CURRENT SCENARIO OF BURIGANGA AND DHALESWARI RIVERS AFTER THE SHIFTMENT OF THE TANNERY INDUSTRY: A WQI STUDY

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A THESIS SUBMITTED FOR THE DEGREE OF BACHELOR OF SCIENCE

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

ISLAMIC UNIVERSITY OF TECHNOLOGY

2023

SUPERVISOR'S APPROVAL

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We hereby declare that this thesis is our original work and it has been written by us in its entirely. We have duly acknowledged all the sources of information which have been used in the thesis.

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To our parents who support us in every possible way in our life.

Thank you for your unconditional love and support.

ACKNOWLEDGEMENTS

First of all, the authors express gratitude to Allah Almighty for the successful completion of this thesis. The authors would also like to express their sincere and heartfelt gratitude to their supervisor, Dr. Amimul Ahsan, Assistant professor, Department of Civil and Environmental Engineering, IUT, for his continuous guidance and support, supervision, discussions, encouraging comments, stimulating ideas, enthusiasm, and valuable suggestions during the research period. His dedication to guiding and constant encouragement aided the authors in completing this research project in this manner. It was a tremendous privilege to be able to work under his supervision.

IUT gratefully acknowledges the laboratory employees of the Department of Civil and Environmental Engineering for their assistance with the research. The authors are also grateful to the entire Environmental Engineering Laboratory staffs for their assistance and support throughout the course of this investigation.

The authors are extremely appreciative of our parents' continuous inspiration and support throughout the research efforts. Without their constant cooperation this research could not have been possible.

ABSTRACT

This study deals with the comparison of water quality parameters between Buriganga and Dhaleshwari river based on DoE Water Quality Index [Malaysia], Canadian Water Quality Index and River pollution Index. It is measured that the water quality of Buriganga is slightly improving on the other hand the water quality of Dhaleshwari is gradually declining. For Buriganga, the DoE Water Quality Index [Malaysia] is increasing in 2022-13 compare to 2017, for example in 2017 WQI value was 32.24975 at Postogola Bridge. But in 2022-23, WQI value was 47.62663 in Season-1, 48.45746 in Season 2 and 38.03453. For Dhaleswari, at Hazratpur WQI value at 2017 was 65.91067 and in 2022-23 it was 29.44778 [Season-1], 34.99186[Season-2] and 33.30495 [Season-3], So, the Water Quality of Buriganga is slowly improving as per DoE Water Quality Index [Malaysia] but it's rapidly declining at Dhaleshwari River. According to River pollution Index, in 2022-23's Season1, 2 &3 RPI was 5.0, 6.0 and 6.75 at Postogola Bridge which is classified as Moderately polluted as River pollution Index. But in 2017, RPI was 8.25 at Postogola Bridge which was classified as severely polluted as per RPI. For Dhaleswari River, RPI in 2017 at Hazratpur was 1.5 which was classified as unpolluted as per RPI. But 2022-23's three season value was 27.25, 7.25 and 8.25 which was classified as severely polluted. So, River Pollution Index also states the rapid degradation in Water Quality of Dhaleshwari river and slow improvement of Buriganga River. The CWQI value for each season and station in 2022-23 were in the range of 0 to 44 range at Buriganga River that means the water quality was poor. And for Dhaleswari, CWQI value was poor at every station expect Dhaleshwari River Bridge. From all the aspects the water quality is gradually declining for Dhaleshwari day by day and is marginally improving for Buriganga.

Keywords: WQI, Water Quality, Parameters, CWQI, DoE, River Pollution Index, RPI, Canadian Water Quality Index, CCME WQI, DoE Water Quality Index [Malaysia], Buriganga, Dhaleshwari.

LIST OF ABBREVIATIONS

BOD	Biochemical Oxygen Demand
CBOD	Carbonaceous Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DoE	Department of Environment
EC	Electroconductivity
ECR	Environmental Conservation Rule
EU	European Union
GoB	Government of Bangladesh
GPS	Global Positioning System
HTRP	Hazaribagh Tannery Relocation Project
TS	Total Solids
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
US	United States
RPI	River Pollution Index
WQI	Water Quality Index
CCME	Canadian Council of Ministers of the Environment
CWQI	Canadian Water Quality Index

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CHAPTER 1. INTRODUCTION

1.1 Background

Buriganga and Dhaleshwari are two of the most well-known rivers in Bangladesh, which has over 700 rivers and tributaries. Both rivers are geographically and economically significant. The Buriganga River flows into the Dhaleshwari River as a tributary.

Dhaleshwari River is one of the tributaries of the Jamuna River in the center of Bangladesh. It originates in the Jamuna towards the northwest corner of the Tangail district. After that, it splits in two; the northern branch, which keeps the name Dhaleshwari, eventually joins up with the southern branch, which becomes the Kaliganga River in the Manikganj area. Finally, the combined flow reaches the Shitalakshya River close to the Narayanganj district. This merged water eventually flows into the Meghna River further south. The river Dhaleshwari has an approximate length of 160 kilometers and an average depth of 37 meters (Wikipedia contributors, 2022).

The Buriganga river formed near Kalatia from the Dhaleshwari river. This river's average width and depth are 400 meters and 10 meters, respectively. The length of this river is about 27 kilometers. At Kamrangirchar in Dhaka, the Turag river meets the Buriganga river. The Buriganga and Dhaleshwari river merge in the Munshiganj district (Kazi M Maraz et al., 2021).

On April 6, 2017, it was ruled that all Hazaribagh tanneries must shut down operations. Prior to this, the dumping of untreated liquid leather processing wastes from tannery factories in Hazaribag, Dhaka, was the primary source of pollution in the Buriganga. For the last 45 years, the chromium emitted by the Hazaribagh tanneries has contaminated the water of the Buriganga River. In the previous fifty years, 95 percent of Hazaribag's tanneries have been constructed in an uncontrolled manner in densely populated areas, according to statistics from the Department of the Environment (Azom et al., 2012). Recent research shows that around 60,000 tons of raw hides and skins are processed annually in these tanneries, which discharge roughly 95,000 liters of untreated effluents into the open environment every day, causing the death of the Buriganga River(Rasul et al., 2006). According to the World Health Organization, more than 8,000 employees in Hazaribag's tanneries suffer from gastrointestinal, dermatological, and other illnesses, and 90 percent of this group dies before the age of 50 (Maurice, 2000)

With the relocation of 155 factories, the tannery industry has migrated from Hazaribagh to Savar in Dhaka. Unfortunately, early delays in the proper functioning of the CETP raised questions as to whether the pollution issue was simply moved from the Buriganga River to the Dhaleshwari River. Eventually, the CETP began to function, although its efficiency remains very questionable.

As the tanning industry was deemed to be one of the biggest sources of the Buriganga river, an improvement in water quality over the last four years is anticipated. Similarly, the decline in Dhaleshwari's water quality. Our primary purpose is to examine the water quality of Buriganga and Dhaleshwari before and after moving of the tannery industry from Hazaribagh to Savar using field measurements, laboratory analysis, and Water Quality Index.

1.2 Objectives

The primary objective of the research is to evaluate the water quality of rivers of Buriganga and Dhaleshwari after the relocation of tannery industries from the bank of river Buriganga to the bank of river Dhaleshwari. Four times a year, the water quality is assessed. The primary aims of the research include

- To analyse of the existing water quality of the Buriganga and Dhaleshwari in terms of selected water quality parameters, including pH, DO, BOD5, COD, TS, TDS, TSS, NH3-N, NO3-N, and orthophosphate concentrations throughout the year.
- To compare the water quality in both rivers before and after the relocation of tanning industries. And demonstrate the deterioration and improvement of both rivers.
- To apply various WQI models in rivers of Buriganga and Dhaleshwari and find the current water quality of each river and compare them with 2017 data.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

According to the globe Health Organisation (WHO), the Buriganga is one of the most polluted rivers in the globe. This is a result of the city's daily disposal of over 60,000 cubic metres of toxic refuse into its waters. The principal sources of pollution have been the leather tanning industry in the neighbourhood of Hazaribagh and the waste discharge of a population lacking adequate sanitation services. The Buriganga River has become one of the world's most polluted and unhealthy rivers as a result of Dhaka's refuse over the past three decades. Since 400 years ago, Dhaka has expanded along the north bank of the Buriganga River.

The tanning industry was considered to be one of the main polluters of the Buriganga River. According to research, nearly 200 untreated tanneries discharge daily approximately 18000 litres of liquid wastes, 115 tonnes of solid wastes during peak hours, and 75 tonnes of solid wastes during off-peak hours. From 1951 to 2018, they directly discharged effluents for 67 years.

In 2018, the tannery industry was relocated to Savar along the Dhaleshwari River. Savar Tanneries: Pollution Puzzle, 2022 reported that the Savar estate's current central effluent treatment facility has the capacity to treat approximately 25,000 cubic metres of liquid waste per day, according to sources from the Department of Environment. However, the estate's tanneries generate 40,000 cubic metres of refuse. Currently, 15,000 cubic metres of untreated waste are being released into the adjacent Dhaleshwari river. Another deficiency contributes to the overall dysfunctional state of the estate. In addition to heavy metals and chromium, the exclusive tanning zone also dumps solid refuse into the river. All of these factors contribute to the transformation of the Savar-river segment into an uncontrolled pollution hotspot.

This chapter provides a review of the research on the Buriganga and Dhaleshwari rivers.

2.2 Previous Study on River Buriganga & Dhaleshwari:

Paul et al. (2014) analysed the data quality of the Buriganga river from 1968 to 2007 in a study. The investigation concentrated on seven riverside locations. The study revealed that the minimal value of dissolved oxygen (DO) in 1974 was 6.1 mg L-1, which represented an increase from the 5.4 mg L-1 value recorded in 1968. The following year, however, saw a precipitous decline to 1.55 mg/l. The minimal DO concentration in the Buriganga river water exceeded the critical limit in 1968, 1973, and 1974. From 1975 to 1988, the minimal DO concentration remained below 4 mg L-1, with the exception of 1988 and 1989, when it was 1.7 mg L-1 and 4.7 mg L-1, respectively. From 1989 to 1993, with the exception of 1991, the minimum DO value remained above the threshold level of 2 mg L-1. The minimal DO in 1994 decreased from 5 mg L-1 in 1993 to 3.2 mg L-1 in 1994. The minimum DO concentration in the Buriganga river decreased from 2 mg L-1 in 2000 to 0 mg L-1 in 2007.

The lowest biochemical oxygen demand (BOD) value was recorded in 1968 at 1.5 mg L-1, while the highest value was recorded in 2007 at 60 mg L-1. Prior to 1994, the BOD value remained below 10 mg L-1; however, it rose sharply thereafter, reaching 60 mg L-1 by 2007. During the course of the investigation, the pH levels ranged from 7.4 to 8.53. The chemical oxygen demand (COD) concentration ranged from 1.1 mg L-1 to 198 mg L-1, with the maximum concentration recorded in 1988. By 2007, the COD concentration had increased to 145 milligrammes L-1 from 68 mg L-1 in 2000. From 1973 to 2007, the total alkalinity ranged from 90 to 264, a significant increase over time.

In a separate research titled "Buriganga Pollution: Reasons & Prospects" (2008), the environmental conditions of Dhaka's Keraniganj Upazilla in 2007 were examined. The research revealed that the average dissolved oxygen concentration and pH of the Buriganga river are 1.8 and 12, respectively. In addition, the chloride concentration in the river exceeded the tolerance standard.

Regarding tanneries, the investigation identified two distinct tanning processes used in their manufacturing. To produce blue leather, chrome tanneries utilised chromium sulphate, CaO, Na2S, NH4Cl, Oropan bate, NaCl, H2SO4, chromosal B, and soda. To produce soft blue leather, chromium and vegetable tanneries combined NaCl, CaO, NH4Cl, bate powder, H2SO4, chromosal B, soda ash, and hydrosulphide. In the dying process, nigrosine, violet, COD oil, TRC oil, Pigme-t, black, and glycerine were utilised. Polishing slug with casin, liquid ammonia, nitrobenzene, formaldehyde, and soliside produced finished leather.

The study also revealed that these tanneries discharged approximately one tonne of refuse per day.

During peak hours, the facility processes 18,000 litres of liquid waste and 115 tonnes of solid waste, or 75 tonnes during off-peak hours. During the summer, when refuse decomposition rates were at their peak, the region of Hazaribagh experienced severe air pollution due to the release of intolerable and offensive odours.

Upon investigation, it was discovered that tannery wastes consist of liquid arsenic, soft sodium sulfate, lime, ammonium sulfate, chromium sulfate, and pigments of different colors. Hexavalent chromium, in particular, is highly carcinogenic. Only 30 percent of the chromium is absorbed by the hides, while the remaining 70 percent is discharged into the Buriganga River. The maximum concentration of chromium in the river is approximately 4 mg per liter. The majority of liquid wastes are dumped directly into the Buriganga River, while a portion is trapped within the Dhaka Flood Control Embankment. Solid wastes from fleshing and shaving are often disposed of on the streets or near garbage cans, although currently, around 90% of trimming wastes are utilized by local shoemakers. Approximately 50% of the tanneries recycle some of their solid waste.

In a study conducted by Ali in 2018, the impact of relocating the tannery industry was examined. It was reported that a significant portion of the pollution load in the Buriganga River originates from tanneries in the Hazaribagh and Rayer Bazar region, flowing through Kamrangir Char Khal and Rayer Bazar Khal. Through field measurements, laboratory analysis, and modeling, the potential effects of tannery relocation on the water quality of the Buriganga River were assessed.

For the study, a section of the Buriganga River between Boshila Bridge and Postogola Bridge was selected to evaluate water quality during the dry seasons of 2017 and 2018. Water samples were collected from nine monitoring locations along this stretch during that time period. It was determined that Kamrangir Char Khal and Rayer Bazar Khal are point sources contributing pollution loads to the river, mainly from tannery industries.

Based on field measurements and laboratory analysis, it was found that the water quality of the Buriganga River in March 2018 was slightly better than in March 2017. Concentrations of biochemical oxygen demand (BOD), electrical conductivity, ammonia, nitrate, and orthophosphate decreased significantly along the river in March 2018 compared to March 2017. For example, during the dry season of 2017, COD values ranged from 65 to 140 mg/L, while in 2018, they ranged from 55 to 85 mg/L. Ammonia concentrations in river water ranged from 13.8 to 16.18 mg/L in March 2017, and from 10.8 to 13.25 mg/L in March 2018.

The study also attempted to calibrate models for further research. The model predicted that, due to the significant waste load carried by the river from upstream locations (locations upstream of tannery industries), the dissolved oxygen (DO) level in the Buriganga River may not improve significantly as a result of tannery relocation. However, the relocation is expected to lead to a significant decrease in BOD, ammonia, nitrate, and phosphate levels. To achieve a significant improvement in river water quality, a reduction in waste load from other upstream locations would be necessary.

In another study by Saha in 2019, the water quality of the Dhaleshwari River was assessed prior to the relocation of the leather industry. The study found that the river water was already polluted, with a slight deterioration during dry periods. Samples were collected monthly from July 2013 to June 2014 from the main stream of the river at different locations. The research revealed that the river water appeared bluish-black during the dry season and faint green during the wet season. The average depth of the river at location 1 was 786.67 ± 39.72 cm, and at location 2 it was 997.50 ± 75.50 cm. The average temperature at location 1 during the study period was 23.54 ± 4.23°C, while at location 2 it was 24.12 ± 4.48°C. Water transparency ranged from a minimum of 18 cm/sec to a maximum of 58.8 cm/sec (maximum value). The minimum concentration of water-soluble solids measured at various locations and times of the year ranged from 3.36 mg/L to 1049 mg/L (maximum value). The highest turbidity observed was 131 NTU in July at Spot-1, while the lowest was 2.38 NTU in November at Spot-2.

After the relocation of the tanning industry in Savar,(Akter et al., 2019) investigated the water quality of the Dhaleshwari River. In their investigation, they attempted to evaluate the chemical parameters of the water in the Dhaleshwari river in Savar, Dhaka, near a recently constructed Bangladeshi tannery village. They determined the chemical parameters pH, Electrical Conductivity (EC), Dissolve Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Salinity. The results indicated that the pH of water collected at various locations and times of the year ranged from 7.60 to 6. The EC of water collected at various locations and times of the year ranged from 11.80 to 2080 S/cm. The average DO concentration at location-1 was 4.79166±3.23 mg/l. Spot-2 had an average DO of approximately 6.571667±1.47 mg/l. The Biological Oxygen Demand (BOD) of water sampled at various locations and times of the year ranges from 1.13 to 17.1 mg/l. Throughout their study period, the minimum monthly COD concentration was 218.12 mg/L and the maximum was 1,276.6 mg/L. (maximum value). Salinity of water samples collected at various locations and times of year in the study area ranged from 0 (minimum) to 0.1 (maximum).

Another study was also conducted on water quality of Dhaleshwari river by (Islam et al., 2021). This study analyzed the physicochemical parameters of water quality and heavy metal concentrations in the Dhaleshwari river, as well as the peripheral rivers surrounding Dhaka, Bangladesh. In certain instances, direct discharge from untreated point sources caused surface water quality parameters such as total dissolved solids (TDS), biochemical oxygen demand (BOD5), and chemical oxygen demand (COD) for the Dhaleshwari river to deviate by as much as 90% from World Health Organization (WHO) standards.

During the study period, he discovered that the Dhaleshwari River water was dark in color and had a pungent odor. The pH ranged from 6.9 to 11.2 depending on the sampling location along the river. Sampling station D-1 (Savar Tannery) had the highest pH value, whereas Sampling station D-3 had the lowest pH value (Dhalla, fish market). The pH level was within the acceptable range, as determined for the other peripheral rivers in Dhaka City. The TDS concentration in the water of the Dhaleshwari River varied from 412 to 3278 mg/L, with the highest concentration found at sampling station D-1 (Savar Tannery) and the lowest concentration found at sampling station D-5 (Nama Bazar) (Figure 4). Except for Savar tannery (D-1) and Sudkhira (D-2), all sampling stations for the Dhaleshwari River exhibited values below the WHO-permitted level of 1000 mg/L.

2.3 Water Quality Standards

2.3.1 Surface water quality standards

The term ' Water Quality' possesses a wide range of meanings. It's defined as the physical, chemical, and biological quality of water by which we can determine whether we should use the water or not. The water quality standards change with the purpose of use. For example, the standard of drinking water and water used for washing aren't the same. So we need to maintain the quality of the water as per the purpose.

Table 2.1: Inland surface water standards

Best Practice Based Classification	pH	BOD mg/l	DO mg/l	Total Coliform number/100
Source of drinking water for supply only after disinfecting	6.5-8.5	2 or less	6 or above	50 or less
Water usable for recreational activity	6.5-8.5	3 or less	5 of more	200 or less
Source of drinking water for supply after conventional treatment	6.5-8.5	6 of less	6 or above	5000 or less
Water usable by fisheries	6.5-8.5	6 of less	5 of more	---
Water usable by various process and cooling industries	6.5-8.5	10 or less	5 of more	5000 or less
Water usable for irrigation	6.5-8.5	10 or less	5 of more	1000 or less

Note:

- The limit for the presence of Ammonium Nitrate as Nitrogen in water used for pisciculture is 1.2 mg/L.

- Irrigation water needs to have a conductivity of 2250 μS/cm (at 25 degrees Celsius), a sodium concentration of no more than 26%, and a boron concentration of no more than 0.2%.

As a result, we need to define water quality requirements or water quality goals for each specific purpose.

Therefore, identifying the uses of water in a body of water is vital for establishing water quality objectives.

2.3.2 Effluent standards:

In contrast, the establishment of water quality standards precedes that of effluent standards due to the fact that the attainment of cleaner effluent would lead to the improvement of water systems' cleanliness. The criterion for water quality, which is based on risk assessment, forms the fundamental basis for establishing standards for water quality.

The establishment of water quality guidelines for both human health and aquatic life has been advocated by the United States Environmental Protection Agency (USEPA) (USEPA, 1996, 2000). Upon the establishment of the water quality standard, the effluent standard can be determined by taking into account various factors such as dilution ratio, treatability, economic feasibility, and other relevant variables. According to Kim et al. (2010), there exist two distinct approaches for setting effluent standards, namely water quality-based and technology-based. The inclusion of water quality criteria and models is an essential aspect of a water quality-focused strategy. Treatment technology has certain limitations, but in light of its potential for effective treatment, technology-based approaches have emerged. Developed countries, including the United States and the European Union, have adopted a technology-focused approach as a potential solution that addresses social, economic, and technological concerns (USEPA, 1996; EU, 1996). The Best Available Technology (BAT) strategy is a frequently used term to describe an approach that is based on technology. This approach is employed within the European Union and the United States. A crucial aspect of the BAT (Best Available Technology) approach is conducting a thorough examination of the sector, the treatment facilities, and the properties of the wastewater. The integration of both techniques has been proposed as a potentially efficacious approach towards the establishment of effluent standards in developing countries, as suggested by Ragas et al. (2005). The water quality-based approach (USEPA, 1991) may be employed in locations where Total Maximum Daily Loads (TMDL) are delineated.

There exist specific stipulations for both direct and indirect discharge. As Indirect provides offsite facilities, its criteria are comparatively less stringent. The Effluent standard encompasses the regulation of parameters such as BOD, TSS, pH, and toxic pollutants. The requirements for these standards vary depending on whether the discharges are direct or indirect.

Table 2.2: Bangladesh standards for industrial effluent

Parameter	**Unit**	**Inland Surface Water**	**Public Sewerage System Connected to Treatment at Second Stage**	**Irrigated Land**
Ammonium Nitrogencal Nitrogen (as elementary N)	mg/L	50	75	75
Ammonium Nitrate (as free Ammonium Nitrogen)	mg/L	5	5	15
Arsenic (As)	mg/L	0.2	0.05	0.2
BOD_5 at 20°C	mg/L	50	250	100
Boron (B)	mg/L	2	2	2
Cadmium (Cd)	mg/L	0.5	0.05	0.05
Chloride (Cl-)	mg/L	600	600	600
Chromium (total Cr)	mg/L	0.5	1	1

COD	mg/L	200	400	400
Chromium (hexavalent Cr)	mg/L	0.1	1	1
Copper (Cu)	mg/L	0.5	3	3
Dissolved Oxygen (DO)	mg/L	4.5-8	4.5-8	4.5-8
Electric Conductivity (EC)	µS/cm	1200	1200	1200
Total Dissolved Solids	mg/L	2100	2100	2100
Fluoride (as F)	mg/L	2	15	10
Sulphide (as S)	mg/L	1	2	2
Iron (as Fe)	mg/L	2	2	2
Total Kjeldahl Nitrogen (as N)	mg/L	100	100	100
Lead (as Pb)	mg/L	0.1	1	0.1
Manganese (as Mn)	mg/L	5	5	5
Mercury (as Hg)	mg/L	0.01	0.01	0.01
Nickel (as Ni)	mg/L	1	2	1
Nitrate (as elementary N)	mg/L	10	Not Yet Fixed	10

Oil and Grease	mg/L	10	20	10
Phenolic Compounds (C_6H_5OH)	mg/L	1	5	1
Dissolved Phosphorus (as P)	mg/L	8	8	15
Radioactive substance	To be specified by Bangladesh Atomic Energy Commission			
pH		6-9	6-9	6-9
Selenium (as Se)	mg/L	0.05	0.05	0.05
Zinc (as Zn)	mg/L	5	10	10
Total Dissolved Solids	mg/L	2100	2100	2100
Temperature	Centigrade Summer Winter	40 45	40 45	40 45
Suspended Solids (SS)	mg/L	150	500	200
Cyanide (as Cn)	mg/L	0.1	2	0.2

CHAPTER 3. METHODOLOGY

3.1 Introduction

The purpose of this study is to evaluate the water quality of the Buriganga and Dhaleshwari rivers. To meet our purpose, during JUNE 2022 to MAY 2023, three sets of water samples were collected and analyzed to generate data on water quality. In addition, secondary data on water quality were collected from the Department of Environment (DoE) of Bangladesh and various reports and journals.

