous khals, which controlled the urbanization in the older period of Dhaka city establishment. The natural flow of these khals have been disrupted and destroyed by illegal encroachment, earth filling, garbage disposal, unplanned urbanization, etc. The adverse effect destroying the water bodies has become very distinct and the city dwellers have been suffering from innumerous problems like water logging for the lack of proper drainage network, scarcity of drinking water for the polluted and contaminated water which is also seeping through into the ground water layer, physiographic and environmental deterioration, etc. The re-excavation and restoration process to bring back the previous condition of these khals must be ensured and enhanced as these waterways have a great influence upon the city's geomorphological, geo-environmental, & socio-economic condition. Among the many other khals some prominent khals which traversed through the topography of Dhaka city are like below:

Rampura Khal, draining to the Balu river in the east side of Dhaka. Now this khal has turned into a drain due to the Banasree Land Development Project.

Katashur khal, on the western side of Dhaka city, drains the water of Dhanmondi and Begunbari khal into the Turag river. This khal also was used as drainage of Rayerbazar and Mohammadpur areas on the west in the past. Recently, the illegal encroachment of this khal turned the Rayerbazar and Kalyanpur area into a waterlogged area polluted by the liquid waste disposal from the tanneries and other industries of the surrounding area.

Ramchandrapur khal was used for old Dhaka area rain and storm water drainage system. Encroachment on this khal caused water logging in Islambagh, Nawabganj and Hajaribagh area.

Mahakhali khal, which was around 3.5 km in length, started from Nakhalpara, and navigated upto Gulshan area to bear the load of eastern Dhaka's storm water and connect with Begunbari khal in the western part of Dhaka city. Encroachment of this khal causes water logging in the residential areas like Nakhalpara, Arjatpara, Rasulbagh, Shahinbagh, Taltola, Tejgaon industrial area, Old Airport road, New DOHS, etc. areas through the Mahakhali busstand and Niketan. The **Gajamahal Khal** of Hazaribagh, used as a sewer and storm water drainage of the area, has been filled up with liquid wastes and garbage turned the area into a pond of stagnant water coming from the tanneries and other sources.

Besides the khals of Dhaka city, other water bodies like the **Hatir jheel**, **Motijheel, Shaplajheel**, etc. had a commotion on the fill and occupation of the land. Among all the jheels those existed in Dhaka City, the most prominent one was the 'Halirjeel'. Hatir jheel was a mighty low-lying marshy land in the central area of the Begunbari khal, comprising an area of approximately 84.09 acres, and spread over the Nayatola, Madhubagh, and Begunbari-Kunipara area under Tejkunipara Mouja, controlling the central area of Dhaka city drainage system. A vast area of Dhaka and Gulshan lake system directly drained south–west into Hatirjheel. Around 5% of the previous area of this jheel exists at present. According to WASA, the areas like Maghbazar, Tejgaon industrial area, Karwanbazar, Dhanmondi, Green road, Farmgate, Tejkunipara, Nakhalpara, Rampura, Merul Badda, etc. has become venerable to water and sewerage system disturbance if the jheel is not protected from further encroachment and land grabbing.

Destruction of the water bodies and khals in Dhaka city began almost 50 years ago. The process went on so rampantly, that only after 50 years the whole area is suffering from water logging and urban flooding due to the blockage of natural drainage system.

The encroachment of Shahjadpur Khal prevents rain and sewage water, as well as liquid waste, from being flushed out of Kuril, Progati Sharani, and the surrounding areas. Water logging is caused by the encroachment of five branches of the Kalyanpur Khal in Taltala, Agargaon, Kazipara, Shewrapara, Barabagh, and Mirpur. Circle-Due to the partial filling of the Diyabari khal by various developers, the eastern housing of Pallabi and its surrounding areas will soon be flooded. The khal transports rainwater and sewage to Goran chatbari pump stations, where it is pumped out. Water logging is a problem for residents of Cantonment, DOHS, Kala Chandpur, and a portion of Baridhara, as a water-draining pipeline built by RAJUK 20 years ago is nearly clogged due to lack of maintenance.

Encroachment on **Ibarahimpur khal** is causing water logging at Uttara and Banani. The main sewerage line in the area is also almost clogged due to lack of cleaning activities.

Encroachment of approximately 54 bigha **Islambagh jheel** area causes water logging. As a result, the residents of that area face a tremendous suffering for in the rainy season.

The seven prominent **Sabujbagh-Khilgaon jheels** area were filled up. As a result, the water retention capacity of that area has decreased causing severe water logging and rapid infiltration of flood water as well.

The encroachment by narrow sewerage pipes of the five main khals are –Rupnagar khal, Housing khal, Baishtaki khal, Journalist Colony khal, Kalshi khal, etc. along with other two khals consequences into a water-logging situation of a large area in Mirpur.

2.5 Water Quality of Hatirjheel lake

A study was by (Alam, 2014) to determine some important water quality parameters that influence water quality and to determine Hatirjheel Lake's most vulnerable position. The assessment included deciding whether the water quality meets ECR'97 drinking water quality requirements and whether it differs during the dry season between different parts of the Hatirjheel Lake. pH levels range from 6.7 to 7.1, with a weighted average of 7.0 in 100 percent of the samples ((ECR, 1997)). Color values ranged from 25 to 50pt-Co units, with an average of 42.0pt-Co units. There was a deviation from the norm in 100% of the samples. CO_2 levels ranged from 35 to 60 mg/l, with a weighted average of 46 mg/l. Alkalinity as $CaCO_3$ ranged from 90 to 345 mg/l, with a weighted average of 162 mg/l. The $CaCO_3$ hardness ranged from 150 to 300 mg/l, with a weighted average of 215 mg/l. 40% of the samples had values that were lower than the ECR'97 norm. Chloride levels ranged from 0.5 to 1.0 mg/l, with a weighted average of 0.70 mg/l, and 100 percent of the samples were found to be out of compliance with the standard. Carbon dioxide (CO_2) concentrations ranged from 28 to 60 mg/l, with an average of 45.7 mg/l. Both samples deviated from the normal. BOD levels ranged from 0.0 to 10 mg/l, with a weighted average of 6.8 mg/l, and 100 percent of the samples were found to be out of compliance with the standard. COD levels ranged from 28 to 60 mg/l, with a weighted average of 45.7 mg/l, and 100 percent of samples were found to be out of accordance with the standard. Another research by (Islam et al., 2015) was carried out to determine the state of the water quality in Dhaka's Ramna, Crescent, and Hatirjheel lakes. Physicochemical parameters such as temperature, pH, EC, TDS, DO, BOD, hardness, alkalinity, and acidity were measured in water samples collected from three different points in each lake between November 2013 and April 2014. The mean temperature was 22.54, 24.59, and 24.24°C; the EC was 15400, 282.00, and 618.27 μS/cm; the TDS was 85.38, 155.60, and 339.90

ppm; the pH was 7.73, 7.85, and 7.67; the DO was 3.51, 3.92, and 3.65 ppm; the BOD was 0.93, 0.73, and 3.15 ppm; the hardness was 9ppm.

CHAPTER 03: METHODOLODGY

3.1 Study are and Sampling details

Hatirjheel Lake is situated at 23°48' N and 90°25' E of Dhaka district, with a length of 4.1 km and a surface area of 0.79 km^2 (collected from Google earth). It is 2.6 meters deep on average. The lake is 0.46 kilometers deep at its widest point. The northern side is Gulshan-Banani, the southern side is Banglamotor, the eastern side is Rampura, and the western side is Tejgaon industrial area.