Then we use three different type water quality index based on our test result of some specific parameters and calculate WQI of Buriganga and Dhaleswari river. After that we compare our WQI result with 2017's data [the year tannery was shifted from Buriganga to Dhaleswari] to get perfect idea of rivers current water condition.

3.2 Study Area

In this study, the location is followed by a second study to adequately compare water quality. To accurately measure the water quality, samples are collected in three different seasons and seven distinct locations, including Kamrangi Char Khal and Rayer Bazar Khal, because water quality varies with distance and time throughout the year. The samples of the Dhaleshwari were collected from four distinct locations upstream to downstream. The year was divided up into four seasons: winter (October to February), summer (March to May), rainy (June to September. In both rivers, data is collected once every season.

The samples were collected in Buriganga beginning at the Bosila Bridge (Latitude 23°44'35.79"N, Longitude 90°20'44.76"E), which is considered upstream of the tanneries' waste loading site. Up to Postogola Bridge (Latitude 23°41'13.44"N Longitude 90°25'37.48"E), samples were collected.

The collection of samples began in Dhaleshwari near the Hazratpur bridge (Latitude 23° 45' 16.416" N, LONGITUDE 90°25'37.48"E).Up to South Kamarchar (Latitude 23° 45' 30.71" N Longitude 90°25'37.48"E), samples were collected.

Using the Global Positioning System (GPS), the correct latitude and longitude were preserved when collecting samples from the same places during multiple seasons.

3.3 Water Samples Collection

Most of the specimens were collected from the midpoint of the watercourse, positioned at a depth of 1–1.5 feet beneath the water's top layer. The collection of water samples involved the use of a 2-liter plastic bottle, which was promptly transferred into a pre-cleaned, 4-liter, opaque container. The container was devoid of any exposure to air or sunlight.

The geographic coordinates, specifically the latitude and longitude, of the sampling stations for the Buriganga and Dhaleshwari rivers are provided below.

3.3.1 BURIGANGA RIVER:

Table 3.1 represents the Global positioning system data of the sampling locations of Buriganga River with Latitude and Longitude.

Table 3.1 Global positioning system data of the sampling locations of Buriganga River

SL No	Sample ID	Latitude	Longitude	Location
1	B-1	23°41'13.44"N	90°25'37.48"E	Postagola Bridge
2	B-2	23°42'16.56"N	90°24'30.03"E	Sadarghat
3	B-3	23°42'30.21"N	90°21'52.64"E	Huzurpara
4	B-4	23°43'57.30"N	90°21'15.68"E	West Hazaribagh
5	B-5	23°44'35.79"N	90°20'44.76"E	Boshila Bridge
Additional 1	B-6	23°42'42.77"N	90°23'9.02"E	Kamrangi Chor Khal
Additional 2	B-7	23°44'31.15"N	90°21'4.66"E	Rayer Bazar Khal

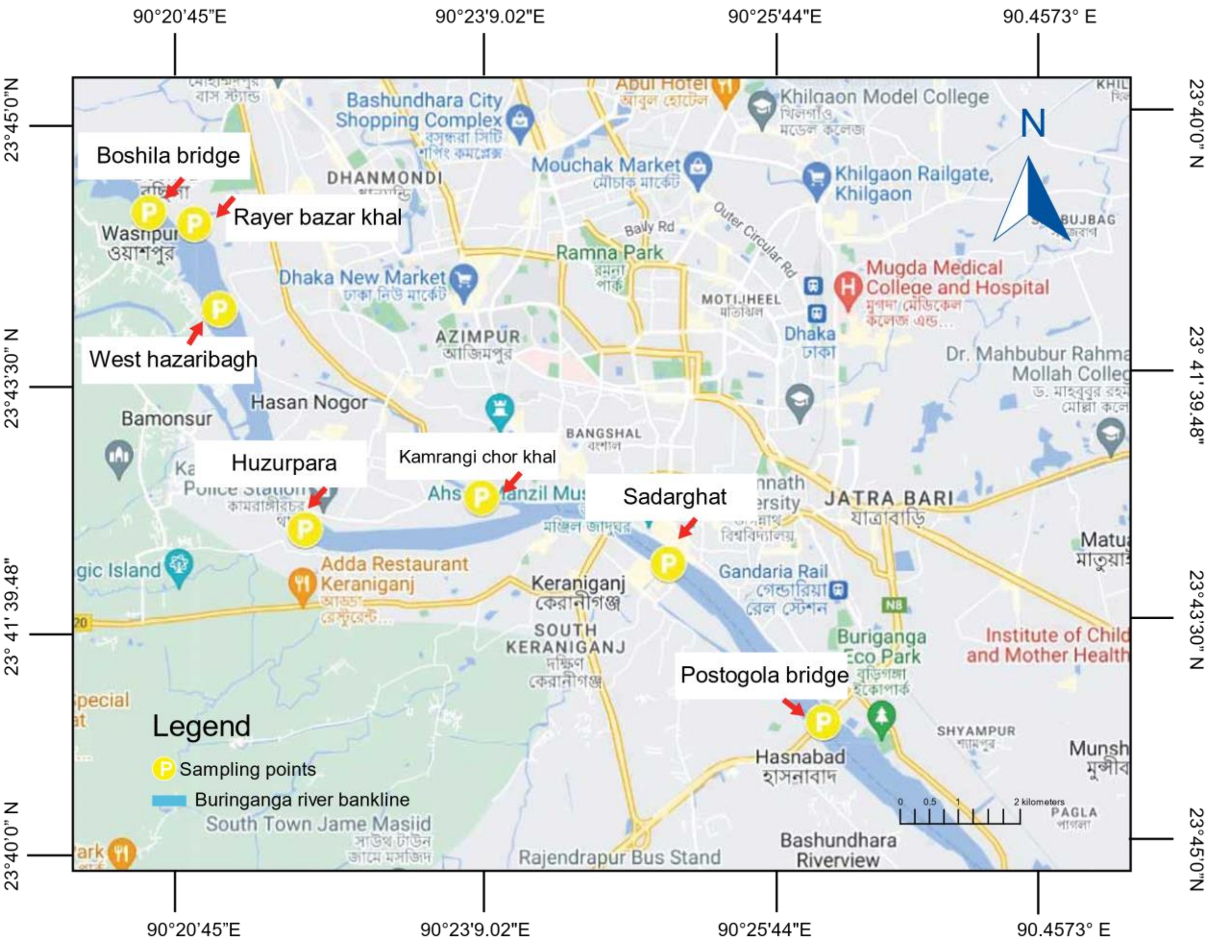

Figure 3.1 Selected area showing the sampling locations of Buriganga River

3.3.2 DHALESHWARI RIVER:

Table 3.1 shows the Global positioning system data of the sampling locations of Dhaleshwari River with Latitude and Longitude.

Table 3.2 Global positioning system data of the sampling locations of Dhaleshwari River

SL No	Sample ID	Latitude	Longitude	Location
1	Dh-1	23° 45' 16.416" N	90° 15' 15.552" E	Hazratpur Bridge
2	Dh-2	23° 47' 53.38" N	90° 14' 39.44" E	Dhaleshwari River Bridge
3	Dh-3	23° 46' 38.35" N	90° 14' 13.6" E	Hazratpur
4	Dh-4	23° 45' 30.71" N	90° 14' 26.66" E	South Kamarchar

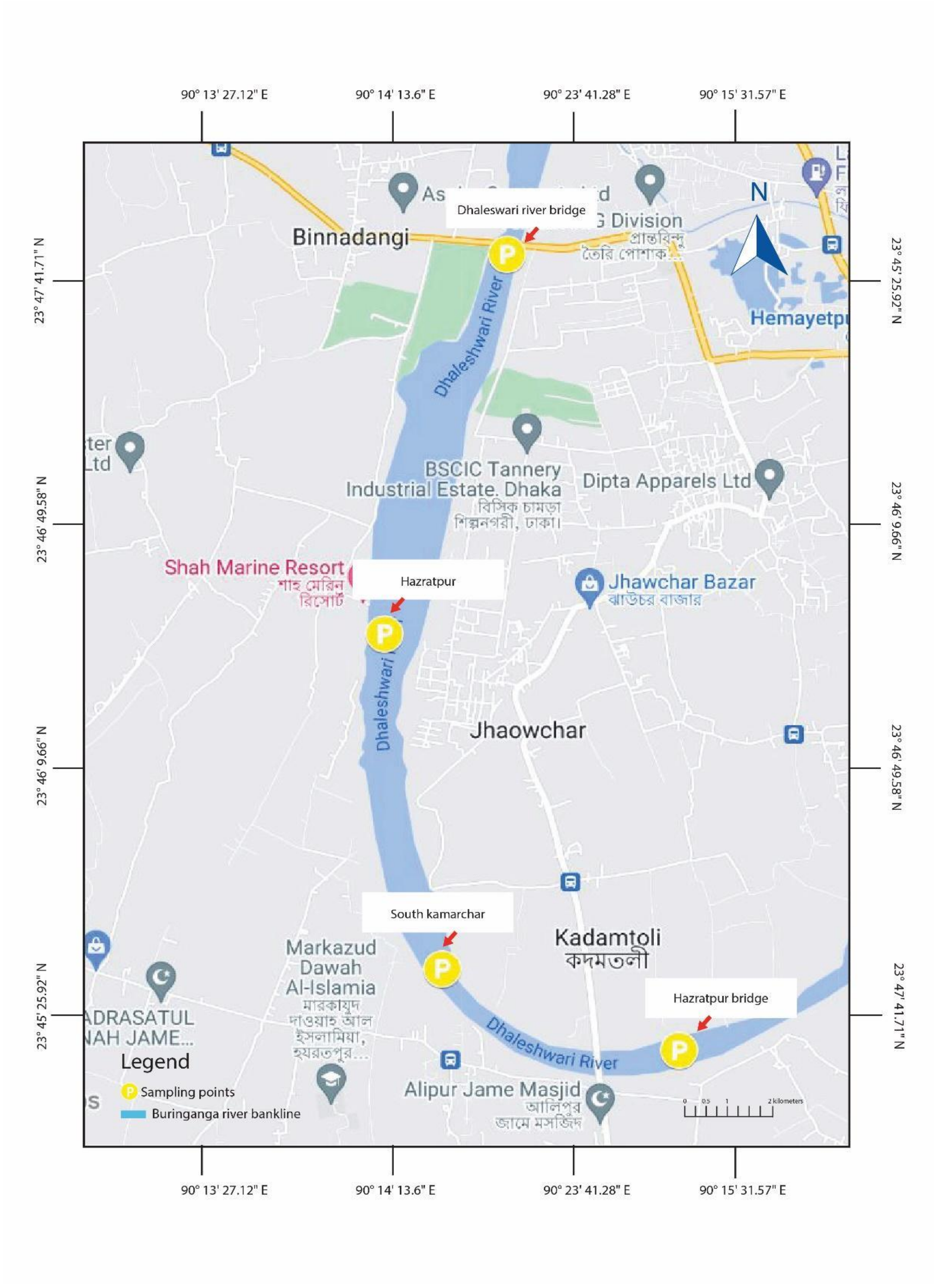

Figure 3.2 Selected area showing the sampling locations of Dhaleshwari river

3.4 Water Quality Measurement

Water quality is assessed through two primary methods. The study involves both in situ investigation and laboratory testing. The testing parameters for both processes are presented herein.

In-Situ Investigation:

1. pH
2. DO
3. TEMPERATURE
4. SALINITY
5. ELECTROCONDUCTIVITY

The samples were collected while utilizing a multimeter to conduct the tests. The stream's temperature and dissolved oxygen levels were measured prior to collecting samples in a beaker for further in situ investigations, such as pH, salinity, and electroconductivity. The temperature and dissolved oxygen levels were recorded at a depth of 1.2-2 feet beneath the water's surface. The water sample that was gathered for the additional tests was obtained from the identical water level.

Laboratory Analysis:

1. Total Dissolved Solids (TDS), Total Suspended Solids(TSS), Total Solids(TS)
2. Orthophosphate
3. Nitrates
4. Ammonium Nitrate
5. Biochemical Oxygen Demand (BOD)
6. Chemical Oxygen Demand (COD)

Two basic procedures are used to determine the water quality. laboratory test and in-situ test. The testing settings for both procedures are shown below.

To determine the total solids, the beaker was subjected to a temperature of 103°C for a duration of one hour, following which its mass was measured. Subsequently, a 100 milliliter aliquot was introduced. Subsequently, the aforementioned vessel was subjected to a heat treatment in an oven operating at a temperature of 103°C for a duration of 24 hours, following which its mass was determined. Subsequently, the mass of the solids was determined by subtracting the weight of the empty beaker from the combined weight of the beaker and its contents.

To ascertain the amount of dissolved solids, present in the water sample, a filtration process was employed, wherein the sample water was passed through two layers of filter paper, and the resultant filtrate was collected. Subsequently, akin to the preceding methodology, the mixture was retained in the oven and the mass of the uncontaminated container was deducted from that of the filtered water container.

The parameter known as Total Suspended Solids (TSS), expressed in milligrams per liter (mg/L), can be calculated by subtracting the concentration of Total Dissolved Solids (TDS) in milligrams per liter (mg/L) from the concentration of Total Solids (TS) also in milligrams per liter (mg/L).

The analytical procedure employed for the determination of Orthophosphate(PO43−) involved the utilization of the PhosVer 3 (Ascorbic Acid) Method. The present technique has the capability to measure the levels of phosphate within the range of 0.02 mg/L to 2.50 mg/L. PhosVer 3 Phosphate Reagent Powder Pillow is utilized in a 10 mL sample. The HACH DR3900 Spectrophotometer, specifically the Stored Programs 490 P. React PV and 492 P. React AV, is utilized for the quantification of orthophosphate levels. The specimens were stored at a temperature of 4 degrees Celsius for a maximum duration of 48 hours.

The Diazotization Method was employed to determine the concentration of Nitrate (NO3-) during the Nitrate concentration testing. The aforementioned technique enables the quantification of concentrations of Ammonium Nitrate within the range of 0.002 mg/L to 0.300 mg/L. During the experiment, a volume of 10 mL of the specimen was combined with a NitriVer 3 Reagent Powder Pillow. In the event of nitrate being present within the sample, a noticeable change in coloration would occur, resulting in a pink hue. Subsequently, the concentration was determined utilizing the HACH DR3900 Spectrophotometer (Stored Program 371 N. Nitrate LR PP).

The concentration of Ammonium Nitrate (NH3) was determined through employment of the Nessler Method. The aforementioned technique has the capability to measure Ammonium Nitrate within the range of 0.02 mg/L to 2.50 mg/L. The experiment involved utilizing a 25 mL sample in conjunction with an Ammonium Nitrate Nitrogen Reagent Set to perform the analysis. The blank solution was prepared by adding three drops of mineral stabilizer to 25 mL of deionized water, in addition to the samples. Three drops of Polyvinyl Alcohol Dispersing Agent were added to each mixing cylinder subsequent to the mixing process. Subsequently, a volume of 1 milliliter of Nessler Reagent was introduced into every mixing cylinder following the mixing process. A volume of 10 mL was extracted from the 25 mL solutions for the purpose of quantifying the concentration of Ammonium Nitrate. The analysis was conducted using the HACH DR3900, specifically the Stored Program 380 N. Ammonium Nitrate, Ness.

The Chemical Oxygen Demand (COD) assay enables the quantification of the oxygen demand of a given waste, expressed as the aggregate quantity of oxygen necessary for the oxidation of the waste to carbon dioxide and water. The principal benefit of utilizing this assessment approach is its efficiency in terms of time consumption. The Reactor Digestion Procedure was employed to conduct the test in this study. The present technique has the capability to quantify COD levels ranging from 200 mg/L to 1500 mg/L. The material underwent homogenization for a duration of 30 seconds using a blender. In addition to the samples, a blank sample was generated within COD Digestion Reagent Vials. The vials were subjected to a two-hour heating process utilizing the DRB200 Reactor. Subsequent to the extraction of the vials from the reactor, they were subjected to a cooling process until they reached ambient temperature, after which they underwent a calorimetric determination.

The process of Calorimetric Determination was carried out by means of a HACH DR3900 Spectral Photometer, utilizing the Stored Programs 431 COD ULR, 430 COD LR, and 435 COD HR. When utilizing the High Range Plus COD Digestion Reagent Vials, the resulting COD value was increased by a factor of 10.

The Hach BOD Track II method was employed to determine the Biochemical Oxygen Demand (BOD). The specimens were subjected to a temperature range of 19-21 degrees Celsius and subsequently underwent homogenization for a duration of 30 seconds utilizing a blender. A nutrient buffer pillow was introduced into the sample. Following the transfer of the specimen to a BOD Trak II container, a pair of potassium hydroxide pellets were introduced into the seal cup of the aforementioned bottle. Subsequently, the bottles were positioned onto the BOD Trak II framework, and the corresponding tubing was affixed to each individual sample bottle. Subsequently, the arrangement is maintained within an incubation chamber at a temperature of 20 degrees Celsius for a duration of five days. The outcome was obtained on the fifth day subsequent to the commencement of the procedure.

3.5 Water Quality Index

Typically, a water quality index amalgamates information from various parameters of water quality and applies a mathematical formula to yield a singular numerical value that represents the holistic condition of a stream. The aforementioned numerical value is allocated on a comparative spectrum that arranges the caliber of water from exceedingly substandard to exceptional.

The determination of index values is facilitated through the utilization of a sub-index rating curve, whereby selected water quality parameters, which may possess varying units of measurement (e.g. mg/L), are transformed into a unitless sub-index value. Each parameter is associated with a rating curve that assigns a numerical value on a scale of 0 to 100, indicating the level of water quality. The rating curve is established by identifying the acceptable and unacceptable values for the specific parameter.

The primary aim of the rating curve is to establish a correlation between the concentration of a given parameter and the quality of water. Upon computation of the sub-index for each parameter through employment of a rating curve, the sub-indices are subsequently subjected to averaging procedures in order to derive the comprehensive value of the water quality index.

In our thesis work we used three types of water quality index:

1) DoE (Malaysia) Water Quality Index
2) River Pollution Index
3) Canadian Water Quality Index (CWQI)/ Canadian Council of Ministers of the Environment (CCME) Water Quality Index

3.5.1 DoE (Malaysia) Water Quality Index:

The National Water Quality Standards for Malaysia, which categorizes the beneficial uses of water bodies based on WQI, is also used by the DOE in conjunction with WQI to evaluate the status of water source quality. The overall quality of rivers and lakes is measured through a parameter known as WQI, which considers several physicochemical water quality parameters such as dissolved oxygen, biochemical oxygen demand, ammoniacal nitrogen, total dissolved solids and pH. The resulting sub-index values are then classified into five different classes: Class I (clean), Class II (slightly polluted), Class III (moderately polluted), Class IV, Class V.

DOE-WQI is a standard set of parameters used to evaluate the quality of river water. It consists of six critical parameters, namely pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammonium Nitrogen (AN), Suspended Solid (SS) and Dissolved Oxygen (DO).

Formula:

WQI = (0.22 * SIDO) + (0.19 * SIBOD) + (0.16 * SICOD) + (0.15 * SIAN) + (0.16 * SISS) + (0.12 * SIpH)

SIDO = Subindex DO (% saturation)

SIBOD = Subindex BOD

SICOD = Subindex COD

SIAN = Subindex NH3 -N

SISS = Subindex SS

SIpH = Subindex pH

$0 \leq WQI \leq 100$

Subindex for DO (in % saturation)

SIDO = 0 for $x \leq 8$

SIDO = 100 for $x \geq 92$

SIDO = -0.395 + 0.030x2 - 0.00020x3 for $8 < x < 92$

Subindex for BOD

$SIBOD = 100.4 - 4.23x$ for $x \le 5$

$SIBOD = 108 * \exp(-0.055x) - 0.1x$ for $x > 5$

Subindex for COD

$SICOD = -1.33x + 99.1$ for $x \le 20$

$SICOD = 103 * \exp(-0.0157x) - 0.04x$ for $x > 20$

Subindex for NH3 -N

$SIAN = 100.5 - 105x$ for $x \le 0.3$

$SIAN = 94 * \exp(-0.573x) - 5 * I\, x - 2\, I$ for $0.3 < x < 4$

$SIAN = 0$ for $x \ge 4$

Subindex for SS

$SISS = 97.5 * \exp(-0.00676x) + 0.05x$ for $x \le 100$ $SISS = 71 * \exp(-0.0016x) - 0.015x$

for $100 < x < 1000$

$SISS = 0$ for $x \ge 1000$

Subindex for pH

$SIpH = 17.2 - 17.2x + 5.02x2$ for $x < 5.5$

$SIpH = -242 + 95.5x - 6.67x2$ for $5.5 \le x < 7$

$SIpH = -181 + 82.4x - 6.05x2$ for $7 \le x < 8.75$

$SIpH = 536 - 77.0x + 2.76x2$ for $x \ge 8.75$

3.5.2 River Pollution Index:

Using sampling data acquired from the Buriganga and Dhaleshwari rivers, the geostatistical method employed in this study calculates the River Pollution Index (RPI). In Taiwan, the conventional classification system for water quality monitoring employs an RPI based on four variables: dissolved oxygen (DO), biochemical oxygen demand (BOD5), suspended particulates (SS), and ammonium nitrogen (NH4-N). When water is contaminated with organic matter, aquatic microorganisms consume DO during decomposition, resulting in reduced oxygen levels in the water, also known as hypoxia. BOD5 denotes the amount of organic matter that can be decomposed by aquatic microorganisms, inferring the extent of organic contamination in bodies of water. Animal waste, animal carcasses, and plant residues are the primary sources of nitrogen-containing organic matter. The presence of Ammonium Nitrogen in water indicates a short-term contamination. SS refers to organic or inorganic particulates that are suspended due to stirring or flow, including colloids. These particulates prevent light from penetrating the water and have the same effect on aquatic life as turbidity. SS deposited along riverbanks impedes water flow, whereas sediments accumulating in reservoirs diminish their capacity. Each water quality variable used to calculate the RPI is converted into an index score (Si = 1, 3, 6, or 10). The RPI is derived by calculating the arithmetic mean of these index scores, which indicate the overall water quality.

$$\mathbf{RPI = 1/4 \sum Si}$$

Where Si represents the index, scores based on Table 3.6 and the RPI value ranges from 1 to 10. According to the river pollution index listed in Table 3.6, the four classifications of pollution are unpolluted, negligibly polluted, moderately polluted, and severely polluted.

Table 3.3 Definition of river pollution index (RPI)

Items	Categories			
	Unpolluted	Negligibly polluted	Moderately polluted	Severely polluted
DO	Above 6.5	4.6-6.5	2.0-4.5	Under 2.0
BOD_5	Under 3.0	3.0-4.9	5.0-15	Above 15
SS	Under 20	20-49	50-100	Above 100
NH_3-N	Under 0.5	0.5-0.99	1.0-3.0	Above 3.0
Index Scores (Si)	1	3	6	10
RPI	Under 2	2.0-3.0	3.1-6.0	Above 6.0

3.5.3 Canadian Water Quality Index (CWQI)/ Canadian Council of Ministers of the Environment (CCME) Water Quality Index

The British Columbia Ministry of Environment, Lands and Parks established the formula upon which the Alberta Environment amended the CCME Water Quality Index (1.0). The Index includes three components: scope, which measures the number of variables that do not satisfy water quality goals, frequency, which measures how frequently these goals are not met, and amplitude, which measures how much. The index generates a value ranging from zero (the worst water quality) to one hundred (the finest water quality). To make the presentation simpler, these numbers are separated into 5 descriptive groups.

The conceptual structure of the CCME Water Quality Index:

CCME water quality index consists of 3 factors.

1. **F1(Scope)**- F1 (Scope) represents the proportion of variables ("failed variables") that did not satisfy their objectives at least once during the period under consideration, relative to the total number of variables measured.

   The formula used to determine the scope of the index is described by,

   $$\textbf{F1(Scope)} = \frac{\text{Total Number of Failed Variables}}{\text{Total Number of Failed Variables}} * 100$$

   Here, the variables represent those water quality parameters whose objective values (threshold limits) are specified and where the observed values at the sampling sites are available for the calculation of the index.

2. **F2(Frequency)**- F2 (Frequency) represents the proportion of individual tests ("failed tests") that do not meet objectives.

   The formula used to determine the frequency of the index is described by,

   $$\textbf{F2(Frequency)} = \left(\frac{\text{Total number of failed tests}}{\text{Total number of tests}}\right) * 100$$

3. **F3(Amplitude)**- F3 (Amplitude) represents the range by which unsuccessful test values fall short of their objectives. F3 is computed through three stages.

   - The number of times an individual concentration exceeds (or falls below, if the objective is a minimum) the objective is known as the "excursion" and is expressed as follows. When the test value cannot surpass the target.

The formula used to determine the "excursion" of the index is described by,

$$\textbf{Excursion} = \frac{Failed\ test\ value}{Objective} - 1$$

For the cases in which the test value must not fall below the objective:

$$\textbf{Excursion} = \frac{Objective}{Failed\ Test\ Value} - 1$$

- The amount by which individual tests are collectively out of compliance is calculated by adding the deviations of individual tests from their objectives and dividing by the total number of tests (including those that met objectives and those that did not). This variable, known as the normalized sum of excursions (nse).

The formula used to determine the "nse value" of the index is described by,

$$\textbf{nse} = \frac{\sum_{i=1}^{n} excursion\ value}{Number\ of\ tests}$$

- An asymptotic function that scales the normalized sum of the excursions from objectives (nse) to a value between 0 and 100 is then used to compute F3.
-

$$\textbf{F3 (Amplitude)} = \frac{nse\ value}{0.01nse + 0.01nse}$$

Then finally the CCME WQI is calculated as:

$$\textbf{WQI} = 100 - \frac{\sqrt{(F1^2 + F2^2 + F3^2)}}{1.732}$$

The aforementioned formula yields a value between 0 and 100 and assigns a numerical value to the water quality status. Note that a number of zero (0) indicates extremely poor water quality, while a value close to 100 indicates excellent water quality. The assignment of CCME WQI values to various categories is a subjective process that also requires expert judgement and the public's water quality expectations. The water quality is categorized into five categories:

Table 3.7 shows the CQWI standard value range and classification as per value,

Table 3.4 CCME WQI/ CWQI Standard

Category	CCME WQI / CWQI Value Range
Excellent	95-100
Good	80-94
Fair	60-79
Marginal	45-59
Poor	0-44

CHAPTER 4. RESULT AND DISCUSSION

4.1 Water quality of Buriganga and Dhaleshwari rivers

The table 4.1 shows the result of 12 water quality parameters, where water samples were collected from 7 distinct locations from Buriganga river. The result showing in the table defines the result of season 1 which corresponds to the months from June to September. As it represents the rainy season of Bangladesh the water quality was quite better that time on perspective of other seasons of the year.

Table 4.1 Buriganga Season -1 Test Result (June- September)

Location / Parameter	Unit	Postagola Bridge	Sadarghat	Huzurpara	West Hazaribagh	Boshila Bridge	Kamrangi Chor Khal	Rayer Bazar Khal
BOD	mg/L	12.74	15.21	12.95	14.2	13.02	19.42	21.17
COD	mg/L	46.45	52.31	49.83	54.66	46.45	65.32	69.08
Ammonium Nitrate	mg/L	7.23	7.91	7.83	8.12	7.23	9.05	9.79
Nitrate	mg/L	0.50	1.00	1.00	1.50	0.50	2.00	2.00
Orthophosphate	mg/L	1.35	1.96	1.87	1.93	1.35	3.02	3.15
Temperature	°C	23.50	24.00	23.80	23.64	23.50	25.00	24.80
EC	µS/cm	426.50	431.30	425.60	438.60	426.50	524.30	540.00
Salinity	%	0.00	0.10	0.10	0.00	0.00	0.20	0.20
pH	-	7.35	7.74	7.60	7.75	7.68	7.80	7.74
TDS	mg/L	286.71	296.32	290.85	315.03	285.73	322.14	325.81
TSS	mg/L	10.72	11.85	16.17	18.51	16.68	28.04	27.56
DO	mg/L	5.79	5.02	5.38	5.05	5.7	4.51	4.41

The table 4.2 shows the result of 12 water quality parameters, where water samples were collected from 7 distinct locations from Buriganga river. The result showing in the table defines the result of season 2 which corresponds to the months from October to February. As it represents the winter season of Bangladesh the water quality was quite worse than rainy season but overall water quality was quite better than summer.

Table 4.2 Buriganga Season -2 Test Result (October- February)

Location / Parameter	Unit	Postagola Bridge	Sadarghat	Huzurpara	West Hazaribagh	Boshila Bridge	Kamrangi Chor Khal	Rayer Bazar Khal
BOD	mg/L	17.5	17	16.19	18.31	16.5	25.51	26.43
COD	mg/L	56.95	64.8	55.31	57.91	56.95	78.93	65.81
Ammonium Nitrate	mg/L	8.00	8.35	8.05	8.96	8.00	10.23	11.83
Nitrate	mg/L	1.00	1.50	1.00	2.50	1.00	3.00	3.00
Orthophosphate	mg/L	2.03	2.39	2.37	2.84	2.03	3.61	4.00
Temperature	°C	20.40	20.80	20.50	21.00	20.40	22.00	22.40
EC	µS/cm	714.40	745.60	708.50	725.60	714.40	858.71	840.46
Salinity	%	0.10	0.00	0.10	0.00	0.10	0.20	0.15
pH	-	7.83	7.92	7.96	8.10	7.81	7.85	7.81
TDS	mg/L	439.31	447.91	441.98	489.31	438.35	523.19	571.35
TSS	mg/L	12.28	13.63	19.87	23.71	21.45	37.87	26.91
DO	mg/L	4.83	4.25	4.76	4.65	4.71	4.13	4.06

The table 4.3 shows the result of 12 water quality parameters, where water samples were collected from 7 distinct locations from Buriganga river. The result showing in the table defines the result of season 3 which corresponds to the months from October to February. As it represents the summer season of Bangladesh the overall water quality was worse than other two seasons.

Table 4.3 Buriganga Season -3 Test Result (March-May)

Location / Parameter	Unit	Postagola Bridge	Sadarghat	Huzurpara	West Hazaribagh	Boshila Bridge	Kamrangi Chor Khal	Rayer Bazar Khal
BOD	mg/L	19.15	22.5	21.33	20	18.31	33.5	45
COD	mg/L	60.54	65.78	61.43	64.31	61.54	82.35	75.67
Ammonium Nitrate	mg/L	9.39	10.56	10.21	11.34	11.39	13.00	13.40
Nitrate	mg/L	1.50	2.00	1.50	3.00	2.00	4.50	3.50
Orthophosphate	mg/L	2.49	2.85	2.61	3.03	2.49	4.05	6.17
Temperature	°C	25.95	26.00	25.90	25.70	25.00	25.70	25.00
EC	µS/cm	838.00	868.00	846.00	935.00	927.00	1175.30	1200.00
Salinity	%	0.10	0.20	0.20	0.10	0.10	0.20	0.00
pH	-	7.92	7.96	7.83	8.15	7.89	8.20	8.00
TDS	mg/L	510.83	518.95	510.95	532.61	508.83	587.31	625.41
TSS	mg/L	15.13	17.84	24.71	26.75	26.00	41.50	35.00
DO	mg/L	4.33	4.21	4.23	4.12	4.38	3.75	0.79

The table 4.4 shows the result of 12 water quality parameters, where water samples were collected from 7 distinct locations from Buriganga river in 2017 before relocation of the tannery industry. The result showing in the table was collected from a DoE report of those stations. The water quality was majorly poor at that time.

Table 4.4 Buriganga 2017 Test Result

Location / Parameter	Unit	Postagola Bridge	Sadarghat	Huzurpara	West Hazaribagh	Boshila Bridge	Kamrangi Chor Khal	Rayer Bazar Khal
BOD	mg/L	24	28	12	22	24	29	32
COD	mg/L	108	112	96	105	108	117	112
Ammonium Nitrate	mg/L	13.65	13.80	13.43	13.45	13.65	14.50	14.75
Nitrate	mg/L	3.00	3.00	3.50	4.50	3.00	4.50	4.50
Orthophosphate	mg/L	3.40	1.90	1.80	2.25	3.40	3.95	4.00
Temperature	°C	23.50	23.00	23.00	23.50	23.50	23.60	23.30
EC	µS/cm	960	950	932	929	932	947	939
Salinity	%	0.20	0.20	0.30	0.20	0.10	0.20	0.20
pH	-	7.42	7.72	7.50	7.64	7.42	7.20	7.45
TDS	mg/L	609	577	601	616	609	655	643
TSS	mg/L	27.00	36.00	18.00	33.00	27.00	41.00	38.00
DO	mg/L	0.31	0.28	0.3	0.31	0.25	0.24	0.33

The table 4.5 shows the result of 12 water quality parameters, where water samples were collected from 4 distinct locations from Dhaleswari river. The result showing in the table defines the result of season 1 which corresponds to the months from June to September. As it represents the rainy season of Bangladesh the water quality was quite better that time on perspective of other seasons of the year but it was quite worse than the days before starting operation of tanning industries.

Table 4.5 Dhaleshwari Season -1 Test Result (June- September)

Location / Parameter	Unit	Hazratpur Bridge	South Kamarchar	Hazratpur	Dhaleshwari River Bridge
BOD	mg/L	5.43	9.95	14.1	13.94
COD	mg/L	28	29.73	89.48	98.75
Ammonium Nitrate	mg/L	2.34	5.35	13.22	6.91
Nitrate	mg/L	0.00	0.50	3.50	1.00
Orthophosphate	mg/L	0.97	1.03	3.35	2.33
Temperature	°C	22.50	23.00	29.90	24.80
EC	µS/cm	254.91	478.41	1007.30	813.21
Salinity	%	0.20	0.30	0.20	0.10
pH	-	7.20	7.30	7.84	7.50
TDS	mg/L	159.04	201.35	463.09	403.81
TSS	mg/L	6.47	9.30	24.61	19.00
DO	mg/L	6.35	5.54	1.30	3.20

The table 4.6 shows the result of 12 water quality parameters, where water samples were collected from 4 distinct locations from Dhaleswari river. The result showing in the table defines the result of season 2 which corresponds to the months from October to February. As it represents the winter season of Bangladesh the water quality was quite worse than rainy season but overall water quality was quite better than summer.

Table 4.6 Dhaleshwari Season -2 Test Result (October- February)

Location / Parameter	Unit	Hazratpur Bridge	South Kamarchar	Hazratpur	Dhaleshwari River Bridge
BOD	mg/L	6	7.84	13.9	11.41
COD	mg/L	30.5	31.93	92.41	105.37
Ammonium Nitrate	mg/L	2.55	5.61	14.71	6.91
Nitrate	mg/L	0.20	0.40	3.50	1.20
Orthophosphate	mg/L	1.00	1.12	3.41	2.27
Temperature	°C	22.00	22.00	27.20	23.60
EC	µS/cm	268.92	470.62	1092.10	900.01
Salinity	%	0.60	0.60	0.62	0.56
pH	-	7.20	6.90	8.04	7.50
TDS	mg/L	151.32	215.74	503.00	478.70
TSS	mg/L	6.79	9.68	29.30	22.85
DO	mg/L	6.22	4.83	1.02	2.84

The table 4.7 shows the result of 12 water quality parameters, where water samples were collected from 4 distinct locations from Dhaleswari river. The result showing in the table defines the result of season 3 which corresponds to the months from October to February. As it represents the summer season of Bangladesh the overall water quality was worse than other two seasons.

Table 4.7 Dhaleshwari Season -3 Test Result (March-May)

Location / Parameter	Unit	Hazratpur Bridge	South Kamarchar	Hazratpur	Dhaleshwari River Bridge
BOD	mg/L	6.13	8.32	16.5	13.74
COD	mg/L	33.8	39.76	104.71	81.65
Ammonium Nitrate	mg/L	2.57	5.73	16.7	6.43
Nitrate	mg/L	0.20	0.50	4.00	1.50
Orthophosphate	mg/L	0.95	1.27	3.90	2.40
Temperature	°C	23.00	23.00	30.20	27.00
EC	µS/cm	273.66	492.31	1142.60	943.61
Salinity	%	0.60	0.60	0.65	0.60
pH	-	6.90	7.20	8.30	7.70
TDS	mg/L	158.53	239.88	561.73	492.19
TSS	mg/L	7.05	9.95	36.41	25.93
DO	mg/L	6.24	4.51	1.00	2.75

The table 4.8 shows the result of 12 water quality parameters, where water samples were collected from 4 distinct locations from Dhaleswari river in 2017 before relocation of the tannery industry. The result showing in the table was collected from a DoE report of those stations. The water quality parameters was mostly under standard value at that time.

Table 4.8 Dhaleshwari 2017 Test Result

Location / Parameter	Unit	Hazratpur Bridge	South Kamarchar	Hazratpur	Dhaleshwari River Bridge
BOD	mg/L	3.2	2.8	2.5	2.2
COD	mg/L	8.41	16.79	15.53	21.95
Ammonium Nitrate	mg/L	0.5	0.5	0.7	0.4
Nitrate	mg/L	0.25	0	0.25	0.25
Orthophosphate	mg/L	0.27	0	0.25	0.25
Temperature	°C	22	22	22.5	22
EC	μS/cm	232.81	247.64	242.83	250.3
Salinity	%	0.15	0	0.2	0.1
pH	-	6.95	7	7	7.05
TDS	mg/L	145.74	152.16	164.31	175.2
TSS	mg/L	1.10	0.80	0.60	0.50
DO	mg/L	18.50	9.50	8.50	9.60

4.2 Comparison of river water quality

Figure 4.1 depicts the BOD levels at seven distinct river stations. The range of BOD values at station 1 is between 12.74 mg/l and 19.15 mg/l. The value was considerably lower than the BOD value in 2017, which was 24 mg/l. In station 2, the BOD ranged from 15.21 mg/l to 22.5 mg/l throughout the entire river. In 2017, however, the BOD at that location was 28 mg/L. At station 3, the BOD value rose from 2017 levels. In 2017, the BOD concentration at station 3 was 12 mg/l, but in 2022, it varied from 12.95 mg/l to 21.33 mg/l throughout the year. The BOD ranged from 14.2 mg/l to 20 mg/l at station 4. And the value is significantly lower than 2017's value of 22 mg/l. The BOD value at station 5 ranged from 13.02 mg/l to 18.31 mg/l. In two canals, the BOD concentration was significantly higher than in the main streams, which ranged from 19.42 to 33.5 mg/l. However, it decreased slightly from the previous days. In addition, at station 2, the BOD ranged from 21.17 to 45 mg/l. In comparison to the value of the summer season, the water quality has declined in recent days. In 2017, the BOD concentration at that location was determined to be 32 mg/l.

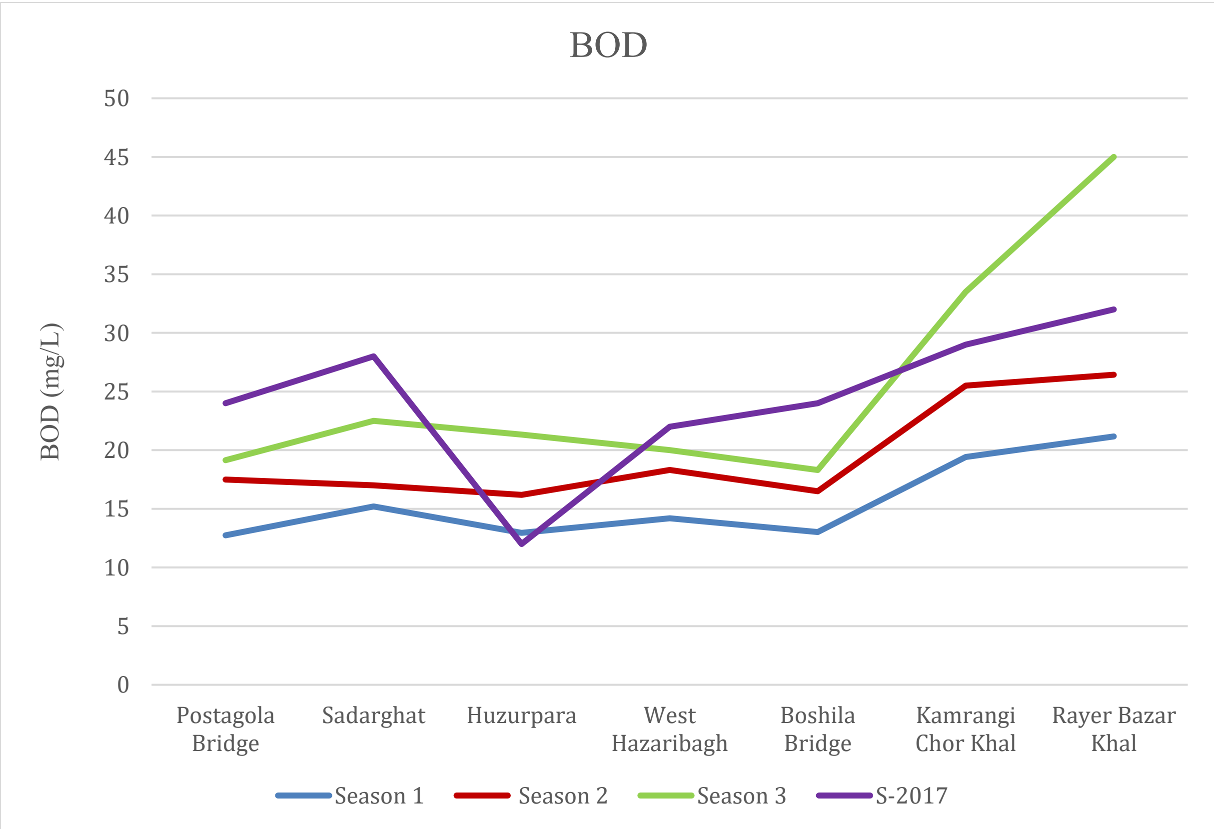

Figure 4.1 BOD value comparison of Buriganga river water

The graph represents the COD concentration at seven distinct stations on the Buriganga River. The COD concentration at station 1 ranged from 46.45 mg/l to 60.54 mg/l. The value is significantly lower than the COD value found in 2017, which was 108 mg/l. At station 2, the COD ranged from 52.31 mg/l to 65.78 mg/l. This station recorded a COD value of 112 mg/l in 2017, which is considerably higher than the current value. In station 3, the COD value was considerably lower than other stations along the main stream. The COD concentration at station 3 ranged from 49.83 mg/l to 61.43 mg/l. Based on Chemical Oxygen Demand, the water quality at station 4 improved substantially. In 2017, the COD concentration was 105 mg/l compared to 54.66 mg/l to 61.54 mg/l. Presently, throughout the year, COD has been discovered. The COD ranged from 46.45 mg/l to 61.54 mg/l at station 5. In two additional stations, the COD value is also higher, but it is lower than it was the day before. Throughout the course of the year, the COD value varied between 65.32 and 82.35 mg/l. In 2017, the value was determined to be 117 mg/l, which was significantly higher than the current level. Additional station 2 measures a range of COD values between 69.08 mg/l and 75.67 mg/l. Comparing the current COD value to the value from 2017, the water quality has improved at nearly all stations.

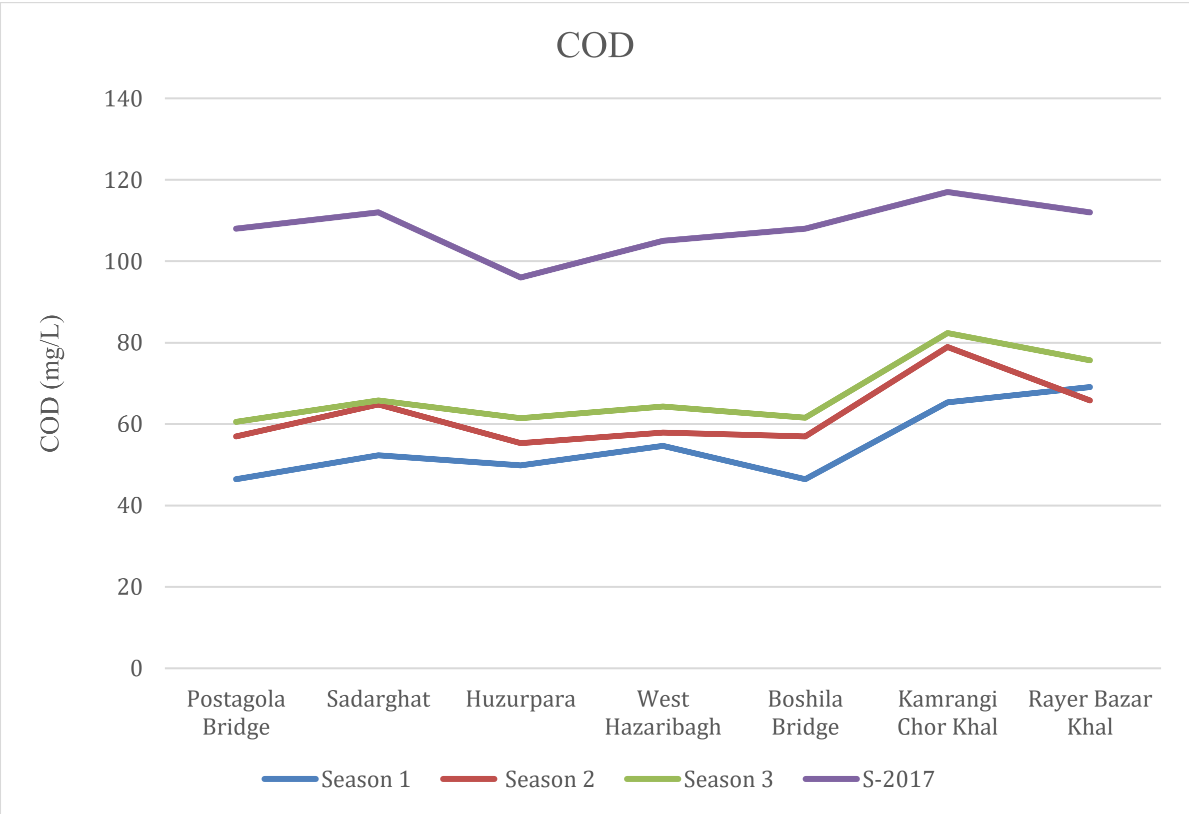

Figure 4.2 COD value comparison of Buriganga river water

The graph depicts the annual concentration of ammonia at seven distinct stations along the Buriganga River. The ammonia concentration at station 1 ranged from 7.23 mg/l to 9.39 mg/l. In 2017, the concentration of ammonia was discovered to be 13.65 mg/l, which was significantly higher than the current concentration. The concentration at station 2 ranged from 7.91 mg/l to 10.56 mg/l. In comparison to its concentration in 2017, the current concentration of ammonia is significantly reduced. In stations 3,4, and 5, the concentration ranged from 7.23 to 11.39 mg/L during all four seasons, which was significantly lower than the range of 13.43 to 13.65 mg/L found in 2017 at the same stations. Ammonia concentrations at additional station 1 ranged from 9.05 mg/l to 13.00 mg/l, which was significantly lower than the previous days. In addition, the ammonia concentration at additional station 2 ranged from 9.79 mg/l to 13.40 mg/l, which is significantly less than the concentration measured in 2017 of 14.75 mg/l.