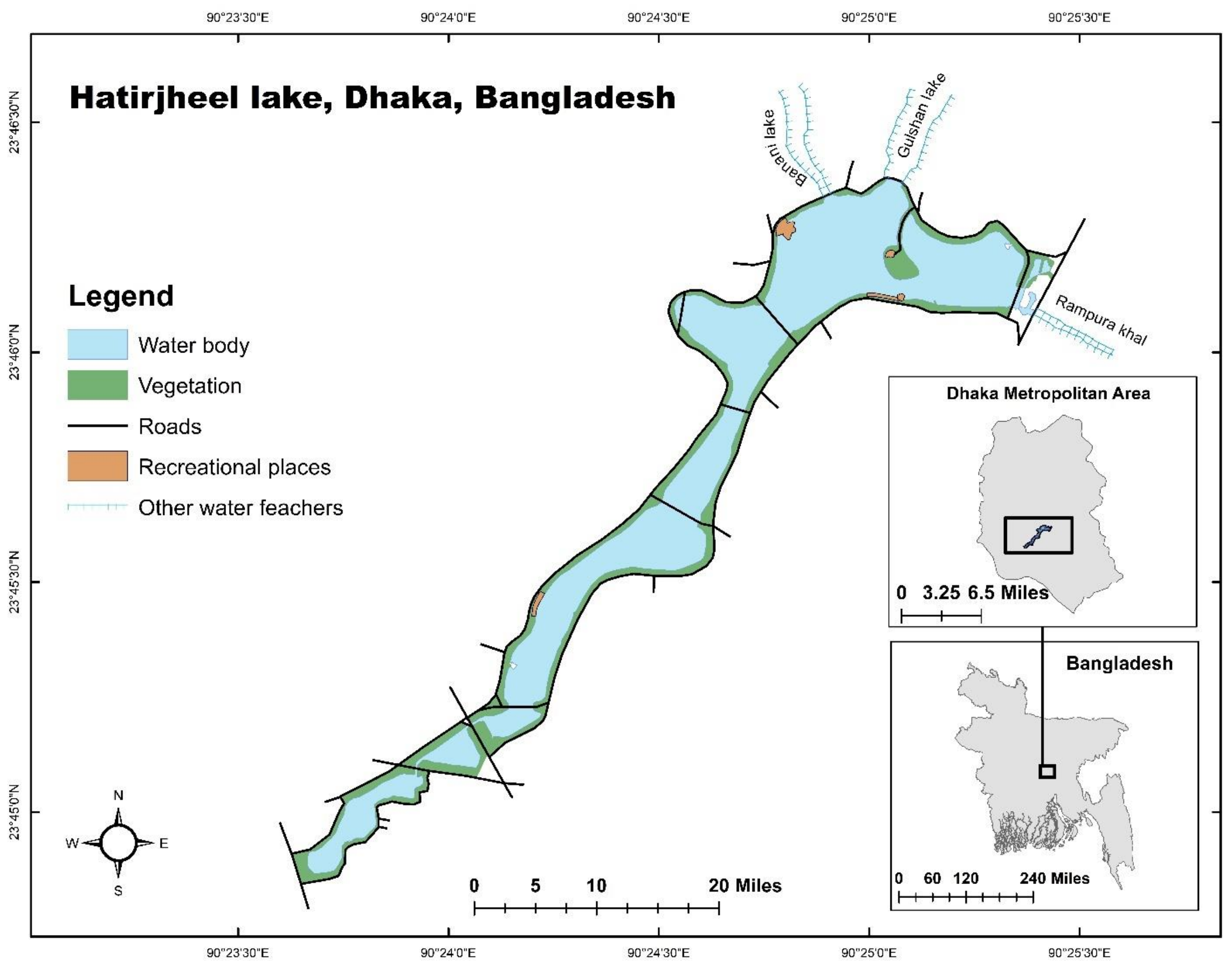


Figure 3.1: Map of the Study area

3.3 Data Collection techniques of the study

To collect and analyze the data here we implemented both qualitative and quantitative tactics on this study. Although, the study widely focuses on primary data collection through various data collection techniques within 9 sampling location (Figure 3.2). The secondary data mainly has been assembled by evaluating various research papers or scientific research papers.

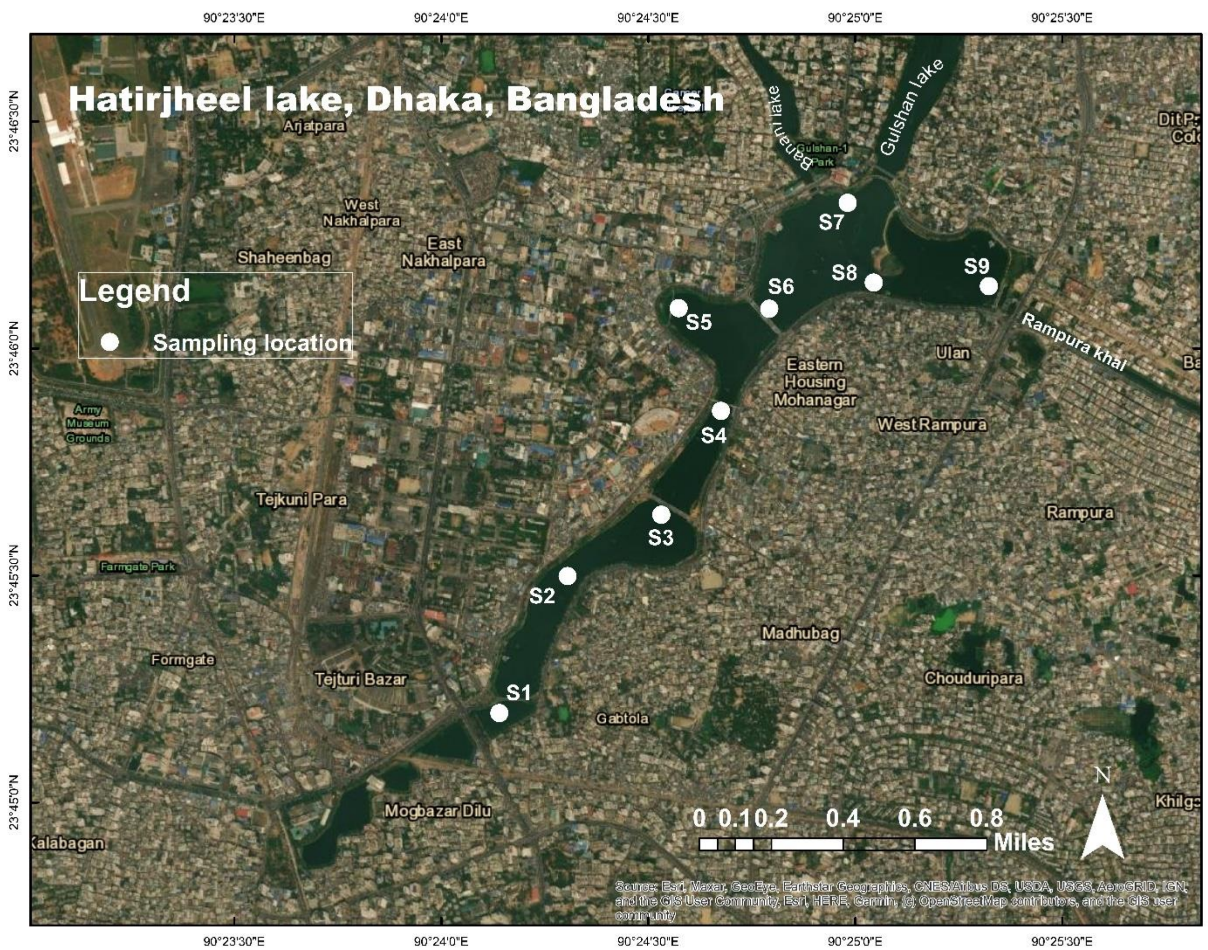


Figure 3.2: Sampling locations of the study area

3.3.1 Water Sample Collection

The water sample were collected from nine location of this during the time of dry season at January 16th 2021. Plastic bottles (HDPE) with stopper having a volume of 250 ml each and marked with sampling point were used for collection of water samples. Bottles were cleaned and washed with detergent solution before collecting water samples. The sampling bottles were then rinsed with deionized water and dried. After sampling, bottles were carefully screwed and labeled with the appropriate identification number. The standard method of water sampling is followed accordingly and immediately transported into the department Environmental Science and Disaster Management (ESDM) Laboratory, Daffodil International University (DIU), Ashulia campus, Savar, Dhaka.

3.3.2 Direct Observation

While collecting water samples of the Hatirjheel lake, we also tried to observe the environmental condition of every place around the sampling locations. We walked almost the surrounding of every sampling area throughout the lake. We tried to observe the surrounding environment of the study area to identify any consequences or issues that are important for our study and tried to find out some issues that could be an issue for further work particularly. We also talked with locals about the continuous state of lake and identified some problematic issues.

3.4 Data Analysis

The collected data have been analyzed according to the following framework:

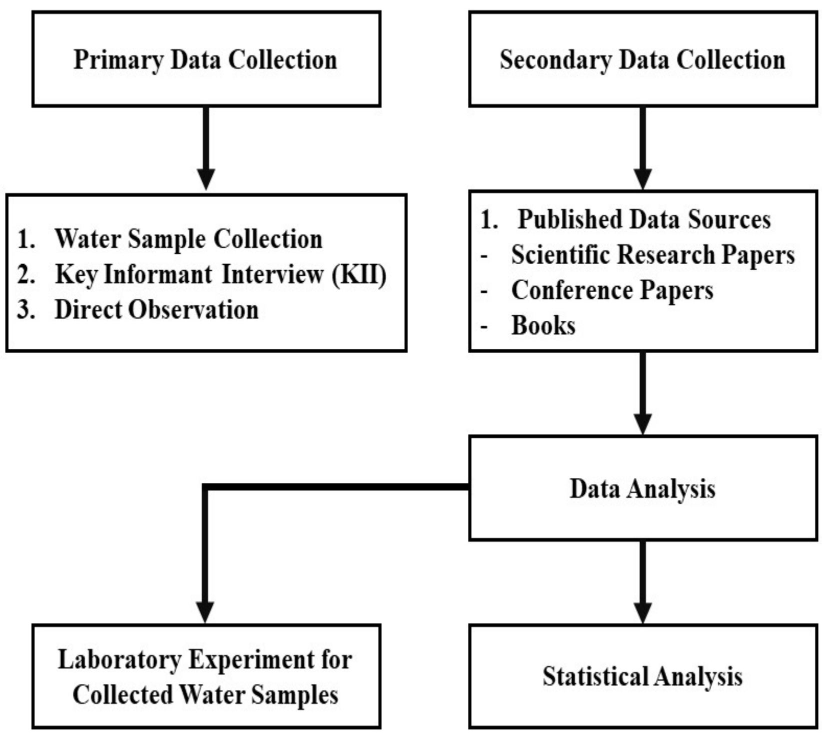


Figure 3.3: Structural framework for Data analysis

3.4.1. Laboratory Experiment

This study conducted to explore the status of water quality level among the different locations of Hatirjheel lake. Collected water samples from all the 9 locations where we conducted the test to measure the physical and chemical properties of the lake.

3.4.1.1. Physical parameters

Salinity of the river water was measured by our lab instrument named the portable salinity refractometer. Both Total Dissolved Solids (TDS) and Electrical Conductivity (EC) were analyzed separately from the water samples collected from the 7 sampling locations. This experiment was taking place in the Environmental Science and Disaster Management (ESDM) Laboratory of Daffodil International University (DIU), Ashulia, Savar. *HANNA* Ph/EC/TDS/Temperature Meter (HI9814) used to measure the TDS value of the 7- water sample separately. *HANNA* EC Tester (HI98304) used to measure the EC value of the water sample separately. They were diluted every time before each lab test to get the value within the existing range of the equipment. Total Suspended solids are analyzed using a filtration apparatus.

3.4.1.2. Chemical parameters

HANNA Ph/EC/TDS/Temperature Meter (HI9814) was also used to measure the pH value of the 7 water samples repetitively. Acidity was analyzed through the titrimetric method using a standard solution of 0.01N NaOH solution. From each sampling point, 25 ml samples were titrated against NaOH. Alkanity were measured through same titrimetric method by titrating samples against 0.01N HCl solution. Total Hardness and Calcium hardness were analyzed through titration process by using standard Solution of 0.01N EDTA. The concentration of Free CO_2 was determined by titrimetric method using 0.05N NaOH standard solution.

3.4.2. Statistical Analysis

Statistical analysis was conducted by using Statistical Packages for Social Science (SPSS Version 22). In order to determine the relationship between water quality variables, the physio-chemical parameters were explored for all the sample by measuring the correlation coefficient (r) value of Pearson. The correlation matrix was built for the purpose of calculating correlation coefficients by measuring the coefficients of various pairs of parameters. A correlation coefficient equal to -1 or 1 indicates that they have the highest negative or positive relationship [kumar et al., 2006]. After that, the significance correlation was checked by adding the p value ([Patel & vaghani, 2015] and [Khatoon et al., 2013]). There is a related increase or decrease in the value of another parameter where an increase or decrease in the value of one parameter is correlated with a direct association between these two variables [Jothivenkatachalam et al., 2010]. The following formula is used to calculate the Pearson r correlation:

$$r = N\sum xy - \sum x\sum y / \sqrt{\{N\sum x^2 - \sum(x)^2\}\{N\sum y^2 - \sum(y)^2\}}$$

Whereas,

r = Pearson r correlation coefficient

N = number of values in each data set

$\sum xy$ = sum of the products of paired scores

$\sum x$ = sum of x scores

$\sum y$ = sum of y scores

$\sum x^2$= sum of squared x scores

$\sum y^2$= sum of squared y scores

The variations are significant if p0.05. The significance is considered at the level of 0.01 and 0.05 (2-tailed analysis).

3.4. Instrumental Techniques

To the successful completion of this study, we used various materials. We used three separate instruments to measure some physical and chemical parameters. We used one Google product for mapping. We used a tool to identify the geographical position of the places. We used one modeling software that helps us to make the various maps. We used statistical software to analyze the collected data.

Table no 5: Used Instruments, Tool, and Software's to Conduct the Study.

Category	Parameter	Model/Name
Instrument	Water salinity	Salinity Refractometer

	TDS	*HANNA* Ph/EC/TDS/Temperature Meter (HI9814)
	EC	*HANNA* EC Tester (HI98304)
	DO	LUTRON DO-5509
Tool	Navigation	GPS Navigation Device
Software	Mapping	Google Earth Pro
	statistics	Microsoft Excel
		IBM SPSS 22.0

So, these are the materials that we used during our study to collect, measure and analysis of the collected data.

Table no 6: Major Characteristics of Instrument

INSTRUMENT	**RANGE**	**RESOLUTION**
Hann pH/EC/TDS Meter (HI9814)	0 to 3999 ppm	10 ppm
LUTRON DO-5509	0 to 20 mg/l	0.1mg/l
Hanna EC Tester (HI98304)	0.00 to 20.00 mS/cm	0.01 mS/cm
Portable Salinity Refractometer	0 to 100%	20%

CHAPTER 04: RESULT AND DISCUSSIONS

The chapter broadly discusses the findings and results of our study in a different form. At the beginning of this research project, we have assumed three different objectives and we worked on it. Here, in this chapter, we tried to get a well-organized understanding of the objectives by analyzing the collected data and findings in different ways. So, this chapter of result and discussion divided into five (05) different sections.