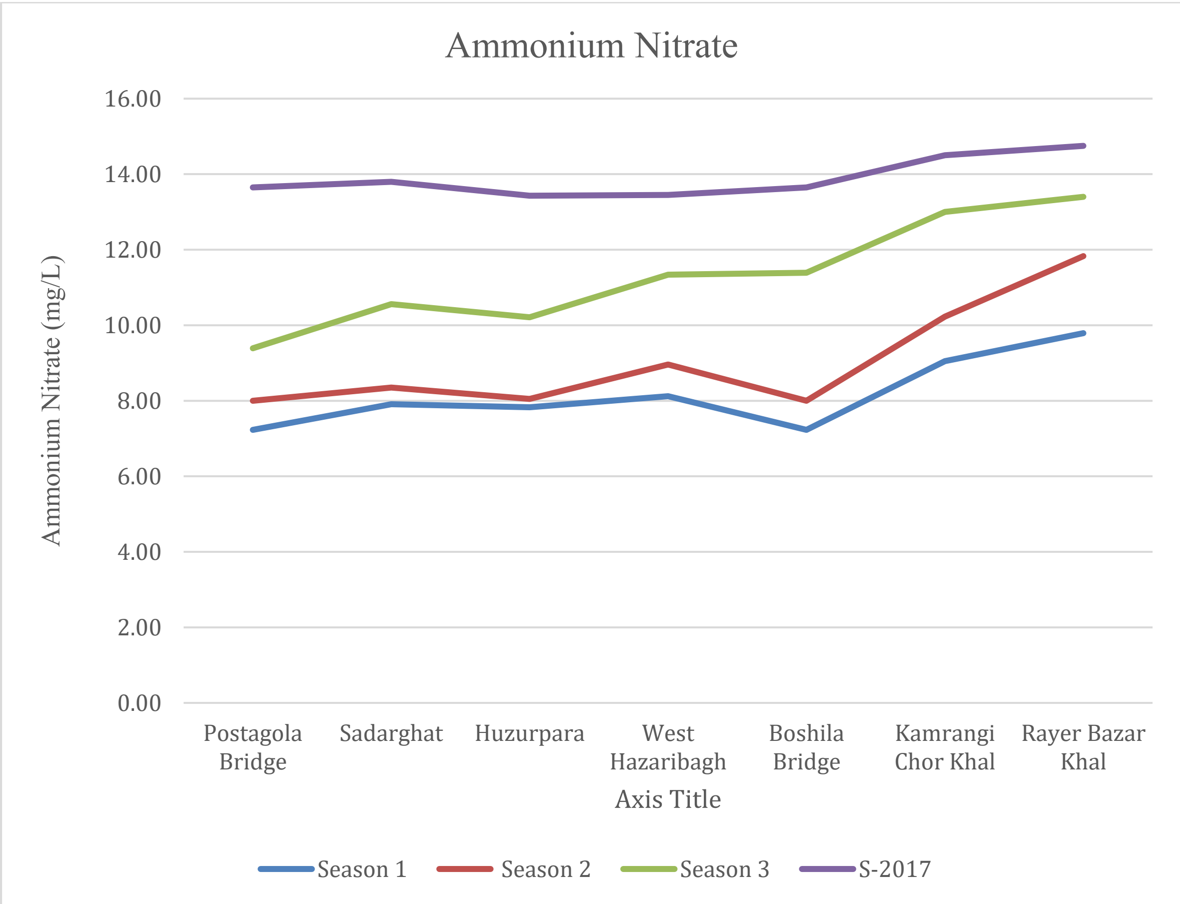

Figure 4.3 Ammonium Nitrate value comparison of Buriganga river water

The graph depicts the Nitrate Concentration along the seven distinct stations of the Buriganga River. Throughout the entire year, the Nitrate concentration varied from 0.50 mg/l to 3.00 mg/l. During the third season, the greatest concentration measured was 3.00 mg/l at station 4. The concentration of ammonia decreased in nearly all mainstream stations. In 2017, the Ammonia concentration ranged between 3.00 mg/l and 4.50 mg/l. In additional station 1, concentrations ranging from 2 mg/l to 4.50 mg/l were measured. In 2017, the concentration at this station was measured to be 4.50 mg/l. Therefore, the concentration has not changed significantly from previous days. At additional station 2, the ammonia concentration ranges from 2.0 mg/l to 3.50 mg/l, which is considerably lower than the 2017 concentration.

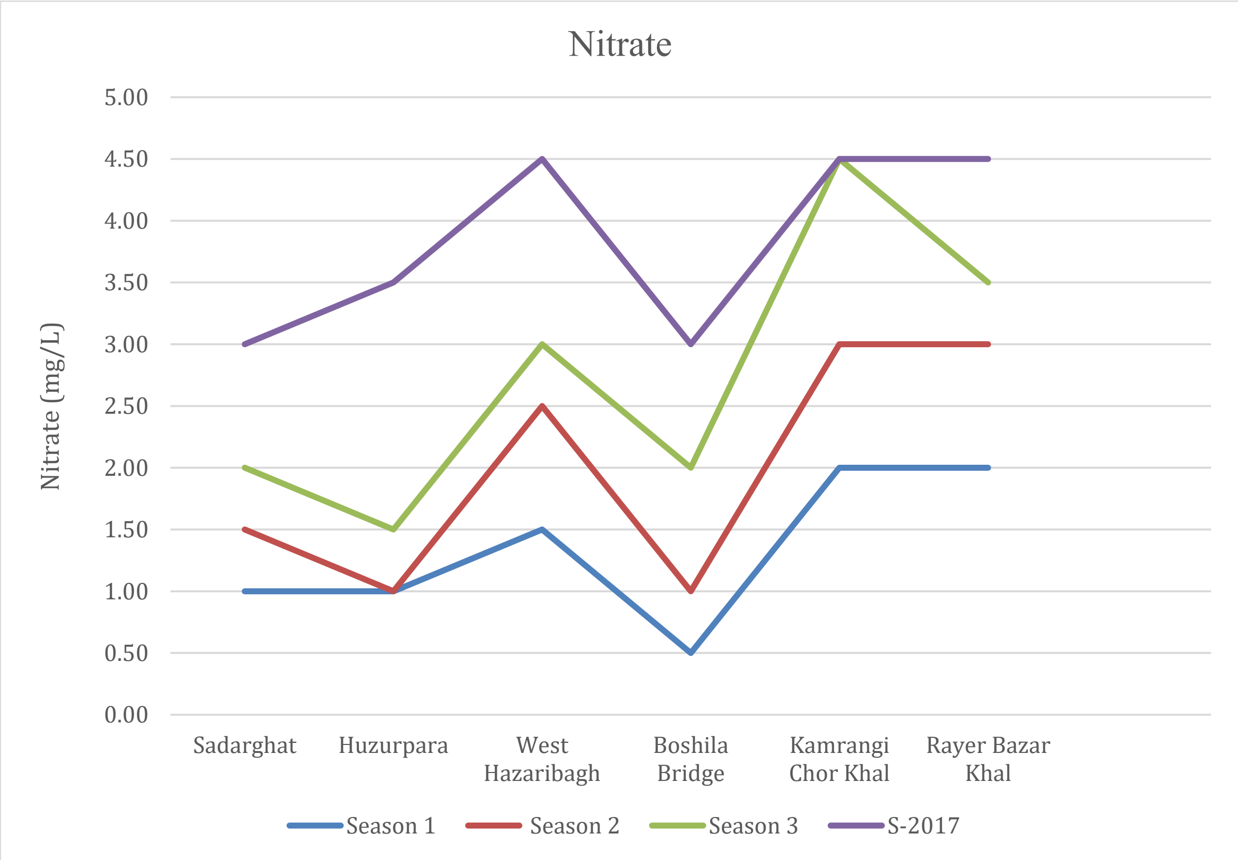

Figure 4.4 Nitrate value comparison of Buriganga river water

The graph shows the variation of the concentration of Orthophosphate concentration along 7 stations of Buriganga river throughout the year. The concentration was found quite higher than the concentration found in 2017 in the main stream. The concentration found in 2017 was in a range from 1.90 mg/l to 3.40 mg/L. In our testing we found the concentration in a range from 1.35 mg/l to 3.03 mg/l. In station 2 the concentration is found in a range from 1.96 mg/l to 2.85 mg/l. which was considerably higher than the previous years. Similar types of increasing also found in other stations. In additional station 1 the concentration was found in a range from 3.02 mg/l to 4.05 mg/l which was almost similar to the concentration in 2017.

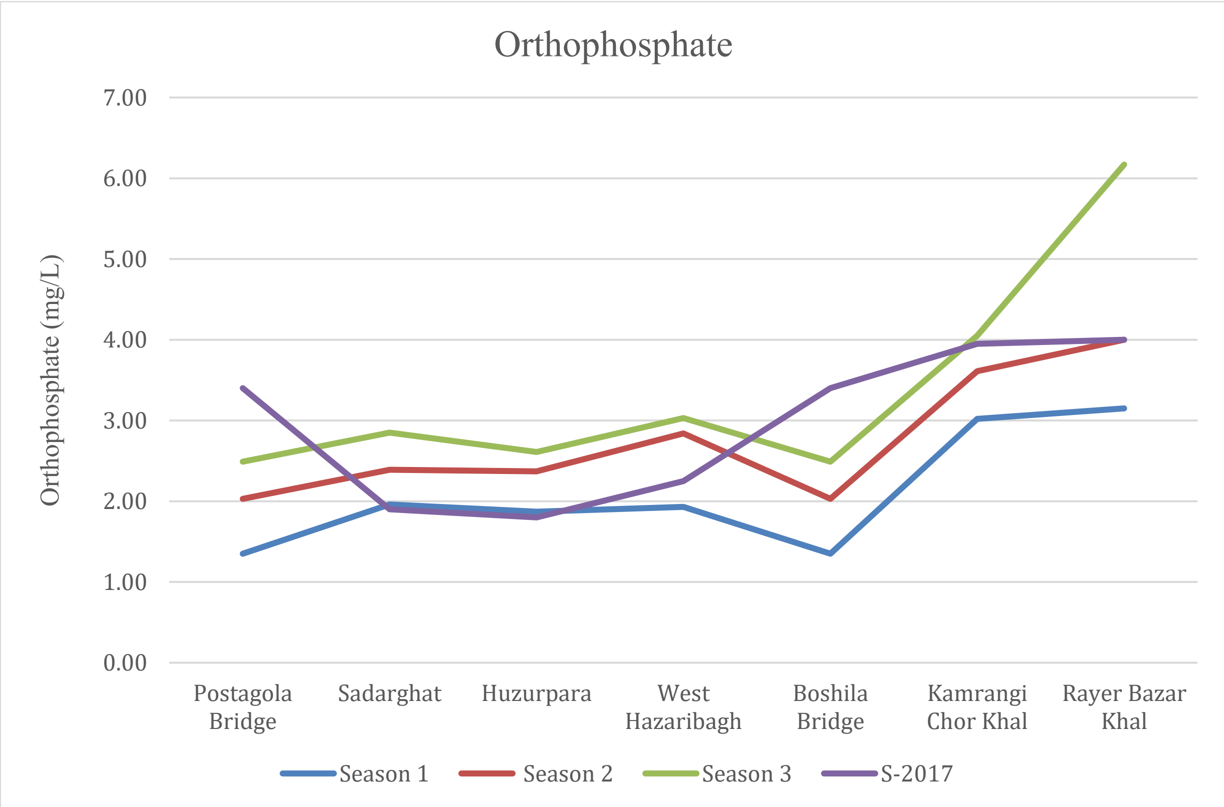

Figure 4.5 Orthophosphate value comparison of Buriganga river water

The graph displays the temperatures of the seven Buriganga river stations. The temperature was within the acceptable range. Station 1 recorded the season's lowest temperature of 20.40 degrees Celsius in the second season. And the maximum recorded temperature was 25.70 degrees Celsius. However, the temperature was much higher than in 2017. In 2017, the average temperature of the Buriganga river ranged from 223,00 degrees Celsius to 23,60 degrees Celsius.

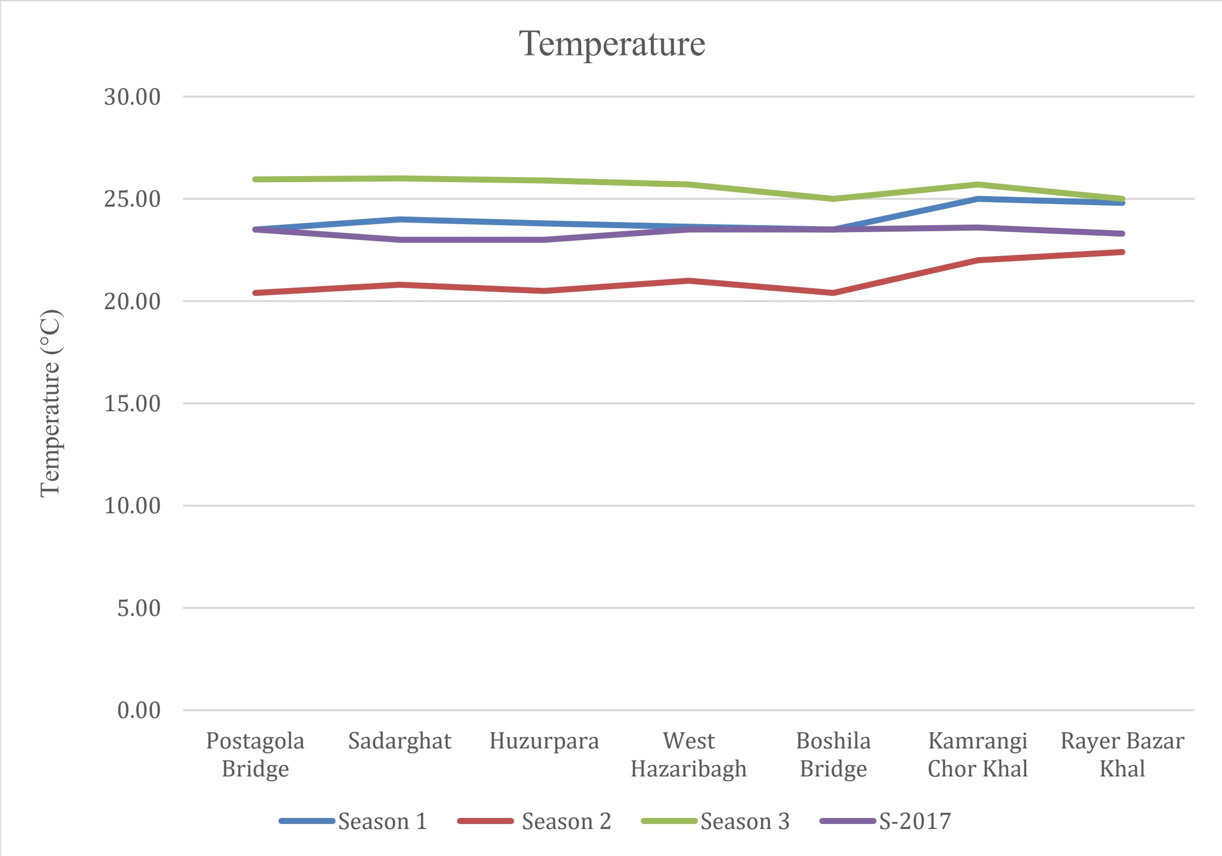

Figure 4.6 Temperature value comparison of Buriganga river water

This graph shows the electro conductivity levels of seven different stations of the river in three different seasons and 2017. For station 1 the value differs from 426µS/cm to 838µS/cm but in year 2017 the value was 960 µS/cm. For station 2,3 the values are quite similar. The values are in between 425µS/cm to 868 µS/cm. On the other hand, the values of these 2 stations were 950µS/cm and 952µS/cm in the year 2017. In the year 2017 the electro conductivity values of station 4,5 were 929µS/cm and 927µS/cm. But after relocating the tannery industries the value of EC reduced accordingly. In station 4 and 5 the EC values were in between 426µS/cm to 935µS/cm. In station 6 the value of EC for three different seasons were in between 524µS/cm to 1175µS/cm. In 2017, station 6 represented the highest electro conductivity value among all seven stations which was 947µS/cm. But this time the highest value of electro conductivity found in station 7 in season 3 which is 1200µS/cm.

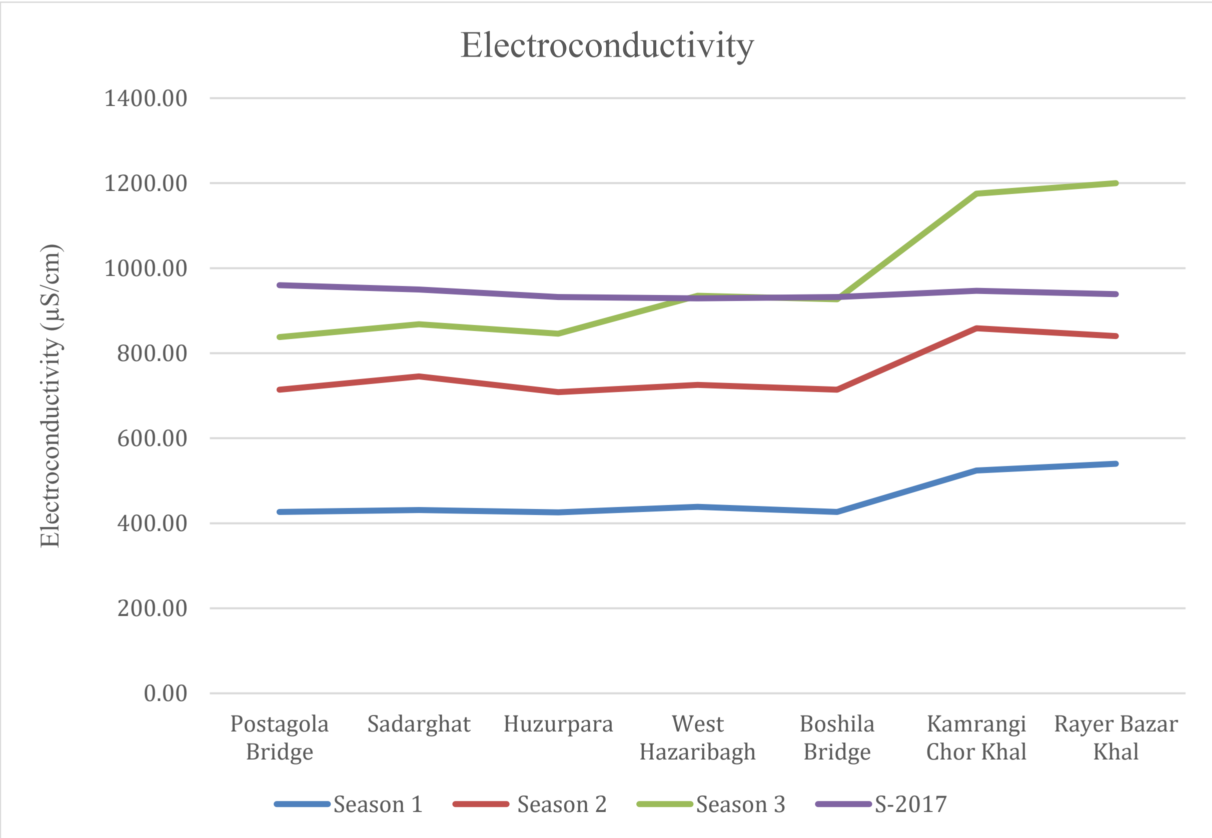

Figure 4.7 Electroconductivity value comparison of Buriganga river water

This graph gives the idea of salinity levels in different times. In season 1 location 1 the salinity of the river was 0%. The value for all three seasons in station 1 were in between 0% to 0.1%. But in 2017 the salinity of this station was 0.2%. Station 2 and 3 gave almost similar results which ranged from 0.1% to 0.2%. But in station 3, 2017 the salinity value was high among all stations which was 0.3%. The salinity was not changed rapidly or frequently which differs from 0% to 0.2% for all stations.

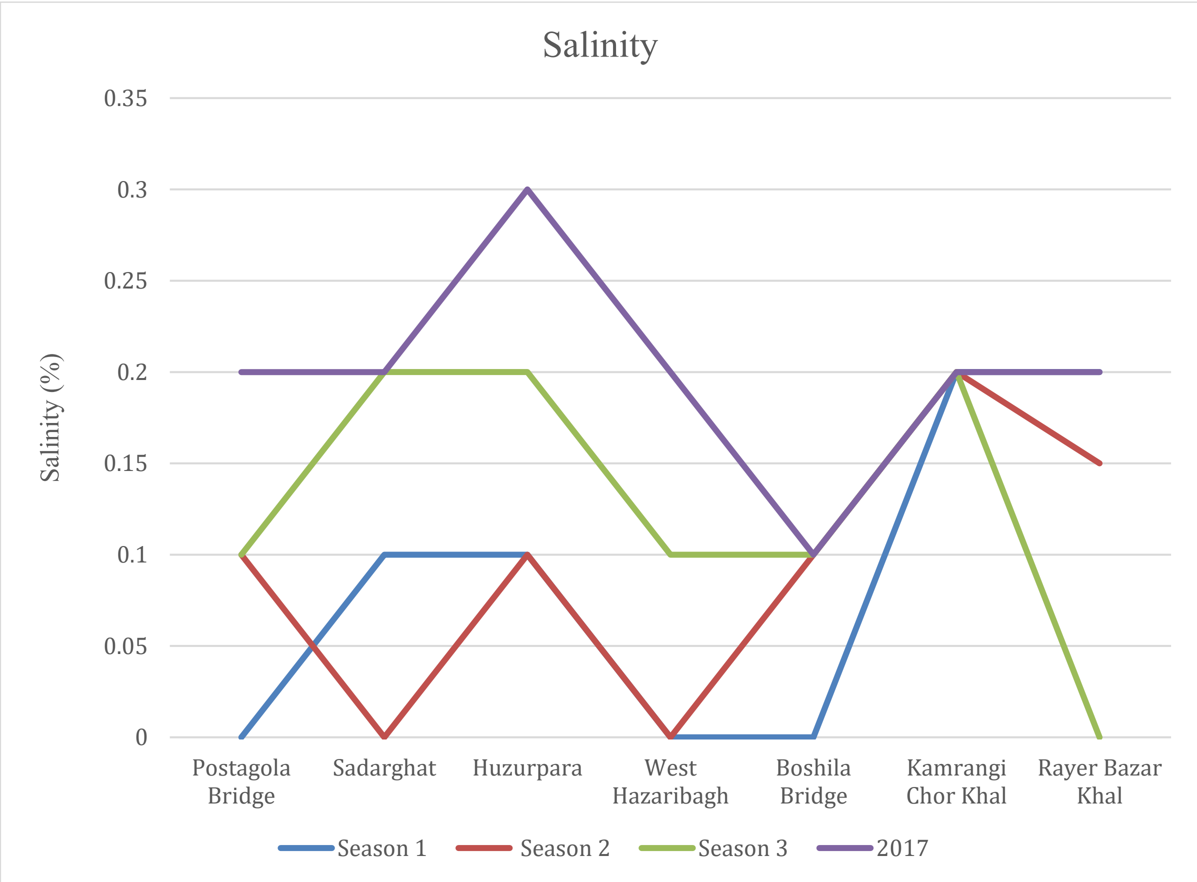

Figure 4.8 Salinity value comparison of Buriganga river water

This graph refers to the pH values of different seasons and station. Basically, there is no significant change in pH values. It differs from 7 to 8 range. Which is normal the highest pH value was 8.2 in season 3 location 6 and the lowest pH value was 7.2 in 2017 location 6 among all seasons and all stations.