The sections are –

4.1 Study Findings

In this section, we tried to show all our findings and results that we observed from the beginning to the end of this research study. Here we tried to demonstrate the status of some physical parameters named Electrical Conductivity (EC), pH, TSS, TDS, Salinity as well as some chemical parameters Total Hardness, Calcium Hardness, Alkalinity, Acidity, Free CO_2, Total chlorine, DO, COD, some major Ions and Heavy Metals ($SO_4^{2,}$ PO_4^{3-}, Cr^{6+}, Cu) from the water samples that were collected from the sampling locations of the study area near BSCIC Tannery Industrial Estate.

4.1.1 pH Concentration

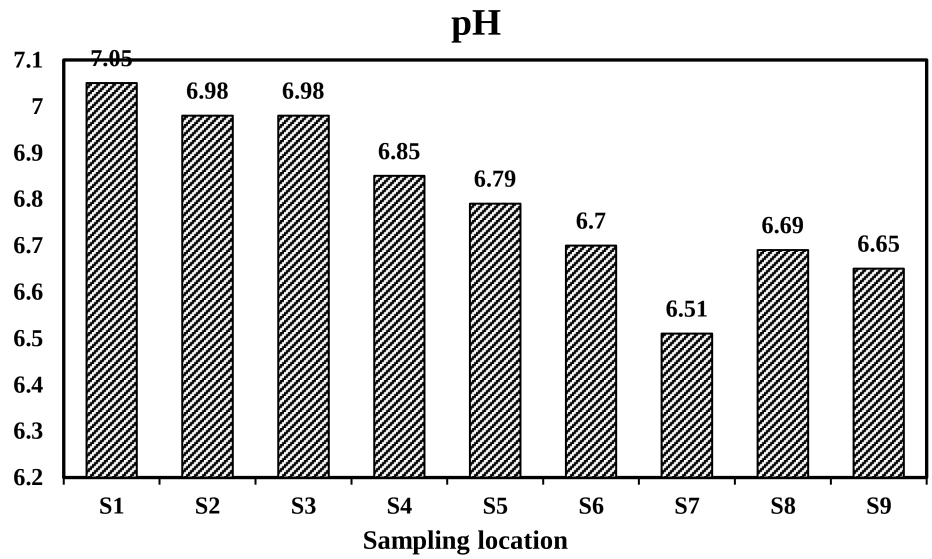


Figure 4.1: Concentration of pH

The hydrogen ion concentration in water is measured by the pH. The pH scale ranging from 0 to 14, with 0 indicating a highly acidic solution and 14 indicating a highly alkaline solution, and 7 indicating neutral. The pH of the majority of open waters is between 6 and 9. The pH of water in a lake or pond is influenced by its age as well as contaminants discharged by populations and industries. When most lakes are formed, they are basic (alkaline) and become acidic over time as organic materials accumulate. As organic matter decomposes, carbon dioxide (CO_2) forms and reacts with water to form a weak acid known as "carbonic" acid. The pH of water is lowered when significant quantities of carbonic acid are present. When some chemicals and metals are exposed to acidic waters (waters with low pH values), they also make them more volatile than natural. In this study the concentration of pH of Hatirjheel lake was ranged between 6.51 to 7.05 with a mean ± SD value 6.80±0.18. The highest pH was found in S1 (7.05) and the lowest pH was found in S7 (6.51). At the S1 sampling location, a sewerage line and effluent discharge line from Tejgaon industrial area is situated. According to WHO standard limit(Gorchev & Ozolins, 2004; WHO, 2011) and Bangladesh standard(ECR, 1997) for surface water, the pH level of Hatirjheel lake is within its limit

4.1.2 Electrical Conductivity

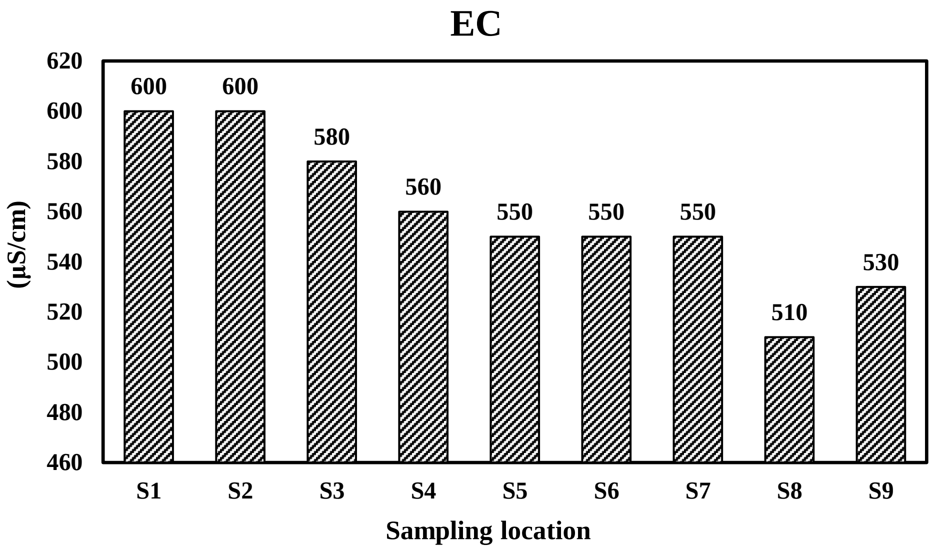


Figure 4.2: Electrical Conductivity (EC)

The potential of a substance to conduct an electric current is measured by its electrical conductivity or specific conductance. Total dissolved salts (TDS), or the total volume of dissolved ions in water, is estimated using electrical conductivity (EC). Geology (rock types), the size of the watershed (lake basin) in relation to the location of the lake, and other sources of ions to lakes all influence EC. There are a variety of contaminants that can be detected by increased EC. The concentration of EC of Hatirjheel lake ranged from 510 to 600 µS/cm with a mean ± SD value 558.89 ± 30.19 according to nine sampling value. EC concentration has exceeded according to the standard limit of WHO(WHO, 2011) and within the limit of Bangladesh standard(DOE (Department of Environment Bangladesh), 2017).

4.1.3 Total Dissolved Solids

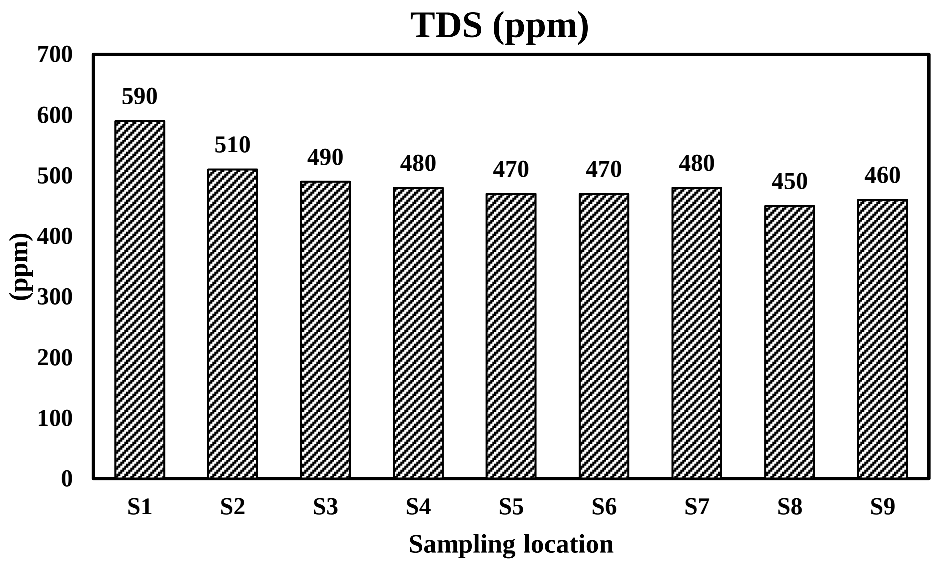


Figure 4.3: Total Dissolved Solids

The portion of total solids that passes through the filter is known as total dissolved solids (TDS). The bulk of solids in potable water are dissolved and consist of inorganic salts, a limited amount of organic matter, and dissolved gases(Parvin et al., 2019). The concentration of total dissolved solid of Hatirjheel lake according to the nine-sampling location ranged from 450-590 ppm with a mean ± SD value 488.89 ± 41.67. The highest concentration of TDS recorded in S1 sampling site where an industrial effluent discharge line is located. Rest of the EC range of the following sampling site ranged from 450 to 510 ppm. The lowest TDS value record in S8 sampling station. According to Bangladesh standard and WHO standard for surface water, the standard limit of TDS is 1000 ppm. So, The TDS concentration of Hatirjheel lake is within the limit of these standard.

4.1.4 Total Suspended Solids (TSS)

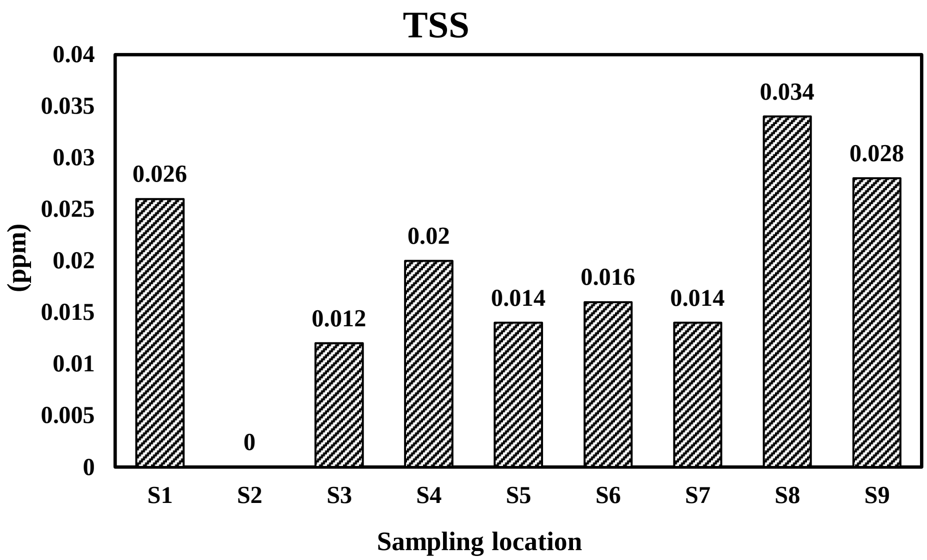


Figure 4.4: Total Suspended Solids

Total suspended solids (TSS) are the dry-weight of suspended particles, that are not dissolved, in a sample of water that can be trapped by a filter that is analyzed using a filtration apparatus. In this study the concentration of Total suspended solids (TSS) of nine sampling locations of Hatirjheel lake ranged between 0.00-0.034ppm with a mean ± SD value 0.02 ± 0.010. The highest concentration of TSS recorded in S8(0.034ppm) and S9 (0.028ppm) and lowest concentration of TSS found in S2 (0ppm). The standard limit of TSS in Bangladesh standard is 10 ppm and 150 ppm in WHO standard. So, the TSS of Hatirjheel lake is within the standard limit.

4.1.5 Total Acidity

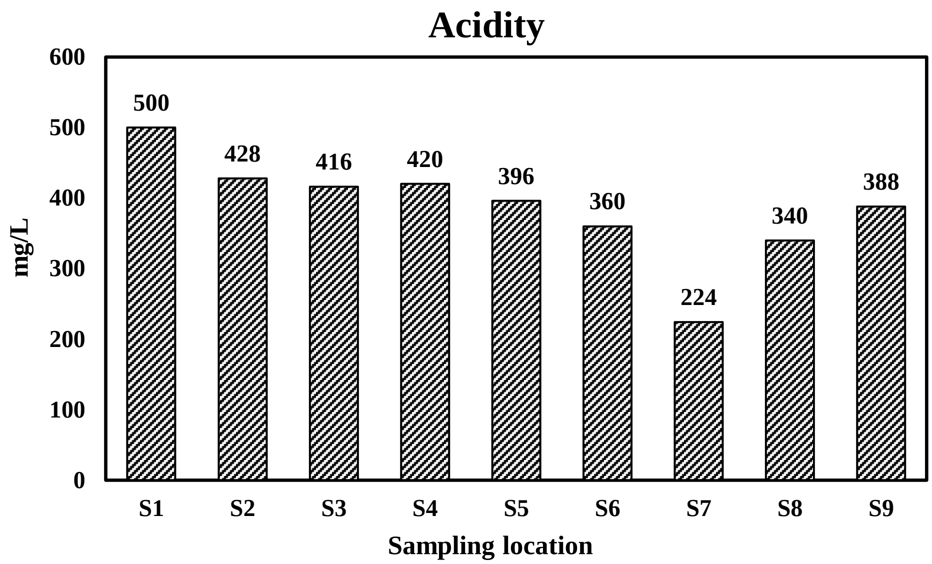


Figure 4.5: Total Acidity

Water's acidity refers to its ability to neutralize a solid base to a specific pH. Strong minerals acids, weak acids like carbonic and acetic acids, and hydrolyzing salts like ferric and aluminium sulphates can all contribute to the acidity calculation. Acidity is important because it contributes to corrosiveness and affects certain chemical and biological processes, depending on the method of measurement. It is the amount of base needed to neutralize a given sample to a particular pH level. The concentration of total acidity of Hatirjheel lake according to the nine-sampling site ranged from 240-500 mg/L with a mean ± SD value 385 ± 75.79. The highest concentration of Total acidity is recorded in S1 (500 mg/L) and the lowest concentration is recorded in S7 (388 mg/L). In the S1 sampling site, there a discharge and sewerage line from Tejgaon industrial area and that is the reason behind the high acidic water.

4.1.6 Total Alkalinity

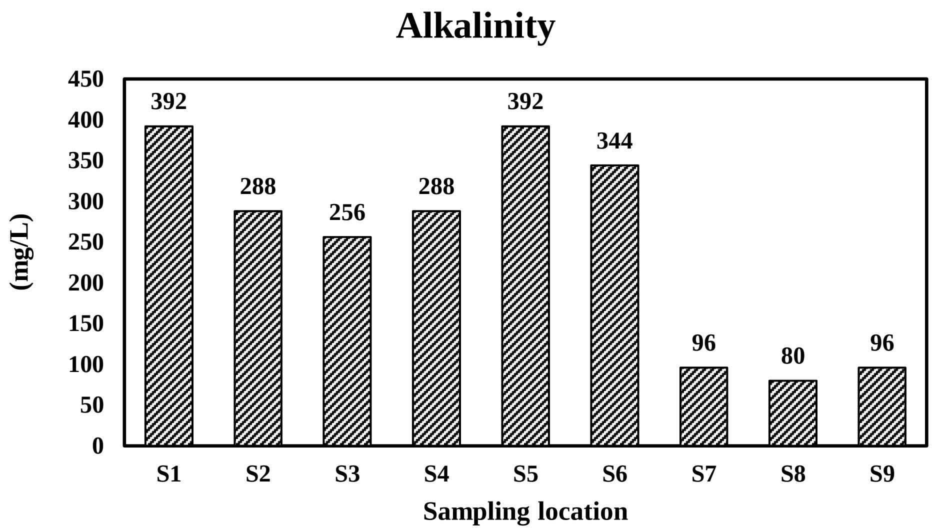


Figure 4.6: Total Alkalinity

The ability of a river's "buffering capability," or ability to neutralize acids, is determined by alkalinity. Bicarbonates (baking soda is one type), carbonates, and hydroxides are alkaline compounds in water that dissolve H+ ions and lower the acidity of the water (which means increased pH). They normally do this by forming new compounds by reacting with H+ ions. Any acid applied to a river would cause an immediate shift in pH if it lacked this acid neutralizing capability(Framework, 2013). The concentration of total alkalinity of Hatirjheel lake ranged between 80 to 392 mg/L according to nine-sampling locations. The concentrations have a mean ± SD value 248 ±126.68. The highest concentration of total alkalinity is found in S1 and S5 (392 mg/L) and the lower concentration of total alkalinity found in S8 (80 mg/L), S7 (96 mg/L) and S9 (96 mg/L). The standard limit of total alkalinity of Bangladesh standard is between 200-500 mg/L and within 200 mg/L in WHO standard. So, the concentration of total alkalinity was exceeded the WHO standard limit.