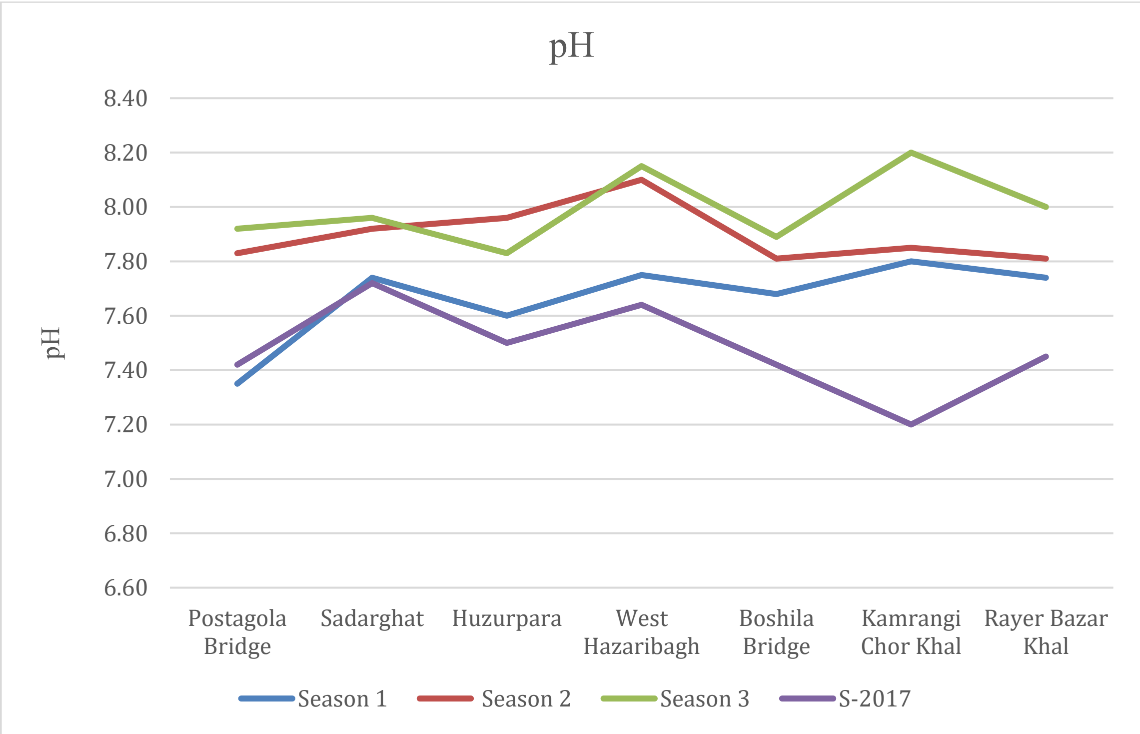

Figure 4.9 pH value comparison of Buriganga river water

This graph represents the Total dissolved solid values. In station 1 the values ranged from 286 mg/L to 510 mg/L and the value was 609 mg/L in 2017. In station 2 the value varies from 296 mg/L to 518 mg/L and the TDS value in 2017 was 577 mg/L. That means the TDS values are decreasing slowly. The TDS was 601 mg/L,616 mg/L and 609 mg/L in 2017 at station 3,4,5 accordingly. For season 1,2 and 3 these values differ from 285 mg/L to 587 mg/L. By analysing the graph, season 3 represents the highest value of TDS among all three seasons but which is also lower than 2017 TDS values that means the pollution is decreasing day by day. For station 6 and 7 the values fluctuate from 322 mg/L to 625 mg/L which are also less than 2017 values individually.

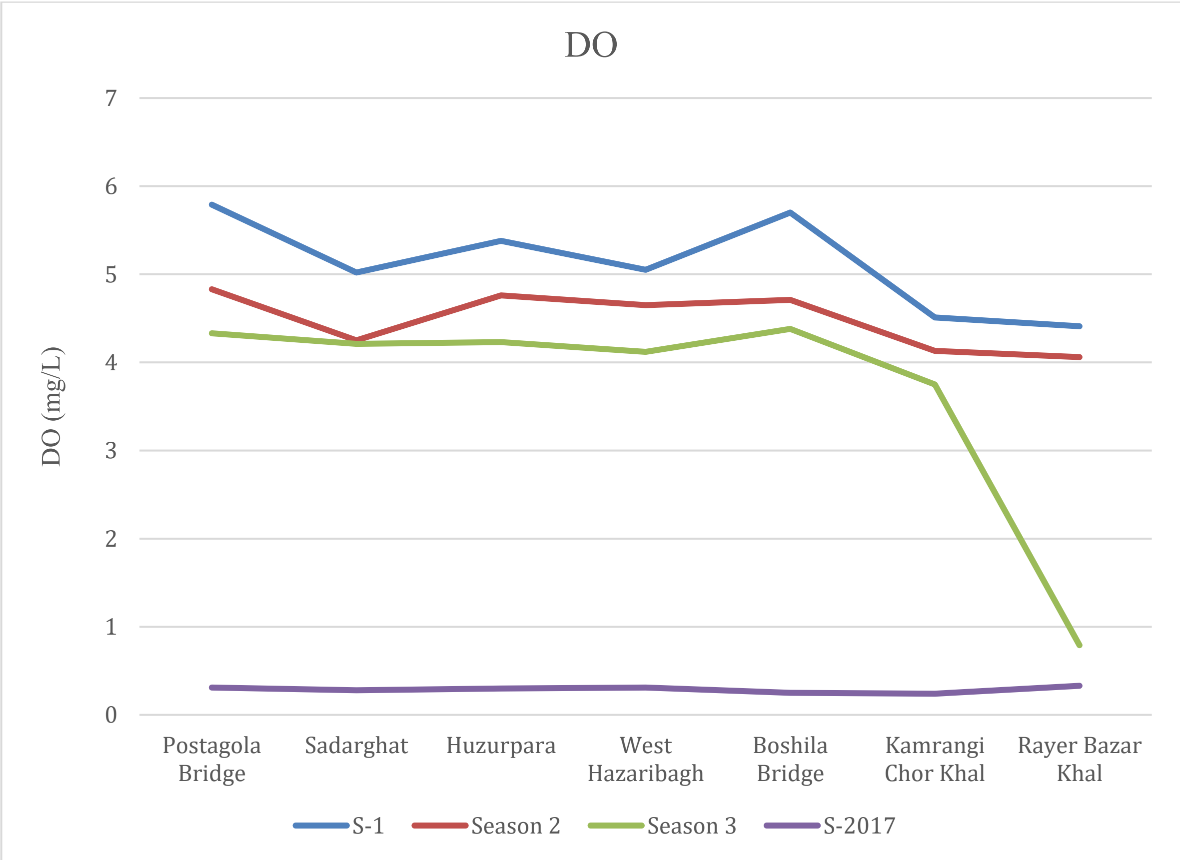

Figure 4.10 DO value comparison of Buriganga river water

This graph depicts the Total suspended solid concentration at seven different stations throughout the year 2022-2023 along with the year 2017. At station 1 the TSS value was in between 10 mg/L to 15 mg/L and in 2017 the value was 27 mg/L. Similarly at station 2 the TSS values were in between 11 mg/L to 18 mg/L and in 2017 the value was 36 mg/L. At station 3 the values increased slightly and stands on 16.17 mg/L,19.87 mg/L and 24.71 mg/L accordingly all three seasons but at the same station the value was 18 mg/L in 2017. At station 4 and 5 the TSS values ranged from 16.68 mg/L to 26.75 mg/L around the years and in 2017 the values for these two stations were 33 mg/L and 27 mg/L. The TSS values increased significantly at station 6 and 7 throughout all three seasons. The highest value stands on 41.5 mg/L in season 3 at station 6 and the value was 41 mg/L in 2017 for this station. For station 7 the TSS values differ from 27 mg/L to 35 mg/L on the other hand the value for this station was 38 mg/L in 2017.

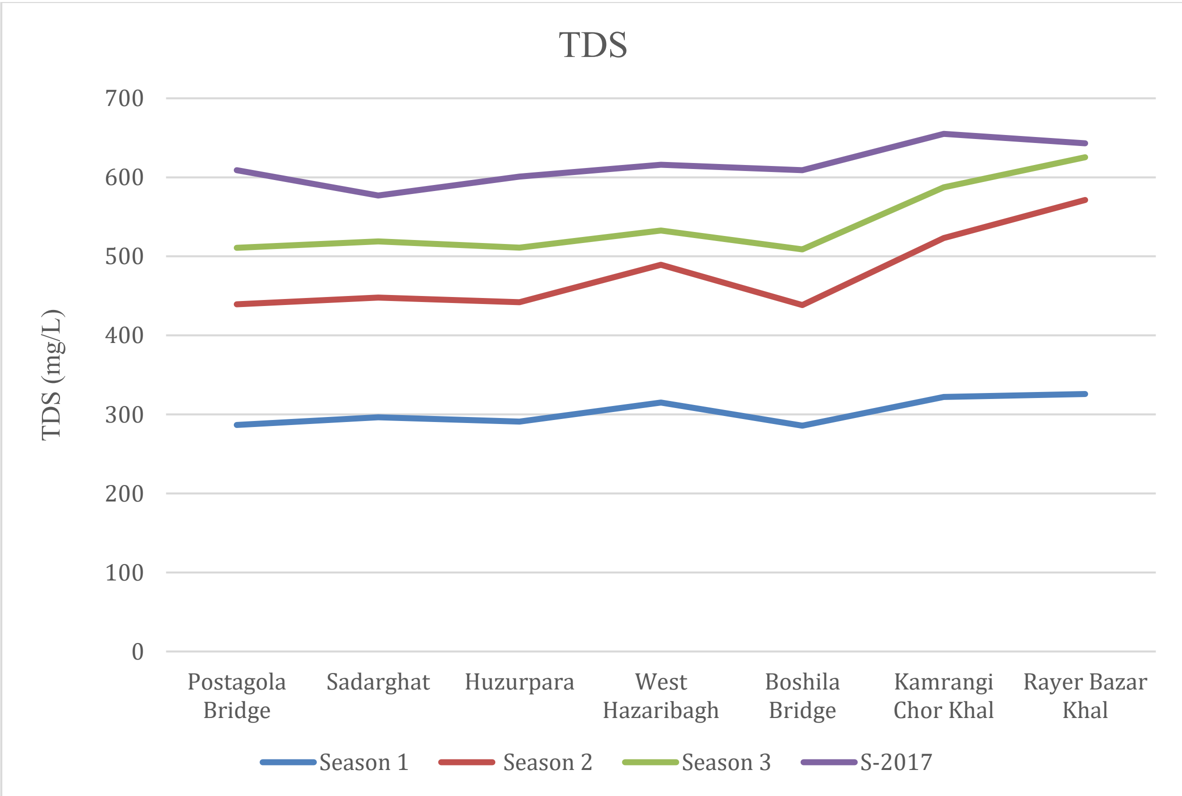

Figure 4.11 TDS value comparison of Buriganga river water

The graph depicts the concentrations of dissolved oxygen (DO) at seven distinct stations along the Buriganga River. Notably, the DO concentrations at stations 1, 2, 3, and 4 changed significantly, ranging from 4.12 mg/L to 5.79 mg/L. This represents a significant improvement compared to the 2017 DO values recorded at these stations, which ranged from 0.28 mg/L to 0.31 mg/L. Therefore, the observed rise in DO levels is an extremely encouraging sign. The DO concentrations at stations 5, 6, and 7 ranged from 0.79 mg/L to 5.7 mg/L. In 2017, the DO concentrations at these stations were 0.25 mg/L, 0.24 mg/L, and 0.33 mg/L, respectively. Following the relocation of tannery industries from Hazaribagh to Savar, it is evident that the river is enduring a recovery process.

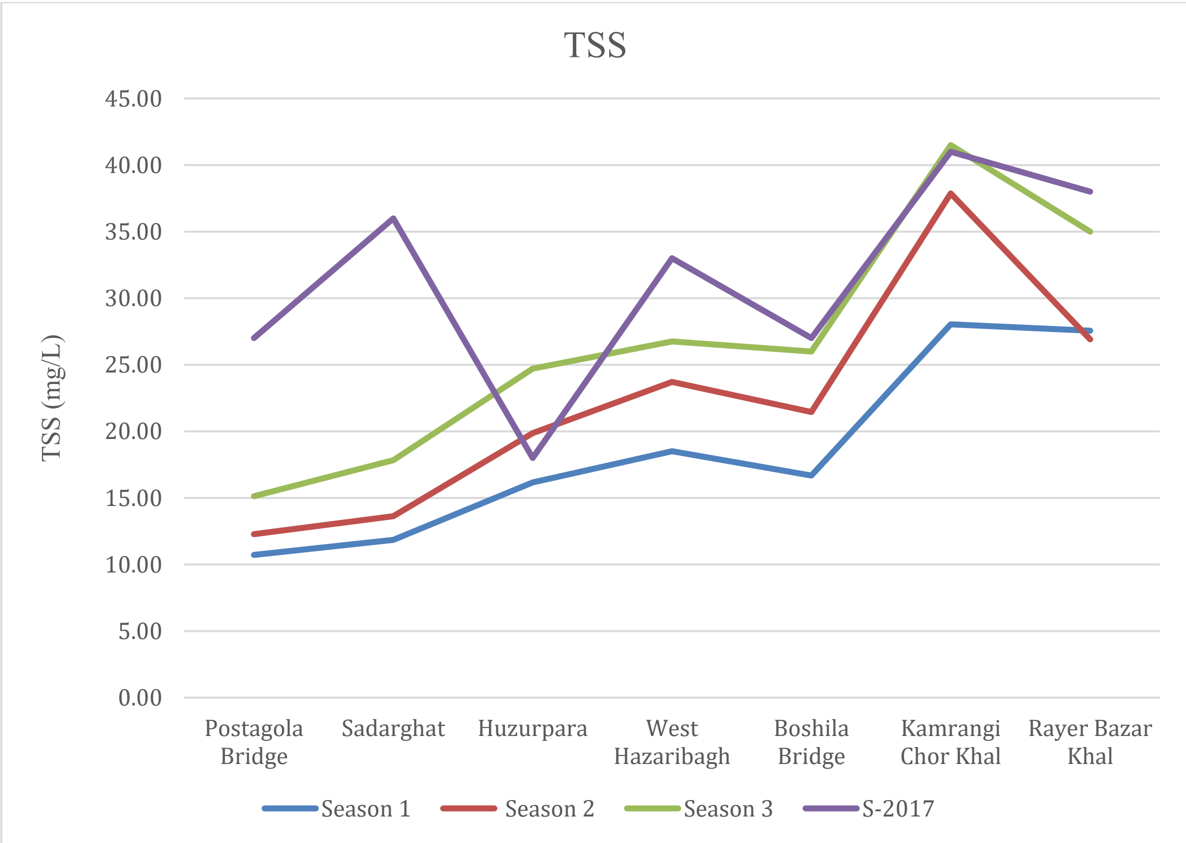

Figure 4.12 TSS value comparison of Buriganga river water

Figure 4.13 depicts a comparison graph of the biochemical oxygen demand (BOD) values for Dhaleswari River water. It is evident that the BOD values in 2017 were considerably lower than the values measured during the three seasons in 2022-23 at each station. However, it is essential to note that the BOD values also vary between stations and seasons. During season 3, the BOD value at the Hazratpur bridge was at its maximum, while during season 1 it was at its lowest. Similarly, the maximum BOD values were recorded at south Kamarchar, Hazratpur, and Dhaleswari River Bridge during seasons 1, 3, and 1, respectively. In contrast, the lowest BOD value was recorded at these three stations during season 2.

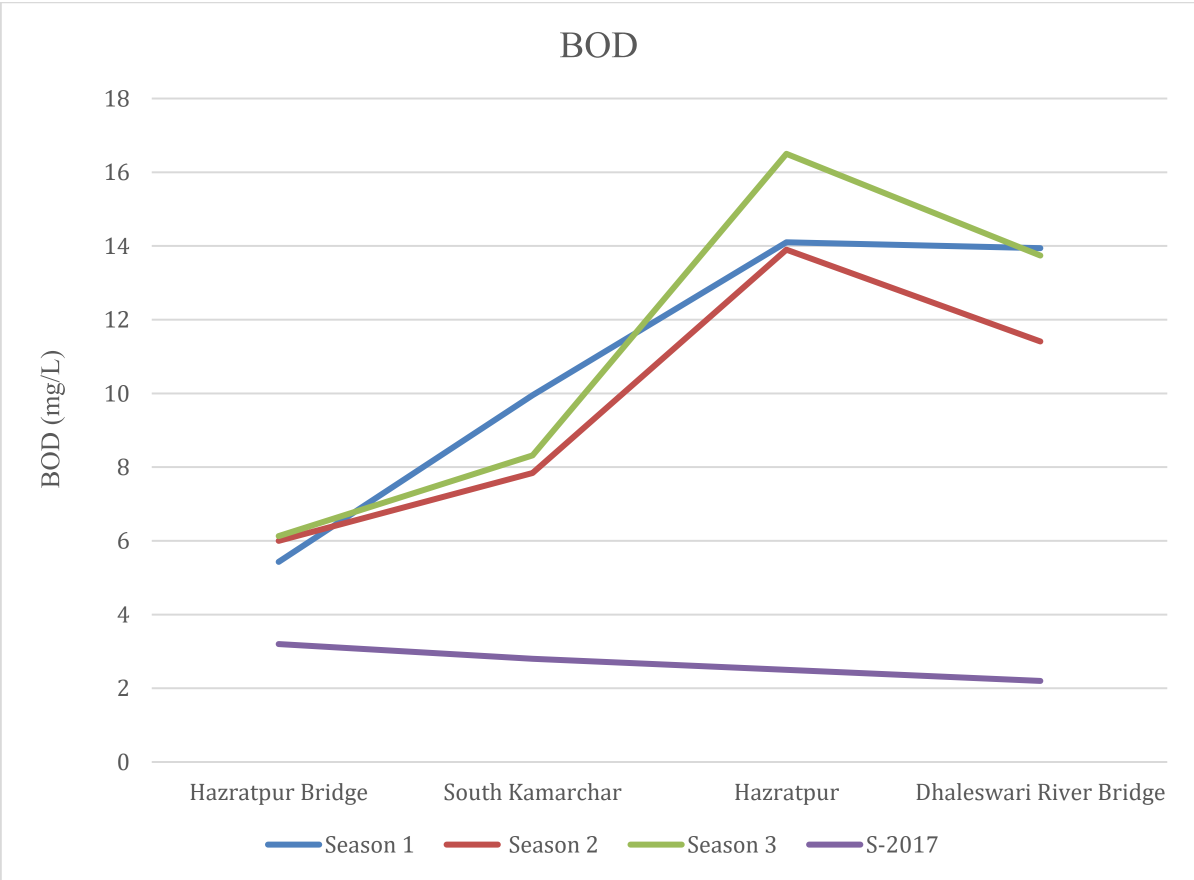

Figure 4.13 BOD value comparison of Dhaleshwari river water

The graph shown in Figure 16 represents a comparison graph of COD values for water from the Dhaleswari River. We can see that the COD value in 2017 is significantly less than the three seasons we measured in 2022-23 at each station. Nevertheless, COD value fluctuates from station to station and season to season. Season three at Hazratpur Bridge had the highest COD value. Likewise, at south Kamarchar, Hazratpur, and Dhaleswari River Bridge, Season-3, Season-3, and Season-2 had the maximum value.

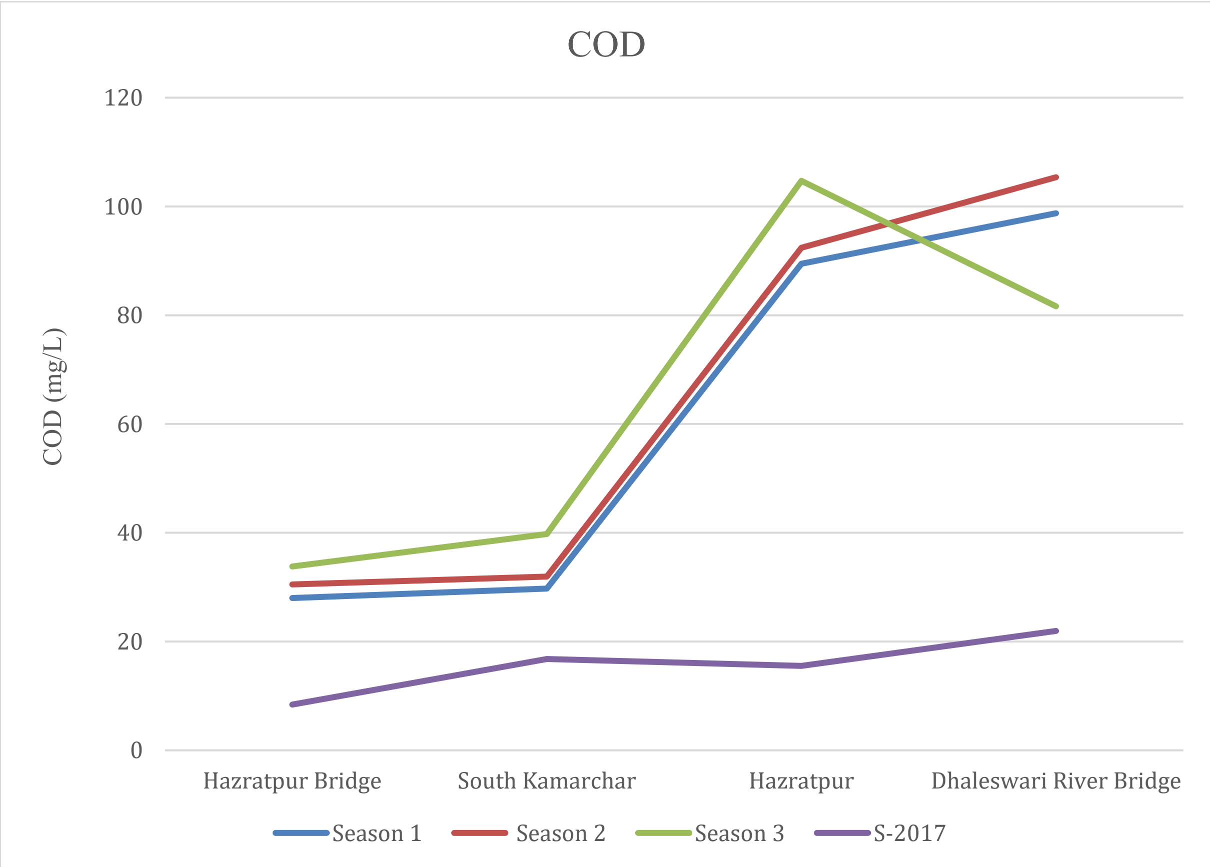

Figure 4.14 COD value comparison of Dhaleshwari river water

The graph in 4.15 is a graph comparing the Ammonium Nitrate levels of water from the Dhaleswari River. 2017's Ammonium Nitrate value is noticeably lower than the three seasons we measured (2022–2023) at all stations. However, the value of Ammonium Nitrate value changes from station to station and from season to season. The Ammonium Nitrate value peaked at Hazratpur bridge in the third season Also, Season 3 had the highest value at the south Kamarchar bridge & Hazratpur bridge, and Season 1 & 2 at the Dhaleswari River bridge.