4.1.7 Total Hardness

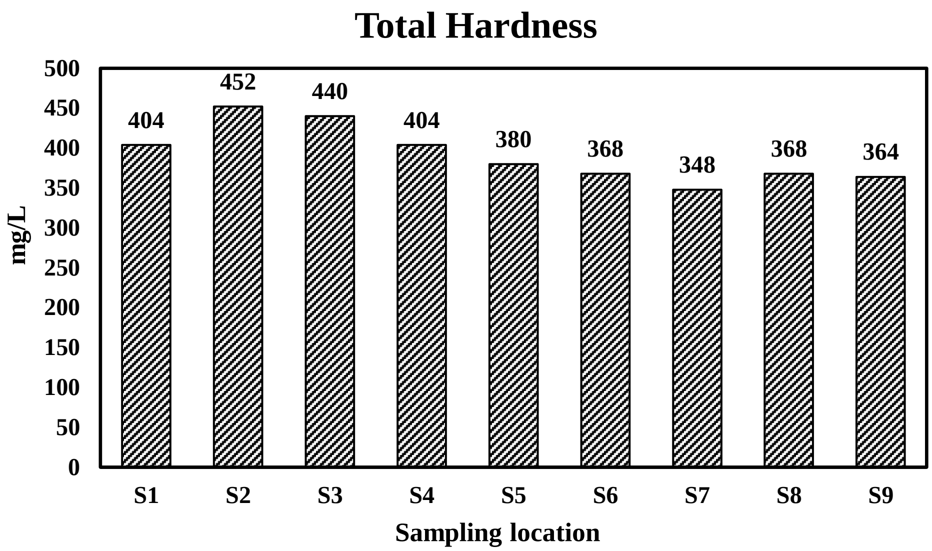


Figure 4.7: Total Hardness

The amount of dissolved calcium and magnesium in the water is the simplest description of water hardness. Dissolved minerals, especially calcium and magnesium, are abundant in hard water. Hard waters are described as those that require a large amount of soap to create foam, as well as those that cause scale in water pipes, heaters, boilers, and other units that raise the temperature of water. Hard water is suitable for human use in the same way as soft water is, but it has an adverse reaction with soap, making it unsuitable for washing and necessitating its withdrawal from water. (Framework, 2013). The concentration of Total Hardness of Hatirjheel lake according to nine-sampling location is ranged between 348-452 mg/L with a mean ± SD value 392 ± 35.72. The highest concentration of total hardness was found in S2 (452 mg/L) and the lowest concentration of total hardness was found in S7 (348 mg/L). The standard limit of total hardness according to Bangladesh standard is 200-500 mg/L and within 500mg/L is in WHO standard. So, the concentration limit of total hardness of Hatirjheel lake is within those standard limits.

4.1.8 Ca^{2+} Hardness

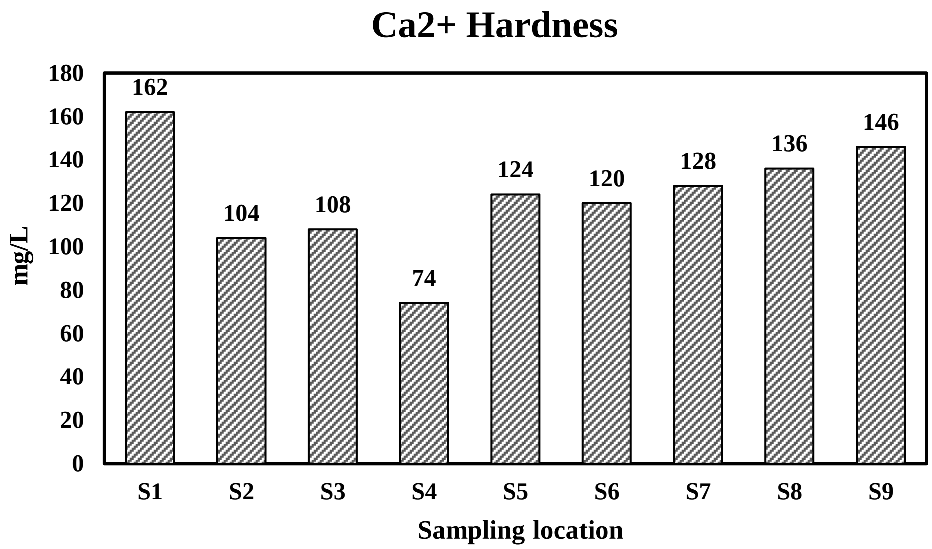


Figure 4.8: Ca^{2+} Hardness

The concentration of Ca^{2+} Hardness of Hatirjheel lake according to nine-sampling location is ranged between 74-162 mg/L with a mean ± SD value 122.44 ± 25.59. The highest concentration of Ca^{2+} Hardness was found in S1 and S9 (146 mg/L) and the lowest concentration of total hardness was found in S4 (74 mg/L). The standard limit of total hardness according to Indian standard is 75 mg/L and within 500mg/L is in WHO standard. So, the concentration limit of total hardness of Hatirjheel lake is WHO standard limits.

4.1.9 Free CO2

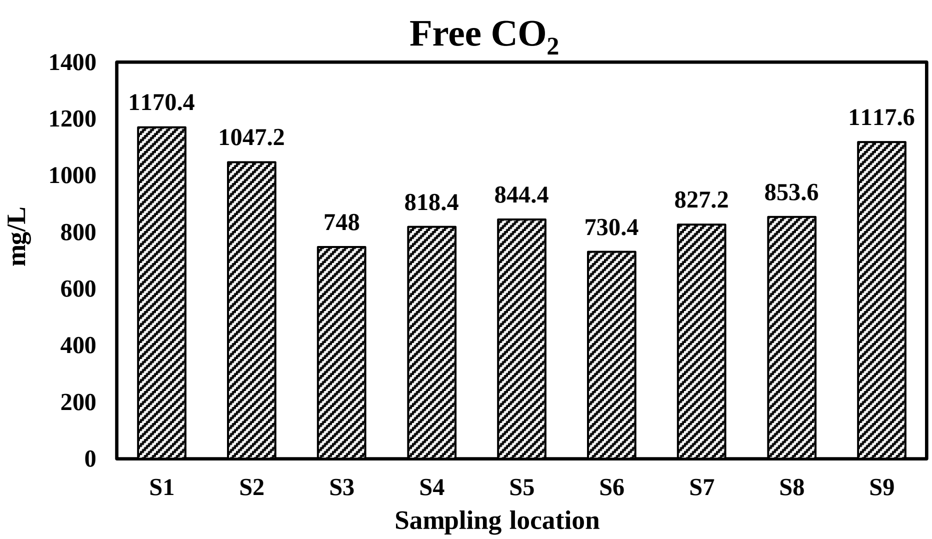


Figure 4.9: Free CO_2

Carbonic acid is formed when CO_2 is present, and it naturally changes the pH to a suitable level. Dissolution of CO_2 in water depends on the pH, because forming H_2CO_3 (CO_2*H_2O) dissociates to CO_3^{2-} and HCO_3^{-} and, herewith, the overall concentration of dissolved carbon CCO_2 increases together with the amount of HCO3 - and CO_3^{2-}ions formed. As the wastewater also contains Ca^{2+-} ions (300-1200 mg/L), determining the actual demand of CO2 is more complex. Contact between Ca^{2+-}ions and CO_2 leads to precipitation of $CaCO_3$, which is practically insoluble at pH ≥ 9(Uibu et al., 2008). The concentration of Free CO_2 of Hatirjheel lake according to nine-sampling location is ranged between 730.4-1170.4 mg/L with a mean ± SD value 906.36 ± 162.34. The highest concentration of Free CO_2 was found in S1 (1170.4 mg/L) and S9 (1117.6 mg/L) and the lowest concentration of total hardness was found in S3 (748 mg/L). The standard limit of Free CO_2 according to Bangladesh standard(DoE, 2015; ECR, 1997) is under 6 mg/L. The concentration limit of Free CO_2 of Hatirjheel lake has exceeds Bangladesh standard limit and concentration is very high in amount in all of the samples of Hatirjheel lake.