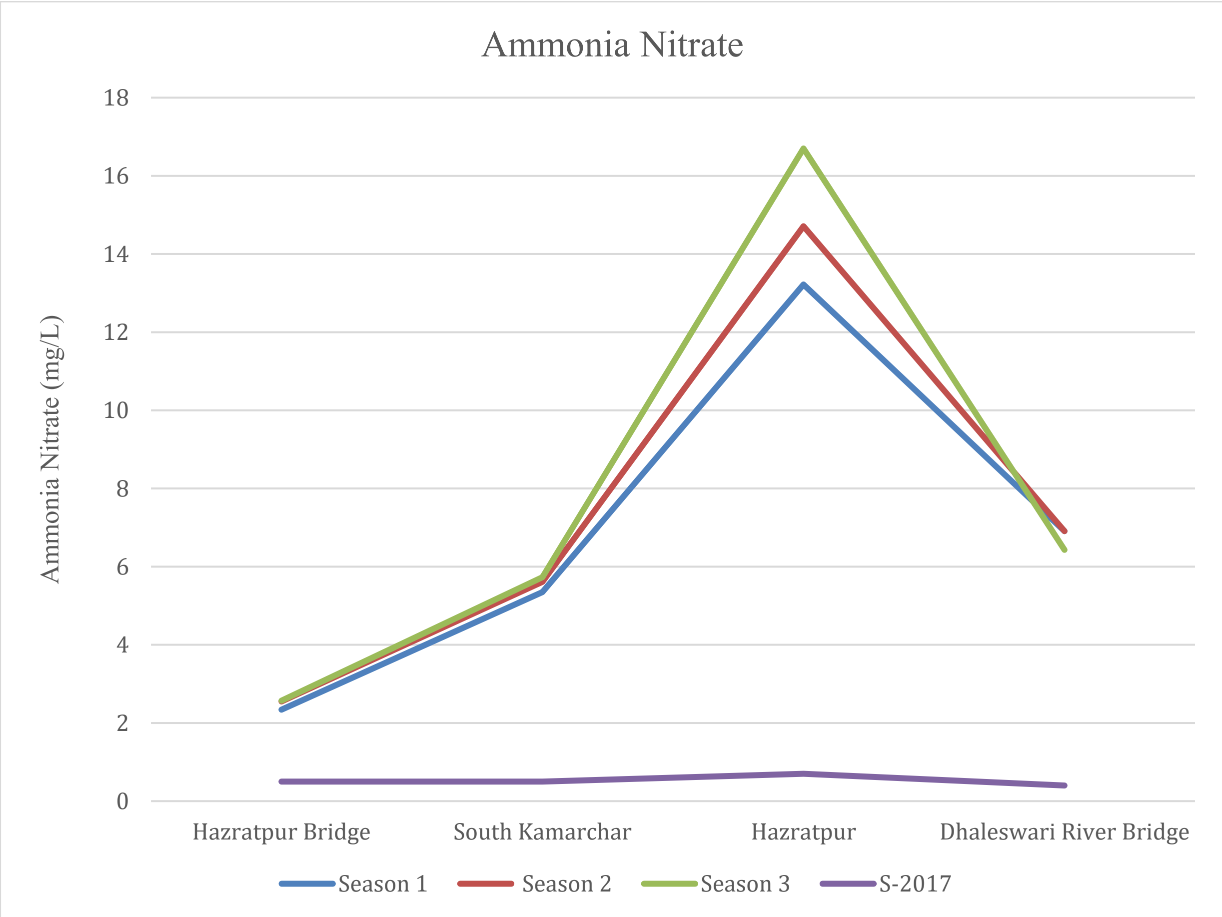

Figure 4.15 Ammonium Nitrate value comparison of Dhaleshwari river water

The graph shown in Figure 4.16 represents a comparison graph of Nitrate values for water from the Dhaleswari River. We can see that the Nitrate value in 2017 at Hazratpur Bridge was the highest comparing with three seasons we measured in 2022-23 at Hazratpur Bridge. But in other three station 2017's value was lowest. Season-3 at Hazratpur, and Dhaleswari River Bridge had the highest Nitrate value. Likewise, at south Kamarchar, Season-1 & Season-2 had the maximum value.

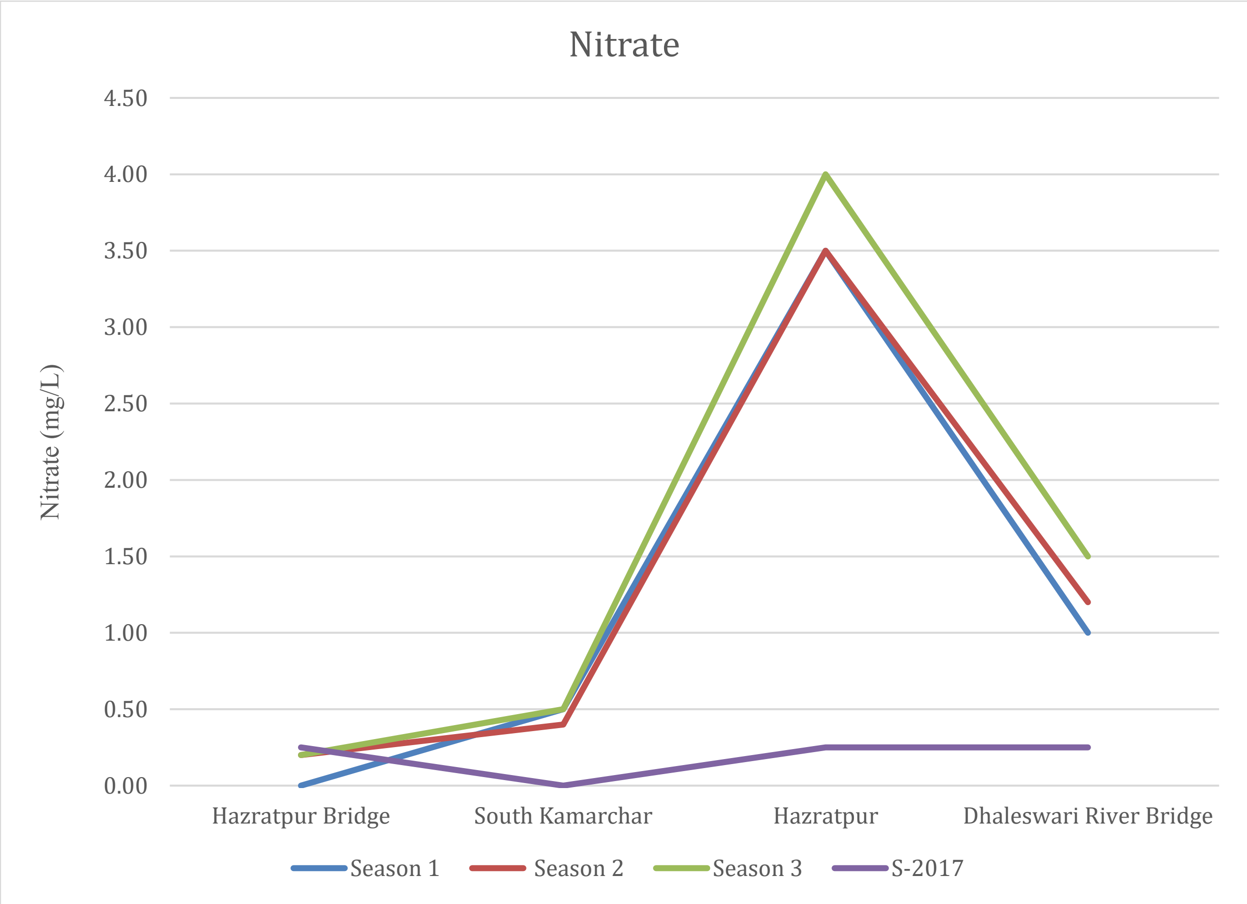

Figure 4.16 Nitrate value comparison of Dhaleshwari river water

The graph shown in Figure 4.17 displays a comparison of the Orthophosphate levels found in water samples collected from the Dhaleswari River. The Orthophosphate value recorded in 2017 shows a significant decrease in comparison to the values obtained during the three seasons of measurement (2022-2023) across all stations. Nevertheless, the Orthophosphate concentration varies across different stations and throughout various seasons. The Orthophosphate value was the highest at Hazratpur bridge in Season-2. Also, Season 3 had the highest value at the south Kamarchar bridge & Hazratpur bridge, and Season 1 & 2 at the Dhaleswari River bridge.

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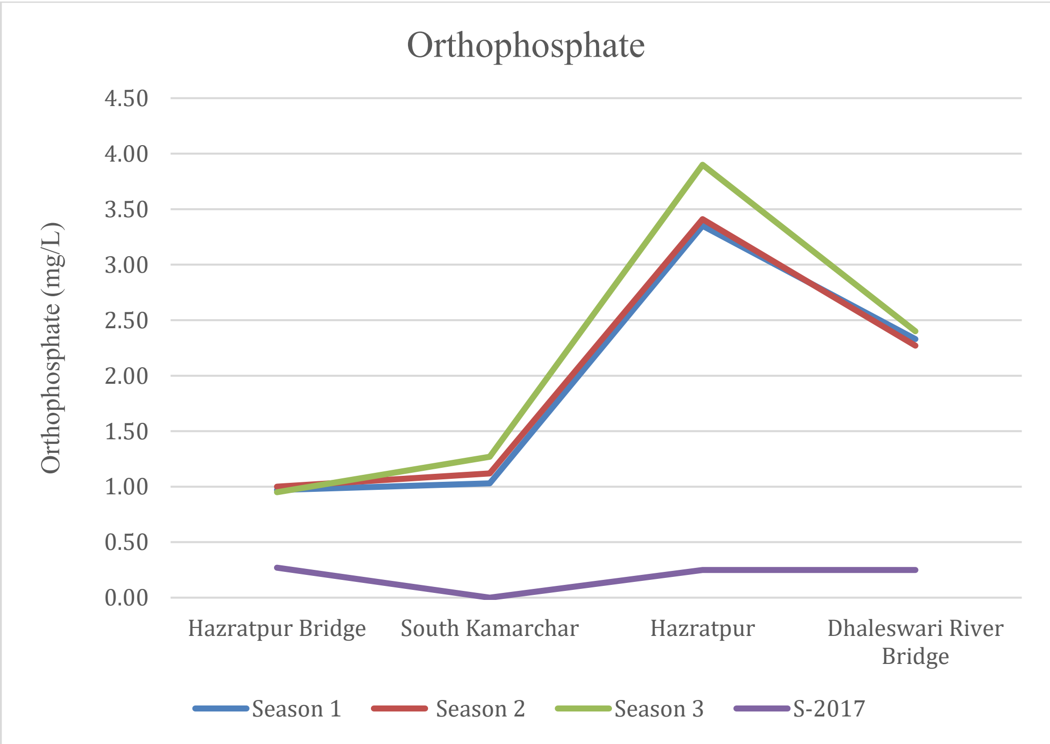

Figure 4.17 Orthophosphate value comparison of Dhaleshwari river water

Graph shown in figure 4.18 represents a comparative analysis of the temperature measurements obtained from water samples gathered from the Dhaleswari River. The temperature at Hazratpur Bridge and South Kamarchar showed a consistent pattern between the years 2017 and 2022-23. But the temperature recorded at Hazratpur and Dhaleshwari River bridge in 2017 was lower than that recorded in 2022-23. During season 3, the temperature at Hazratpur reached a maximum of 30.20°C, whereas at Dhaleshwari River bridge, it was 27°C.

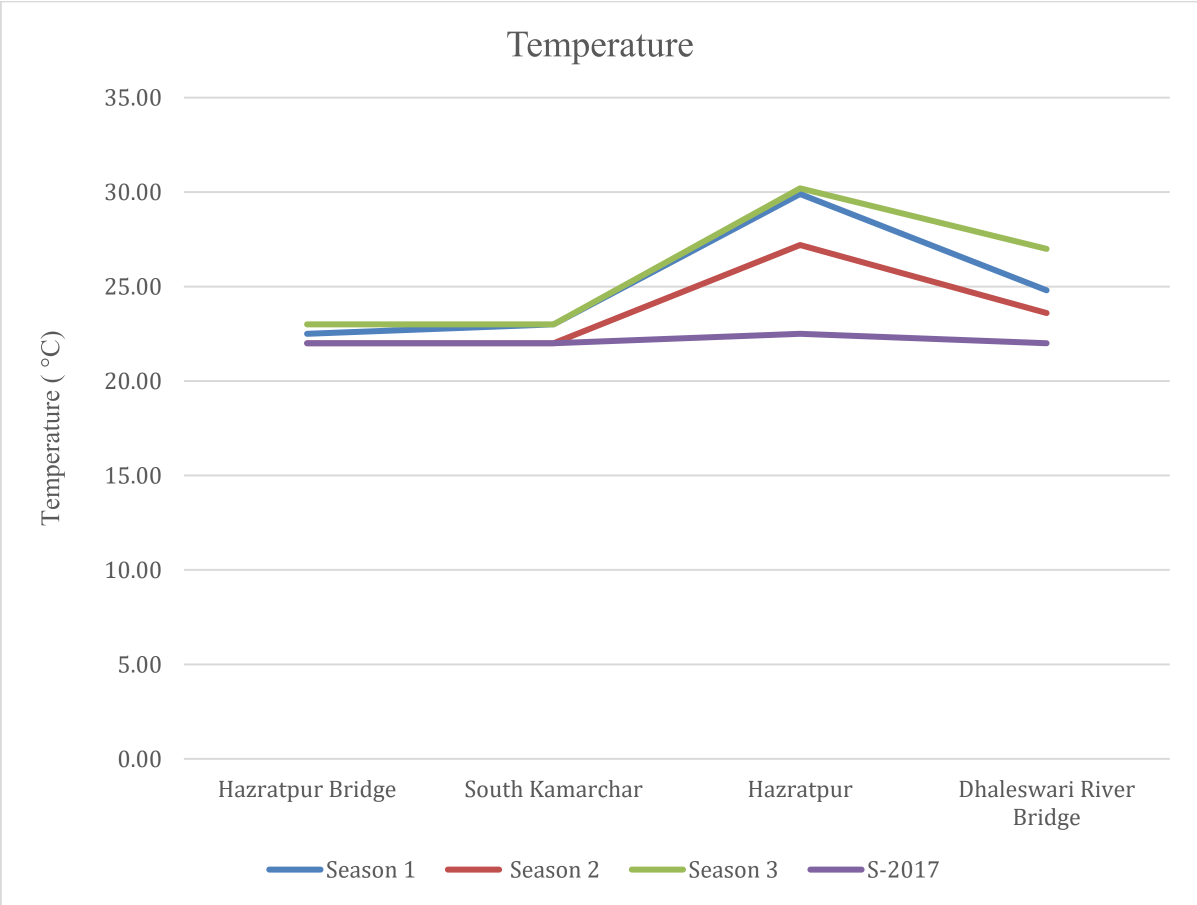

Figure 4.18 Temperature value comparison of Dhaleshwari river water

The graph shows the electroconductivity concentration of four stations of Dhaleswari river. The EC concentration of station 1 ranged between 254.91 µS/cm and 273.66 µS/cm over the course of three seasons but in 2017, the EC concentration of this stations was 232.81 µS/cm. The EC concentration of station 2 fluctuated between 470.62 µS/cm and 492.31 µS/cm, whereas the concentration was less than that which is 247.64 µS/cm in 2017. Throughout the year, the EC value at station 3 varied between 1007.30 µS/cm and 1042.60 µS/cm and in 2017, the value was way less than that which is 242.83 µS/cm. The EC value at station 4 fluctuated between 813.21 µS/cm and 943.61 µS/cm and the EC value was 250.30 µS/cm in this station in 2017 which is less than that of recent time.

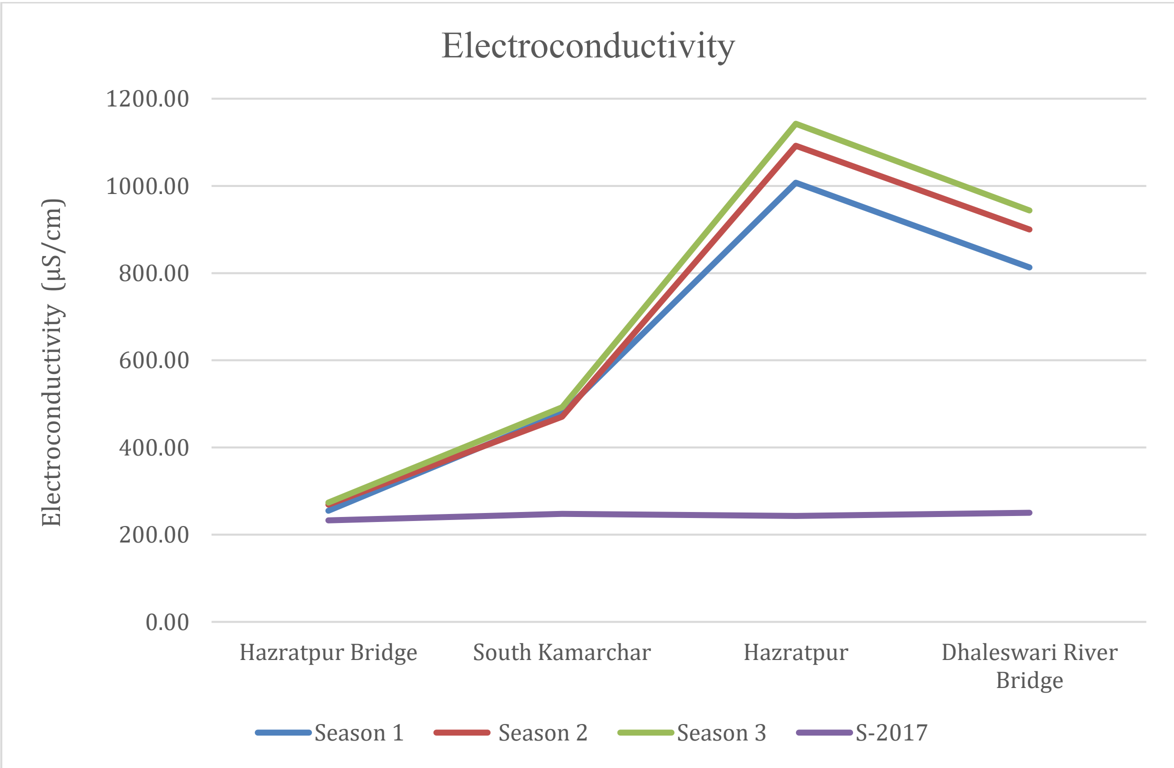

Figure 4.19 Electroconductivity value comparison of Dhaleshwari river water

This graph depicts the salinity values of Dhaleswari river stations. The salinity of station 1 varied from 0.20% to 0.60% over the course of three seasons, while the salinity value of this station 2017 was lower than that which is 0.15%. The salinity value of station 2 fluctuated between 0.30% and 0.60% but in 2017, the salinity was much lower than that (0.00%). Station 3 had similar value as station 1 and the salinity value was 0.20% in 2017 in that station. Station 4 had a salinity value fluctuating from 0.10% to 0.60% over the course of the year but the value of salinity was 0.10% in these station in 2017.

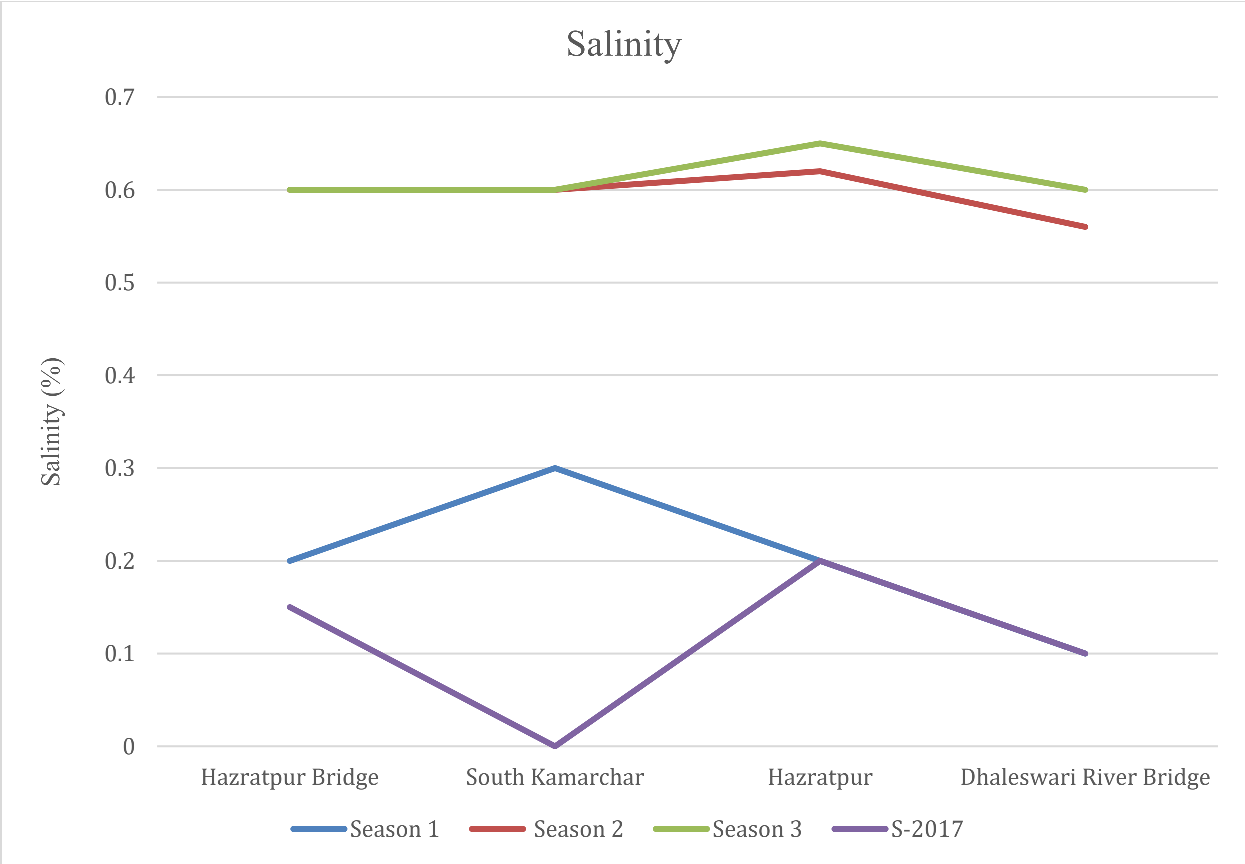

Figure 4.20 Salinity value comparison of Dhaleshwari river water

The graph represents the pH of Dhaleswari river stations. The pH value of station 1 fluctuated between 6.90 and 7.20 over the course of three seasons, while the pH value of this station was 6.95 in 2017. Station 2 fluctuated between 6.90 and 7.30 but in 2017, the pH value was 7. Throughout the year, station 3's pH ranged between 7.84 and 8.30 whereas, the pH value was 7 in 2017 and station 4's pH varied between 7.50 and 7.70 whereas, in 2017, the value was 7.05 which was lower than present time.

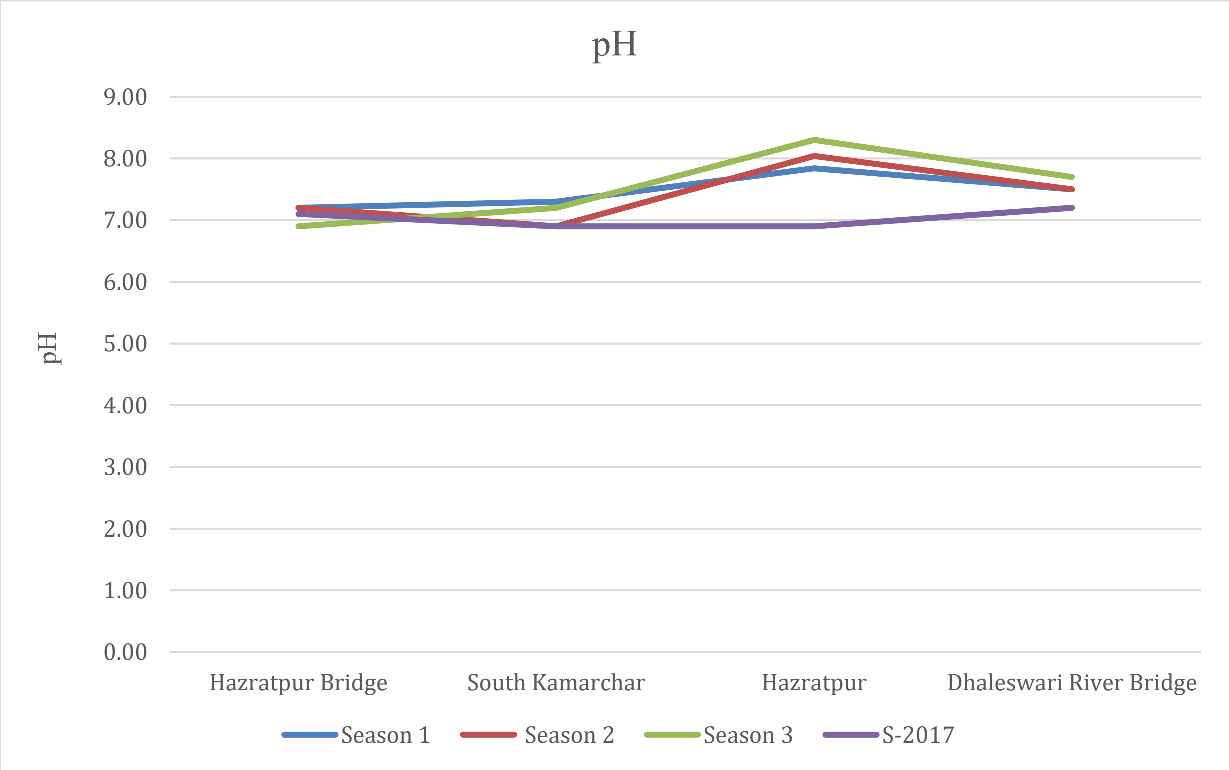

Figure 4.21 pH value comparison of Dhaleshwari river water

The graph shows the total dissolved solids concentration of Dhaleswari river stations. In station 1, TDS fluctuated between 151.32mg/L and 159.04 mg/L but the concentration was 145.75 mg/L in 2017. In station 2, TDS varied from 201.35mg/L to 239.88 mg/L, whereas, the value was 152.16 mg/L in 2017. In station 3, TDS fluctuated between 463.09 mg/L and 561.73 mg/L but in 2017, TDS was lower which is 164.31 mg/L in this station. TDS varied from 403.81mg/L to 492.19 mg/L in station 4 and in 2017, the concentration was 175.2 mg/L which was lower than present situation.

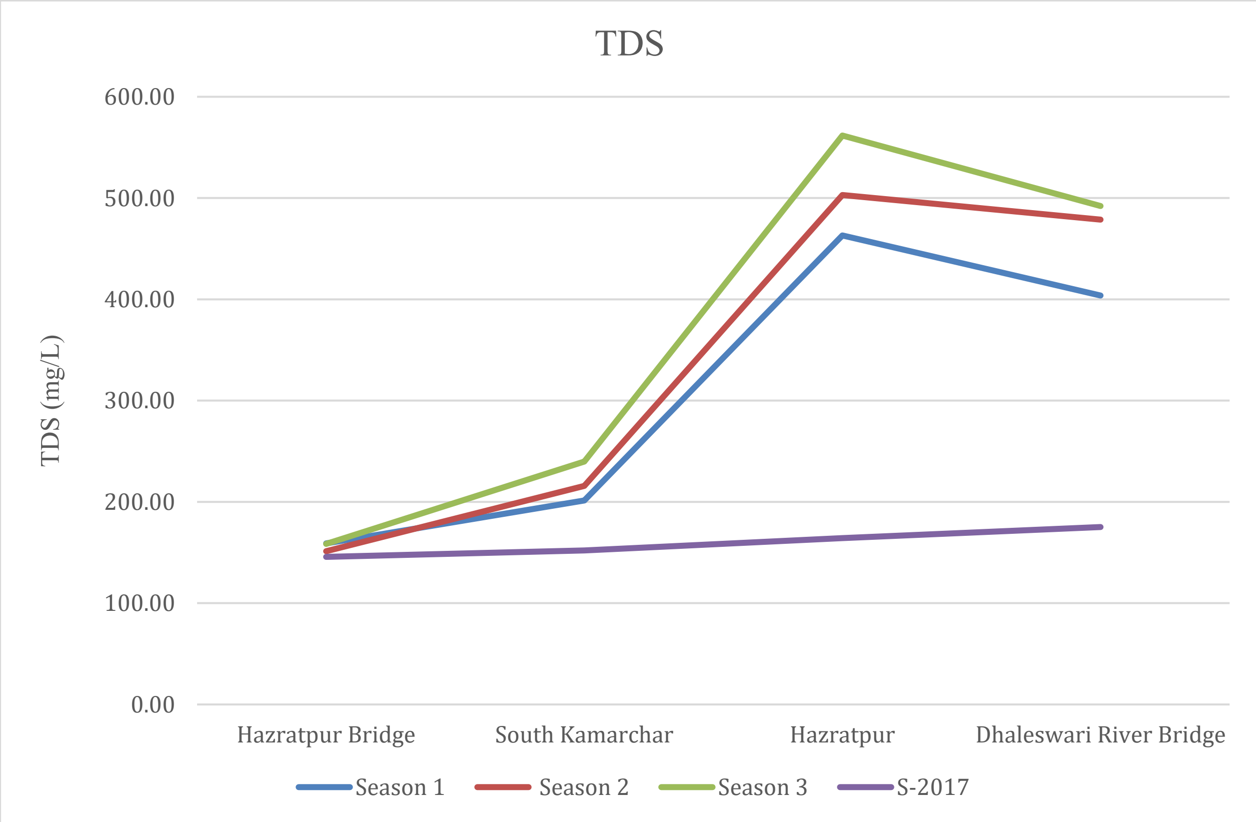

Figure 4.22 TDS value comparison of Dhaleshwari river water

The graph depicts the total suspended solids concentration of Dhaleswari river stations. In station 1, TSS ranged from 6.47 mg/L to 7.05 mg/L but the value was 1.10 mg/L in 2017. In station 2, TSS was found slightly changed throughout the seasons and the values fluctuated between 9.30 mg/L and 9.95 mg/L, while the value was much lower than that which was 0.80 mg/L in 2017. TSS values ranged from 24.61 mg/L to 36.41 mg/L in station 3 but in 2017, the value was 0.60mg/L which is very much lower than present time. In station 4, TSS value varied from 19.00 mg/L to 25.93 mg/L and in 2017, the value was 0.50 mg/L.

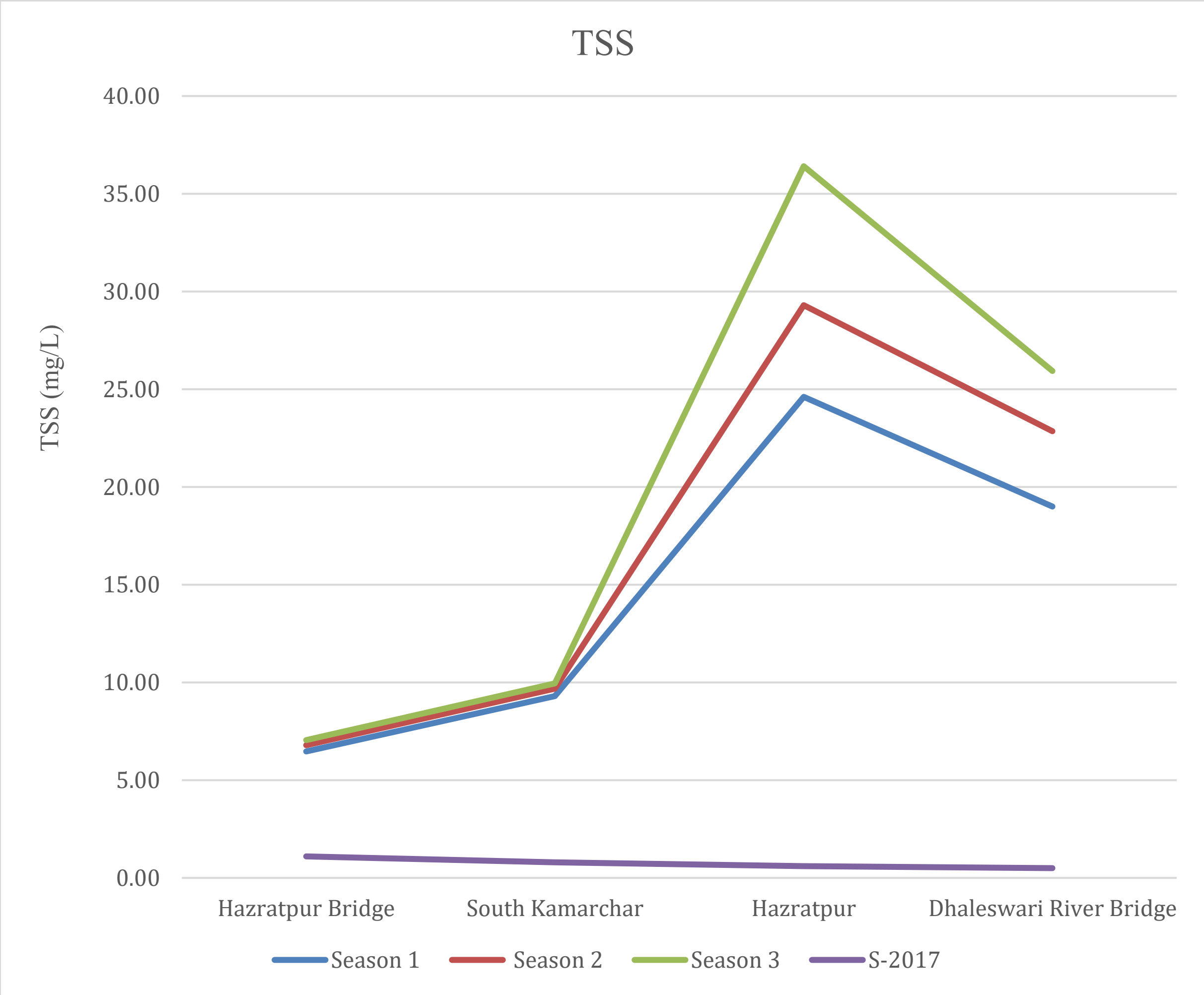

Figure 4.23 TSS value comparison of Dhaleshwari river water

The graph represents the dissolved oxygen value of Dhaleswari river stations. In station 1, DO was found varied from 6.22 mg/L to 6.35 mg/L and in station 2, the value ranged from 4.51 mg/L to 5.54 mg/L. But the values were 18.50 mg/L and 9.50 mg/L of these stations respectively in 2017. While in station 3, DO ranged from 1.00 mg/L to 1.30 mg/L and in 2017, the value of dissolved oxygen was higher than that which is 8.50 mg/L. In station 4, the values varied from 2.75 mg/L to 3.20 mg/L and the value was found 9.60 mg/L in 2017.

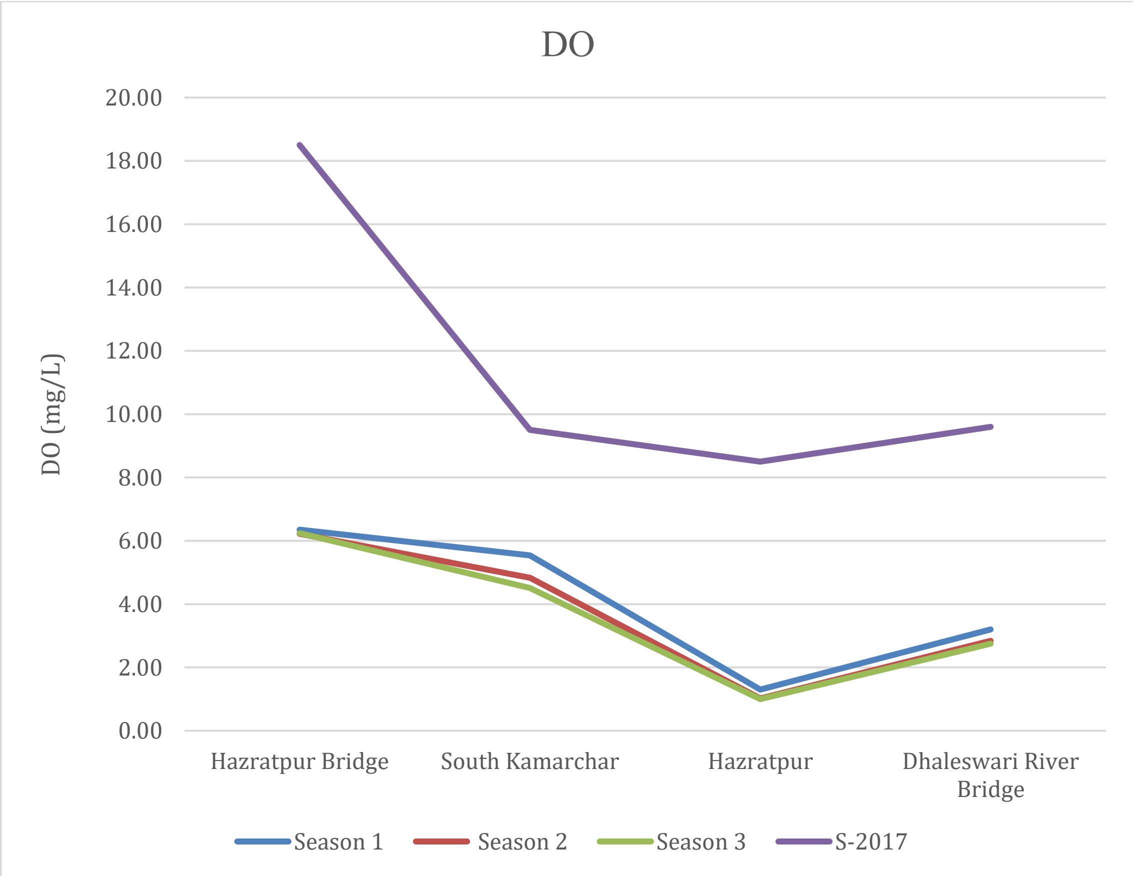

Figure 4.24 DO value comparison of Dhaleshwari river water

4.3 WQI Calculation Table According to DoE, Malaysia

The table represents the DoE WQI (MALAYSIA) value of Buriganga river along 7 distinct locations of season 1. The WQI (MALAYSIA) value was found in Polluted category though the values were quite higher than other seasons

Table 4.9 Buriganga Season -1 DoE(Malaysia)-WQI Result

STATION	DO	BOD	COD	AN	TSS	pH	SIDO	SIBOD	SICOD	SIAN	SITSS	SIpH	WQI	RESULT
Postagola Bridge	5.79	5.21	55.34	6.53	12.15	7.76	0	80.57075	40.98858	0	90.41948	94.10752	47.62663	polluted
Sadarghat	5.02	15.21	62.31	7.91	16.27	7.74	0	45.26487	36.23169	0	88.15862	94.33502	39.82298	polluted
Huzurpara	5.38	7.23	62.46	7.98	13.17	7.6	0	71.84189	36.13461	0	89.85334	95.792	45.30307	polluted
West Hazaribagh	5.05	9.46	51.98	6.75	13.97	7.75	0	63.24296	43.46316	0	89.41228	94.22188	44.58286	polluted
Boshila Bridge	5.7	12.74	52.35	7.23	15.72	7.7	0	52.31968	43.18458	0	88.45647	94.7755	42.37637	polluted
Kamrangi Chor Khal	4.51	19.42	72.34	9.05	18	7.3	0	35.17337	30.18845	0	87.22959	98.1155	37.24369	polluted
Rayer Bazar Khal	4.41	21.17	69.08	9.79	19.06	7.74	0	31.59255	32.05614	0	86.66619	94.33502	36.31836	polluted

Note: All the units are mg/L except pH.

The table represents the DoE WQI (MALAYSIA) value of Buriganga river along 7 distinct locations of season 2. The DoE WQI (MALAYSIA) value was found in Polluted category though the index values were quite higher than summer.

Table 4.10 Buriganga Season -2 DoE(Malaysia)-WQI Result

STATION	DO	BOD	COD	AN	TSS	pH	SIDO	SIBOD	SICOD	SIAN	SITSS	SIpH	WQI	RESULT
Postagola Bridge	4.83	1.3	57	6.81	14.25	8.54	0	94.901	39.81079	0	89.25852	81.45982	48.45746	polluted
Sadarghat	4.25	1.59	67.8	8.35	19.21	7.92	0	93.6743	32.81415	0	86.58683	92.11328	47.95587	polluted
Huzurpara	4.76	2.33	64.31	8.05	17.88	7.96	0	90.5441	34.95465	0	87.29365	91.56632	47.75106	polluted
West Hazaribagh	4.65	2.7	50.02	6.7	16.35	7.97	0	88.979	44.96478	0	88.1154	91.42656	49.17002	polluted
Boshila Bridge	4.71	3.89	56.95	8	20.28	7.83	0	83.9453	39.8458	0	86.0232	93.2731	47.2814	polluted
Kamrangi Chor Khal	4.13		78.93	10.23	23.47	7.42	0	100.4	26.6732	0	84.36916	97.31678	48.52079	polluted
Rayer Bazar Khal	4.06	3.86	69.4	11.83	24.91	7.81	0	84.0722	31.8688	0	83.6352	93.5176	45.6764	polluted

Note: All the units are mg/L except pH.

The table represents the DoE WQI (MALAYSIA) value of Buriganga river along 7 distinct locations of season 3. The DoE WQI (MALAYSIA) value was found in Polluted category and it was observed that the index values were lowest from all other seasons which indicates the most polluted water of all seasons.

Table 4.11 Buriganga Season -3 DoE(Malaysia)-WQI Result

STATION	DO	BOD	COD	AN	TSS	pH	SIDO	SIBOD	SICOD	SIAN	SITSS	SIpH	WQI	RESULT
Postagola Bridge	4.33	19.15	60.54	9.39	15.13	7.92	0	35.75565	37.39369	0	88.77734	92.11328	38.03453	polluted
Sadarghat	4.21	22.5	65.78	10.56	17.84	7.96	0	29.08173	34.03968	0	87.31501	91.56632	35.93024	polluted
Huzurpara	4.23	21.33	61.43	10.21	24.71	7.83	0	31.28121	36.80562	0	83.73669	93.27316	36.42298	polluted
West Hazaribagh	4.12	20	64.31	11.34	26.75	8.15	0	33.95008	34.95465	0	82.70878	88.70388	35.92113	polluted
Boshila Bridge	4.38	18.31	61.54	11.39	26.00	7.89	0	37.6208	36.7334	0	83.0848	92.5108	37.4202	polluted
Kamrangi Chor Khal	3.75	33.5	82.35	13.00	41.50	8.20	0	13.75945	24.97693	0	75.72413	87.878	29.27183	polluted
Rayer Bazar Khal	0.79	45	75.67	13.40	35.00	8.00	0	4.58960	28.3701	0	78.7074	91	28.9244	polluted

Note: All the units are mg/L except pH.

The table represents the WQI (MALAYSIA) value of Buriganga river along 7 distinct locations 2017 before relocations of tannery industries. The WQI (MALAYSIA) value was found in Polluted category and it was observed that the index values were lowest from all seasons at present which indicates the water was more polluted at that time than now a days.

Table 4.12 Buriganga 2017 DoE(Malaysia)-WQI Result

STATION	Postagola Bridge	Sadarghat	Huzurpara	West Hazaribagh	Boshila Bridge	Kamrangi Chor Khal	Rayer Bazar Khal
DO	0.31	0.28	0.3	0.31	0.25	0.24	0.33
BOD	24	28	12	22	24	29	32
COD	108	112	96	105	108	117	112
AN	13.65	13.80	13.43	13.45	13.65	14.50	14.75
TSS	27.00	36.00	18.00	33.00	27.00	41.00	38.00
pH	7.42	7.72	7.50	7.64	7.42	7.20	7.45
SIDO	0	0	0	0	0	0	0
SIBOD	26.4506	20.3531	54.6199	30.0053	26.4506	19.0141	15.3808
SICOD	14.5793	13.269	18.9775	15.6108	14.5793	11.7289	13.269
SIAN	0	0	0	0	0	0	0
SITSS	82.5838	78.2389	87.2295	79.6549	82.5838	75.9484	77.3124
SIpH	97.3167	94.5576	96.6875	95.3999	97.3167	98.648	97.0898
WQI	32.2497	29.8552	38.9734	32.3915	32.2497	29.4788	29.0661
RESULT	polluted	polluted	polluted	polluted	polluted	polluted	polluted

Note: All the units are mg/L except pH.

The table represents the WQI (MALAYSIA) value of Dhaleswari river along 4 distinct locations of season 1. The WQI (MALAYSIA) value was found in Polluted category and it was observed that the index values were highest of all seasons at that time.

Table 4.13 Dhaleshwari Season-1 DoE(Malaysia)-WQI Result

STATION	**Hazratpur Bridge**	**Dhaleshwari River Bridge**	**Hazratpur**	**South Kamarchar**
DO	6.35	5.54	1.30	3.20
BOD	2.43	18.63	29.37	7.95
COD	48	98.75	118.48	59.31
AN	2.55	6.91	13.22	5.35
TSS	12.47	28.71	39.21	16.81
pH	7.9	7.5	7.2	7.3
SIDO	0	0	0	0
SIBOD	90.1211	36.90058	18.53568	68.95248
SICOD	46.55892	17.90334	11.2929	38.21923
SIAN	19.05512	0	0	0
SITSS	90.24141	81.73575	76.75862	87.86736
SIpH	92.3795	96.6875	98.648	98.1155
WQI	52.95487	34.55587	29.44778	45.04869
RESULT	polluted	polluted	polluted	polluted
Note: All the units are mg/L except pH.				

The table represents the WQI (MALAYSIA) value of Dhaleswari river along 4 distinct locations of season 2. The WQI (MALAYSIA) value was found in Polluted category though the index values were quite higher than summer.

Table 4.14 Dhaleshwari Season-2 DoE(Malaysia)-WQI Result

STATION	DO	BOD	COD	AN	TSS	pH	SIDO	SIBOD	SICOD	SIAN	SITSS	SIpH	WQI	RESULT
Hazratpur Bridge	6.22	17	51.11	2.55	30	7.8	0	40.69927	44.1243	19.05512	81.10305	93.638	41.86406	polluted
Dhaleshwari River Bridge	4.83	23	105.37	6.91	20	7.7	0	28.18184	15.48129	0	86.17027	94.7755	32.99186	polluted
Hazratpur	1.02	16	124.41	13.22	24	7.65	0	43.19655	9.63047	0	84.09812	95.29888	34.63978	polluted
South Kamarchar	2.84	18	62	5.35	25	7.66	0	38.33028	36.43302	0	83.58962	95.19662	37.90997	polluted

Note: All the units are mg/L except pH.

The table represents the WQI (MALAYSIA) value of Dhaleswari river along 4 distinct locations of season 3. The WQI (MALAYSIA) value was found in Polluted category and it was observed that the index values were lowest from all other seasons which indicates the most polluted water of all seasons.

Table 4.15 Dhaleshwari Season-3 DoE(Malaysia)-WQI Result

STATION	DO	BOD	COD	AN	TSS	pH	SIDO	SIBOD	SICOD	SIAN	SITSS	SIpH	WQI	RESULT
Hazratpur Bridge	6.24	6.13	33.8	2.57	7.05	6.90	0	76.47759	59.23431	18.70666	93.31483	99.3913	53.67156	polluted
Dhaleshwari River Bridge	4.51	8.32	39.76	5.73	9.95	7.20	0	67.51046	53.58388	0	91.65515	98.648	47.90299	polluted
Hazratpur	1.00	16.5	104.71	16.7	36.41	8.30	0	41.93143	15.71284	0	78.04788	86.1355	33.30495	polluted
South Kamarchar	2.75	13.74	81.65	6.43	25.93	7.70	0	49.35163	25.31734	0	83.12009	94.7755	38.09986	polluted

Note: All the units are mg/L except pH.