4.1.10 Dissolved Oxygen

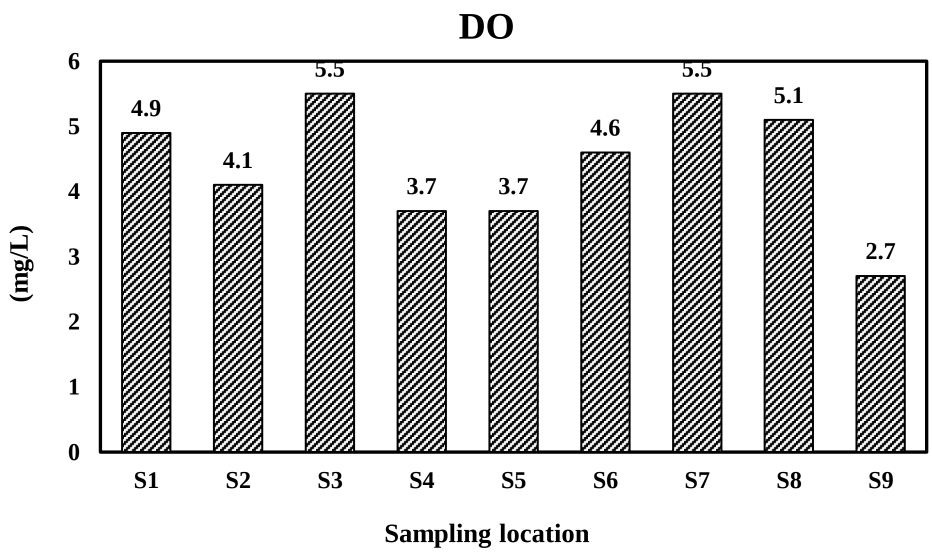


Figure 4.10: Dissolved Oxygen

The word "dissolved oxygen" refers to oxygen that has been dissolved in water. Diffusion from the surrounding air, aeration of water tumbling over falls and rapids, and as a waste result of photosynthesis are all ways it gets there. The free oxygen in water is important for fish and other marine life, as well as the prevention of odors. The amount of oxygen in a water body is regarded as one of the most significant indicators of its ability to sustain desirable aquatic life. Secondary and advanced waste management are usually planned to ensure that waste-receiving waters have ample DO. The following is an oversimplified formula for photosynthesis (in the presence of light and chlorophyll):

Carbon dioxide + Water → Oxygen + Carbon-rich foods

$$CO_2 + H_2O \rightarrow O_2 + C_6H_{12}O_6$$

DO is a strong measure of water quality and its relationship to the distribution and abundance of different algal species, as well as the degree of organic matter toxicity, degradation of organic matter, and the extent of water self-purification(Framework, 2013; Guidelines, 2003)

In this study the concentration of dissolved oxygen of Hatirjheel lake ranged between 2.7-5.5 mg/L with a mean ± SD value 4.42 ± 0.95. The highest concentration of DO recorded in S3 (5.5 mg/L) and S7 (5.5 mg/L). The lowest concentration of DO found in S9 (2.7 mg/L). DO range of Hatirjheel lake is very low according to the standard limit of Bangladesh standard of surface water(DoE, 2015).

4.2 Parameters with its standard limits

Table no 7: Parameters with standard limit

Parameters	Range	Minimum	Maximum	Mean	SD	Bangladesh standard	WHO Standard
pH	0.54	6.51	7.05	6.80	0.18	6.5-8.5	6.5-8.5
EC (µS/cm)	90	510	600	558.89	30.19	500-700	150
TDS (ppm)	140	450	590	488.89	41.67	1000	1000
TSS (ppm)	0.034	0.00	0.034	0.02	0.010	10	150
Acidity (mg/L)	276	224	500	385.78	75.79	-	-
Alkalinity (mg/L)	312	80	392	248.00	126.68	200-500	200
Total Hardness (mg/L)	104	348	452	392.00	35.72	200-500	500
Ca^{2+} Hardness (mg/L)	88	74	162	122.44	25.59	75 *IS	500
Free CO_2 (mg/L)	440.0	730.4	1170.4	906.36	162.34	6 *IS	-
DO (mg/L)	2.8	2.7	5.5	4.422	0.95	6	-

Note: SD= Standard deviation, *IS=Indian Standard (BIS 1982), WHO 1984, 2004, ECA 1997

4.3 Correlation

Pearson's correlation has done to identify the relations among the plants, physical and chemical parameters of water.

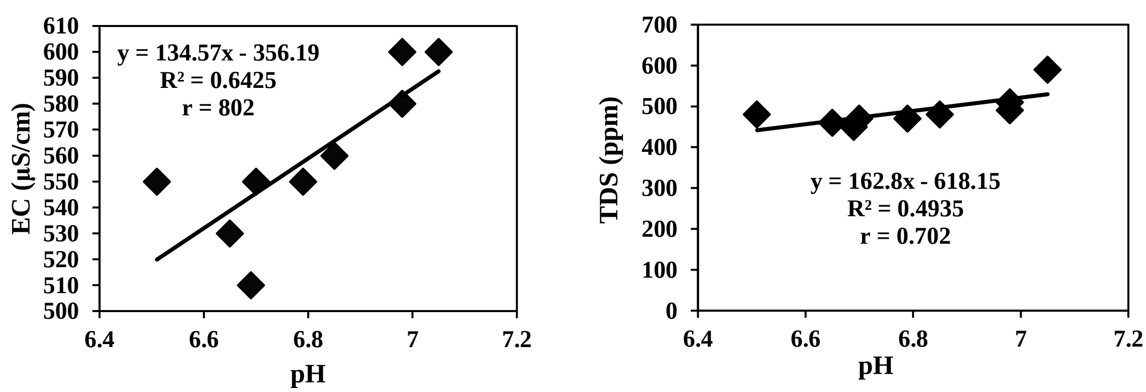
Table no 8: Correlation of the parameters

Parameters	pH	EC	TDS	TSS	Acidity	Alkalinity	Total Hardness	Ca^{2+} Hardness	Free CO_2	DO
pH	1									
EC	****0.802**	1								
TDS	***0.702**	****0.814**	1							
TSS	-0.280	-0.621	-0.106	1						
Acidity	****0.893**	0.593	0.618	-0.002	1					
Alkalinity	0.664	0.641	0.539	-0.381	0.659	1				
Total Hardness	****0.879**	***0.774**	0.440	-0.567	0.665	0.440	1			
Ca^{2+} Hardness	-0.132	-0.142	0.326	0.515	0.017	-0.147	-0.423	1		
Free CO_2	0.316	0.319	0.581	0.193	0.487	0.011	0.146	0.558	1	
DO	0.059	0.176	0.232	-0.084	-0.301	-0.070	0.068	0.089	-0.405	1

Legend: ** =Significant at 0.01 level; ***** =Significant at 0.05 level

4.3.1 Relation between the parameters

Pearson's correlation has done to identify the relations among the water parameters. We have found many strong positive and moderate positive relation which is describes in Figure 4.11 to 4.13.



A **B**

Figure 4.11: (A) Correlation between pH and EC (B) Correlation between pH and TDS.

Figure 4.11 describes the relationship between pH and EC of the samples and the relationship between pH and TDS. The relationship between pH and EC represents that the value pH is increasing with the increase of EC. It is a positive relationship where r = 0.802 (strong positive relationship) and the regression equation is y = 134.57x - 356.19 (Figure 4.11A). The relationship between pH and TDS of the sample waters represented that the value of pH is increasing with the increase value of TDS. It is also a positive relationship where the r = 0.702 (moderate positive relationship) and the regression equation is y = 162.8x - 618.15(Figure 4.11B).

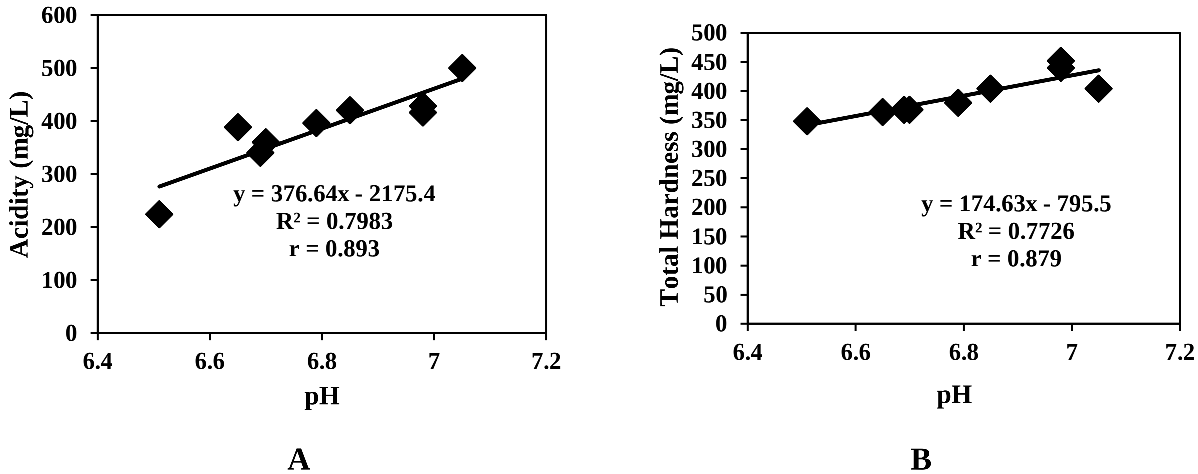


Figure 4.12: (A) Correlation between pH and Acidity (B) Correlation between pH and Total Hardness.

Figure 4.12 describes the relationship between pH and Acidity of the samples and the relationship between pH and Total Hardness. The relationship between pH and Acidity represents that the value pH is increasing with the increase of Total Harness. It is a positive relationship where r = 0.893 (strong positive relationship) and the regression equation is y = 376.64x - 2175.4 (Figure 4.12A). The relationship between pH and Total Hardness of the sample waters represented that the value of pH is increasing with the increase value of Total Hardness. It is also a positive relationship where the r = 0.879 (strong positive relationship) and the regression equation is y = 174.63x - 795.5(Figure 4.12B).

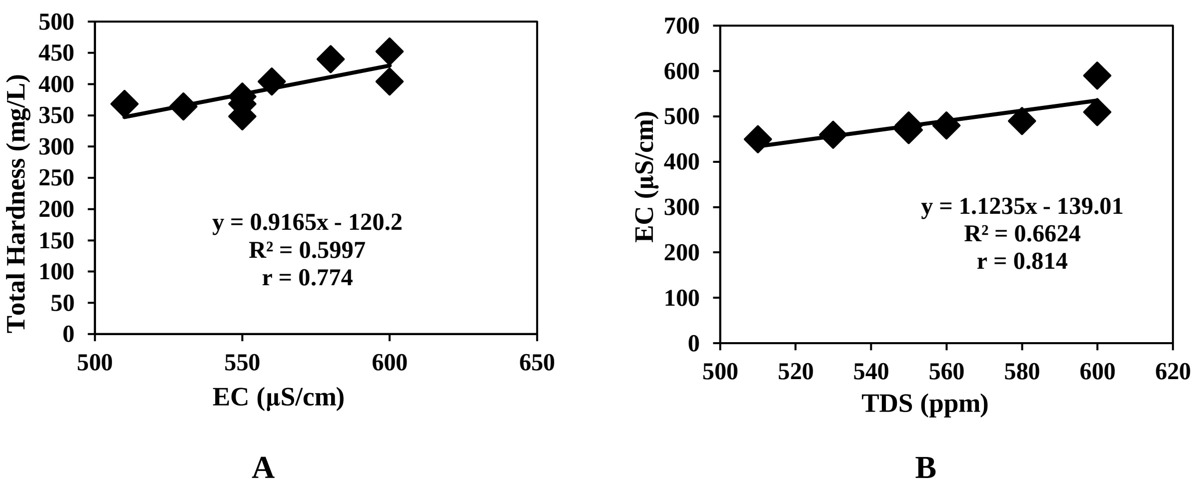


Figure 4.13: (A) Correlation between EC and Total Hardness (B) Correlation between TDS and EC

Figure 4.13 describes the relationship between EC and Total Hardness of the samples and the relationship between TDS and EC. The relationship between EC and Total Hardness represents that the value pH is increasing with the increase of Total Hardness. It is a positive relationship where r = 0.774 (moderate positive relationship) and the regression equation is y = 0.9165x - 120.2(Figure 4.13A). The relationship between EC and TDS of the sample waters represented that the value of EC is increasing with the increase value of TDS. It is also a positive relationship where the r = 0.814 (strong positive relationship) and the regression equation is y = 1.1235x - 139.01(Figure 4.13B).

CHAPTER 05: CONCLUSION AND RECOMMENDATION

Dhaka has developed without much planning, and the city also lacks a formal waste management system. Hatirjheel Lake has tremendous economic and environmental importance in addition to its scenic beauty. The lake holds a large amount of water during exceptionally dry seasons. The water of the Hatirjheel Lake is severely polluted compared to the Gulshan, Banani Lake and Ramna Lake. Sewage and Industrial toxic discharge from Tejgaon Industrial Area is affecting the quality of Hatirjheel lake. From the laboratory test result, it has been observed that the physiochemical parameters of selected lake water are not in good condition. Especially the dissolved oxygen (DO) and CO_2 concentration are in the worst condition and very dangerous for aquatic life. It is necessary to developing a holistic management plan for the restoration of all Dhaka city lakes, khals, and wetlands.

There are several ways to protect Lake Water from being polluted. The following are some measures that can be taken into consideration for preventing contamination of Dhaka city lakes based on the findings of the report:

- Household waste should not be discharged into the lake. The RAJUK authority may be able to help clear the lake of encroachers.
- To protect the lakes from contamination, a public awareness campaign should be launched.
- A team to track water quality can be created.
- Implementation of Dhaka's original Master Plan by the appropriate authorities.
- Various NGOs should collaborate with the government to boost the current state of the lakes.
- Controlling and preventing dangerous discharges.
- Detecting emerging hazardous compounds and putting pollution-prevention and-control measures in place.
- Conservation strategies to conserve native species and restore habitat are being created.

Pollution can be successfully handled in the future by a combination of government action and increased understanding of the value and fragility of freshwater resources.

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