The table represents the WQI (MALAYSIA) value of Dhaleswari river along 4 distinct locations 2017 before relocations of tannery industries. The WQI (MALAYSIA) value was found in slightly Polluted category and it was observed that the index values were highest off all seasons at present which indicates the water was in quite better condition at that time than now a days.

Table 4.16 Dhaleshwari Season-2017 DoE(Malaysia)-WQI Result

STATION	DO	BOD	COD	AN	TSS	pH	SIDO	SIBOD	SICOD	SIAN	SITSS	SIpH	WQI	RESULT
Hazratpur Bridge	18.50	3.2	8.41	0.5	1.10	6.95	8.606175	86.864	87.9147	63.08339	96.83268	99.54733	69.36529	slightly polluted
Dhaleshwari River Bridge	9.50	2.8	16.79	0.5	0.80	7	2.141025	88.556	76.7693	63.08339	97.01414	99.35	66.48652	slightly polluted
Hazratpur	8.50	2.5	15.53	0.7	0.60	7	1.649675	89.825	78.4451	56.44081	97.13534	99.35	65.91067	slightly polluted
South Kamarchar	9.60	2.2	21.95	0.4	0.50	7.05	2.192853	91.094	72.09679	66.74593	97.19601	99.21988	66.79541	slightly polluted

Note: All the units are mg/L except pH.

4.4. DoE (Malaysia) WQI Comparison Graph

Figure 4.25 shows WQI value comparison between 3 seasons in 2022-23 and 2017 value. In first season of 2022-23 Buriganga river water classified as polluted as per calculating data. In that season, the most polluted station was Rayer Bazar Khal and least polluted station was Postogola Bridge. In season 2& 3 of 2022-23, the river water classified as polluted also where Rayer Bazar Khal was most polluted and Kamrangi Chor Khal was least polluted in Season 2. And in season-3, Rayer Bazar Khal was most polluted and Postogola Bridge was least polluted. In the graph we can see the WQI value in 2022-23 is comparatively better than 2017 value expect station 3& season-3 [Huzurpara].

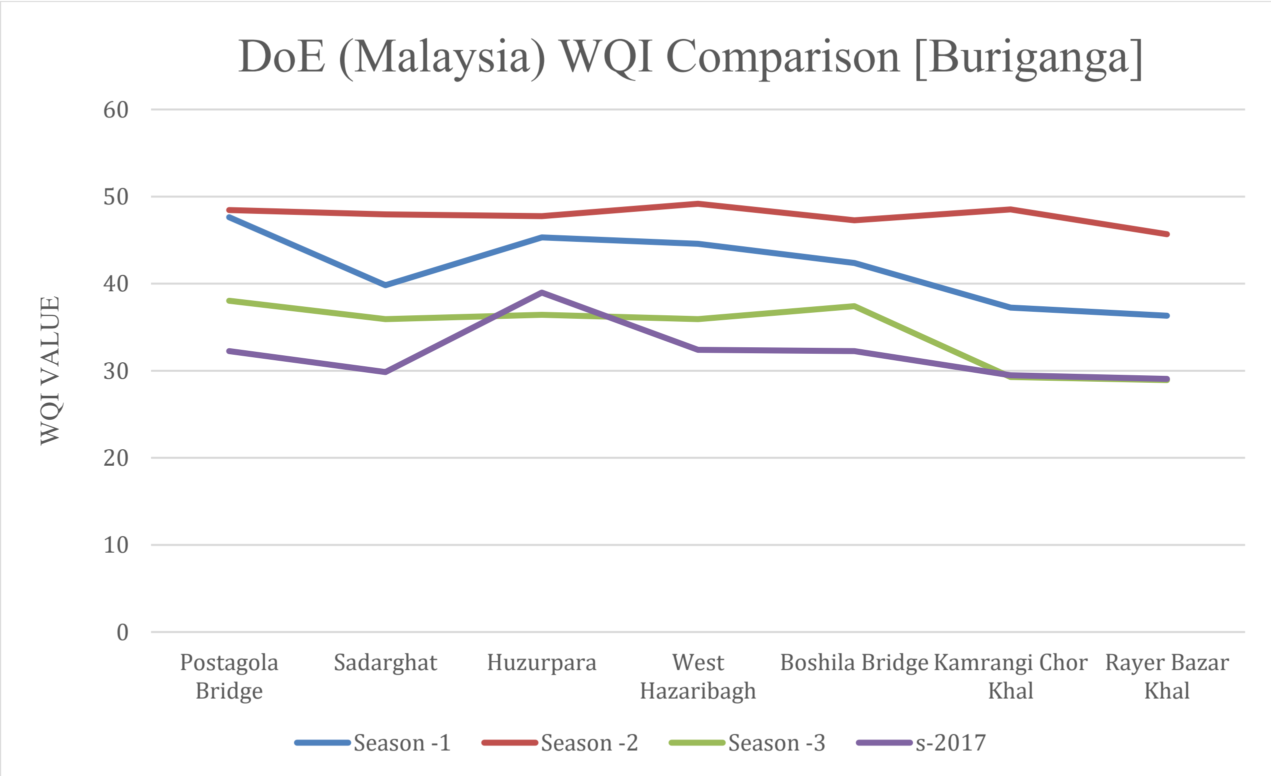

Figure 4.25 WQI Value Comparison of Buriganga river water

Figure 4.26 shows WQI value comparison between 3 seasons in 2022-23 and 2017's value. In the first season of 2022-23 Dhaleshwari river water classified as polluted as per calculating data. In that season, the most polluted station was Rayer Bazar Khal and least polluted station was Postogola Bridge. In season 2& 3 of 2022-23, the river water classified as polluted also where Rayer Bazar Khal was most polluted and Kamrangi Chor Khal was least polluted in Season 2. And in season-3, Rayer Bazar Khal was most polluted and Postogola Bridge was least polluted. In 2017, WQI value at Dhaleswari river was classified as slightly polluted at each four stations.

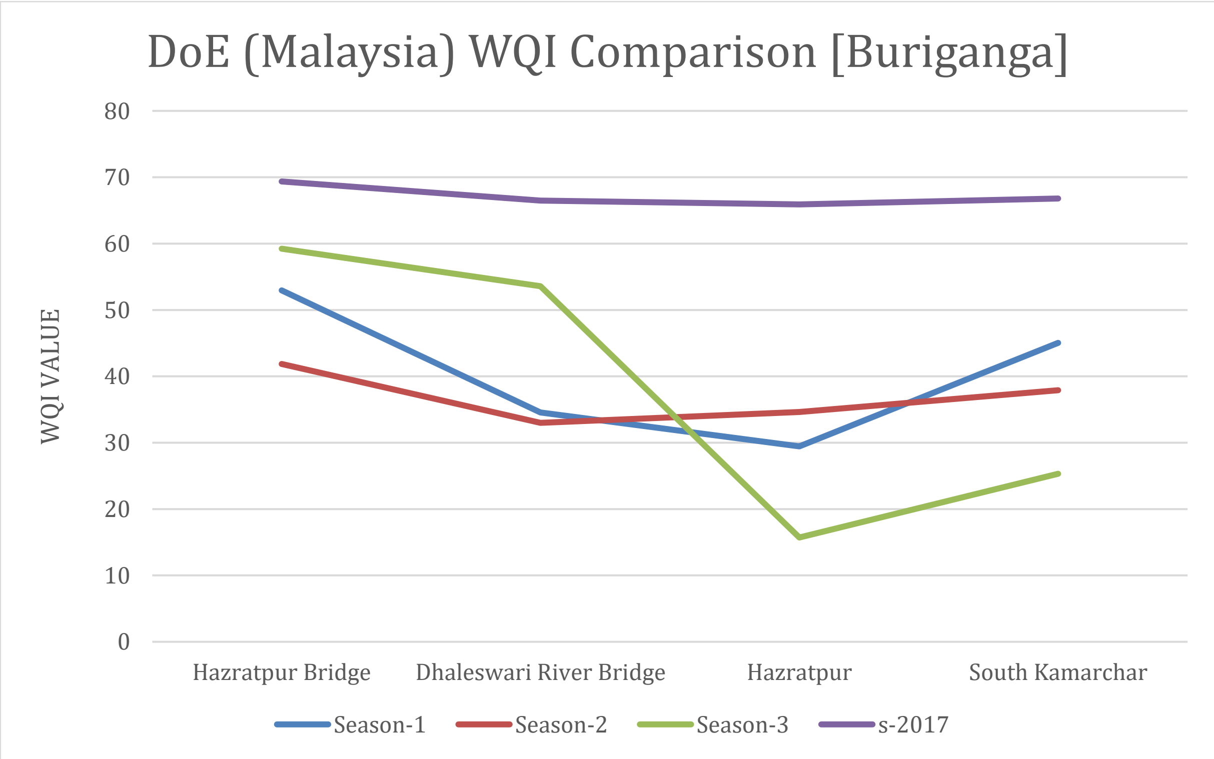

Figure 4.26 WQI Value Comparison of Dhaleshwari river water

4.5. RPI Calculation Table

Table 4.17 shows the river pollution index (RPI) value of Buriganga river stations for season 1. RPI value indicates the water quality of a river. All stations have moderately polluted water except Rayer Bazar Khal. It has severely polluted water.

Table 4.17 Buriganga Season -1 RPI Result

Stations	DO	BOD	SS	NH3-N	Si(DO)	Si(BOD)	Si(SS)	Si(NH3-N)	RPI	Comments
Postagola Bridge	5.79	12.74	10.72	7.23	3	6	1	10	5.00	Moderately polluted
Sadarghat	5.02	15.21	11.85	7.91	3	10	1	10	6.00	Moderately polluted
Huzurpara	5.38	12.95	16.17	7.83	3	6	1	10	5.00	Moderately polluted
West Hazaribagh	5.05	14.2	18.51	8.12	3	6	1	10	5.00	Moderately polluted
Boshila Bridge	5.7	13.02	16.68	7.23	3	6	1	10	5.00	Moderately polluted
Kamrangi Chor Khal	4.51	19.42	28.04	9.05	1	10	3	10	6.00	Moderately polluted
Rayer Bazar Khal	4.41	21.17	27.56	9.79	6	10	3	10	7.25	Severely polluted

Note: All the units are mg/L.

The RPI values of Buriganga river stations for season 2 are displayed in table 4.18. Station 1& 3 have moderately polluted water and others have severely polluted water.

Table 4.18 Buriganga Season -2 RPI Result

Stations	DO	BOD	SS	NH3-N	Si(DO)	Si(BOD)	Si(SS)	Si(NH3-N)	RPI	Comments
Postagola Bridge	4.83	17.5	12.28	8.00	3	10	1	10	6.00	Moderately polluted
Sadarghat	4.25	17	13.63	8.35	6	10	1	10	6.75	Severely polluted
Huzurpara	4.76	16.19	19.87	8.05	3	10	1	10	6.00	Moderately polluted
West Hazaribagh	4.65	18.31	23.71	8.96	3	10	3	10	6.50	Severely polluted
Boshila Bridge	4.71	16.5	21.45	8.00	3	10	3	10	6.50	Severely polluted
Kamrangi Chor Khal	4.13	25.51	37.87	10.23	6	10	3	10	7.25	Severely polluted
Rayer Bazar Khal	4.06	26.43	26.91	11.83	6	10	3	10	7.25	Severely polluted

Note: All the units are mg/L.

The river pollution index (RPI) results of the Buriganga river stations for the third season are displayed in Table 4.19. It provides a simplified way to understand the health of the stations based on various parameters (DO, BOD, suspended solid and NH_3-N). Here most of the stations have severely polluted water.

Table 4.19 Buriganga Season -3 RPI Result

Stations	DO	BOD	SS	NH3-N	Si(DO)	Si(BOD)	Si(SS)	Si(NH3-N)	RPI	Comments
Postagola Bridge	4.33	19.15	15.13	9.39	6	10	1	10	6.75	Moderately polluted
Sadarghat	4.21	22.5	17.84	10.56	6	10	1	10	6.75	Moderately polluted
Huzurpara	4.23	21.33	24.71	10.21	6	10	3	10	7.25	Severely polluted
West Hazaribagh	4.12	20	26.75	11.34	6	10	3	10	7.25	Severely polluted
Boshila Bridge	4.38	18.31	26.00	11.39	6	10	3	10	7.25	Severely polluted
Kamrangi Chor Khal	3.75	33.5	41.50	13.00	6	10	3	10	7.25	Severely polluted
Rayer Bazar Khal	0.79	45	35.00	13.40	10	10	3	10	8.25	Severely polluted

Note: All the units are mg/L.

Table 4.20 shows the RPI values of the Buriganga river stations for 2017. All stations have RPI values above 6, so these stations had severely polluted water.

Table 4.20 Buriganga 2017 RPI Result

Stations	DO	BOD	SS	NH3-N	Si(DO)	Si(BOD)	Si(SS)	Si(NH3-N)	RPI	Comments
Postagola Bridge	0.31	24	27.00	13.65	10	10	3	10	8.25	Severely polluted
Sadarghat	0.28	28	36.00	13.80	10	10	3	10	8.25	Severely polluted
Huzurpara	0.3	12	18.00	13.43	10	6	1	10	6.75	Severely polluted
West Hazaribagh	0.31	22	33.00	13.45	10	10	3	10	8.25	Severely polluted
Boshila Bridge	0.25	24	27.00	13.65	10	10	3	10	8.25	Severely polluted
Kamrangi Chor Khal	0.24	29	41.00	14.50	10	10	3	10	8.25	Severely polluted
Rayer Bazar Khal	0.33	32	38.00	14.75	10	10	3	10	8.25	Severely polluted

Note: All the units are mg/L.

The RPI values of the Dhaleswari river stations for the 1st season are shown in table 4.21. There are four stations and among them three stations have moderately polluted water and one has severely polluted water.

Table 4.21 Dhaleshwari Season -1 RPI Result

Stations	DO	BOD	SS	NH3-N	Si(DO)	Si(BOD)	Si(SS)	Si(NH3-N)	RPI	Comments
Hazratpur Bridge	6.35	5.43	6.47	2.34	3	6	1	6	4	Moderately polluted
South Kamarchar	5.54	9.95	9.3	5.35	3	6	1	10	5	Moderately polluted
Hazratpur	1.3	14.1	24.61	13.22	10	6	3	10	7.25	Severely polluted
Dhaleshwari River Bridge	3.2	13.94	19	6.91	6	6	1	10	5.75	Moderately polluted

Note: All the units are mg/L.

The RPI values of the four stations of Dhaleswari for the second season are shown in table 4.22 Two of them have moderately polluted and other two have severely polluted water.

Table 4.22 Dhaleshwari Season -2 RPI Result

Stations	DO	BOD	SS	NH3-N	Si(DO)	Si(BOD)	Si(SS)	Si(NH3-N)	RPI	Comments
Hazratpur Bridge	6.22	6	6.79	2.55	3	6	1	6	4	Moderately polluted
South Kamarchar	4.83	7.84	9.68	5.61	3	6	1	10	5	Moderately polluted
Hazratpur	1.02	13.9	29.30	14.71	10	6	3	10	7.25	Severely polluted
Dhaleshwari River Bridge	2.84	11.41	22.85	6.91	6	6	3	10	6.25	Severely polluted

Note: All the units are mg/L.

Table 4.23 displays the RPI values of the stations of Dhaleswari river for the 3rd season. These values are almost same as season 2 and two of the stations have moderately polluted water whereas two of them have severely polluted water.

Table 4.23 Dhaleshwari Season -3 RPI Result

Stations	DO	BOD	SS	NH3-N	Si(DO)	Si(BOD)	Si(SS)	Si(NH3-N)	RPI	Comments
Hazratpur Bridge	6.24	6.13	7.05	2.57	3	6	1	6	4	Moderately polluted
South Kamarchar	4.51	8.32	9.95	5.73	1	6	1	10	4.5	Moderately polluted
Hazratpur	1.00	16.5	36.41	16.7	10	10	3	10	8.25	Severely polluted
Dhaleshwari River Bridge	2.75	13.74	25.93	6.43	6	6	3	10	6.25	Severely polluted

Note: All the units are mg/L.

The RPI results of the Dhaleswari river stations for 2017 are shown in Table 4.24. The results were too good compared to recent seasons, one stations had negligibly polluted water and others had unpolluted water.

Table 4.24 Dhaleshwari 2017 RPI Result

Stations	DO	BOD	SS	NH3-N	Si(DO)	Si(BOD)	Si(SS)	Si(NH3-N)	RPI	Comments
Hazratpur Bridge	18.50	3.2	1.10	0.5	1	3	1	3	2	Negligibly polluted
South Kamarchar	9.50	2.8	0.80	0.5	1	1	1	3	1.5	Unpolluted
Hazratpur	8.50	2.5	0.60	0.7	1	1	1	3	1.5	Unpolluted
Dhaleshwari River Bridge	9.60	2.2	0.50	0.4	1	1	1	1	1	Unpolluted

Note: All the units are mg/L.

4.6. RPI Graphs

This graph [4.27] shows the river pollution index (RPI) values of Buriganga river stations. RPI value represents the quality of water. Station 1 has RPI value ranged between 5 and 6.73 throughout the year. In season 1& 2, RPI value were 5 &6, which mean in that time the water was moderately polluted. But in season 3, the station had severely polluted water. On the contrary, in 2017, the value was higher (8.25) which represents severely polluted water. The RPI value of station 2 was 6 in season 1, which represents moderately polluted water and in season 2 &3, the value was equal which is 6.75. So, in these seasons, the water was severely polluted. In 2017, the station had severely polluted water too. In station 3, in 1st two seasons the water moderately polluted and in 3rd season the water was severely polluted. On the other hand, in 2017, the water was severely polluted. The water of station 4 was moderately polluted in season 1, severely polluted in season 2 & 3. But in 2017, the water was severely polluted. Station 5 has moderately polluted water in season 1 and severely polluted water in season 2, 3 & 2017. The RPI value of station 6 shows that the water was moderately polluted in season 1 and severely polluted in other seasons and in 2017. The water of station 7 had severely polluted water in all seasons and in 2017

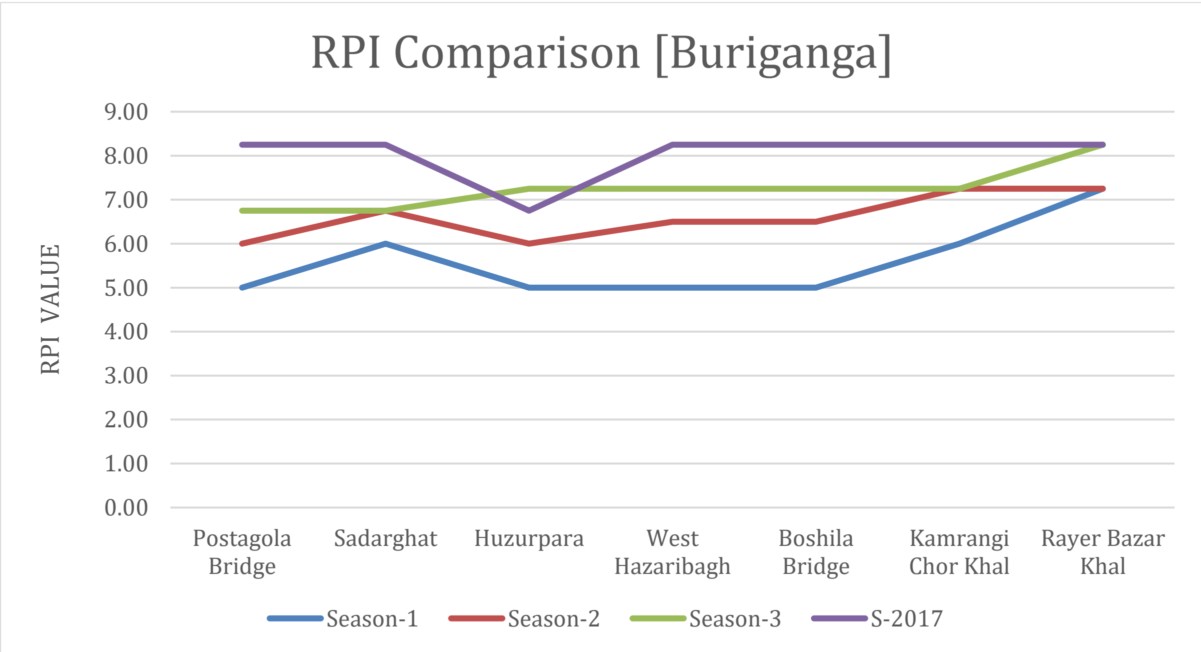

Figure 4.27 RPI Value Comparison [Buriganga]

The graph [4.28] shows the RPI value of Dhaleswari river stations. The RPI value of station 1 was 4 in all season, which means the water was moderately polluted. But in 2017, the RPI value was 2, which means negligibly polluted water. The water of station 2 was moderately polluted in all seasons but in 2017, the water was unpolluted. The water of station 3 was severely polluted in all seasons but unpolluted in 2017. The water of station 4 was moderately polluted in season 1 and severely polluted in season 2. But in 2017, the water was unpolluted.

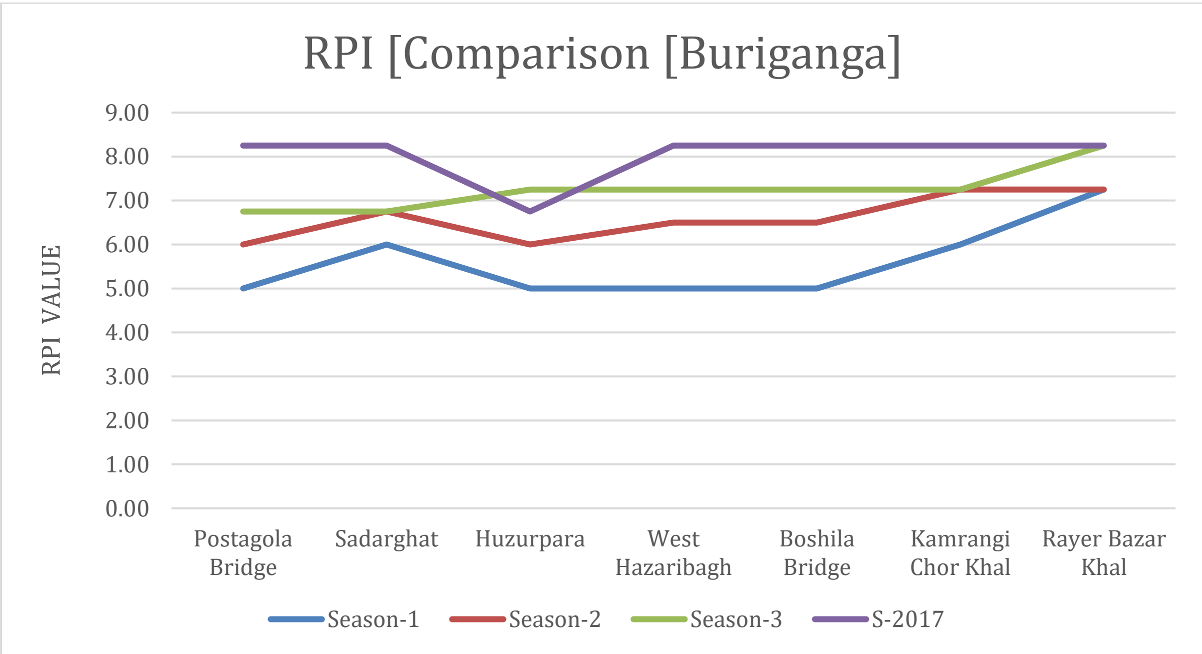

Figure 4.28 RPI Value Comparison [Dhaleshwari]

4.7. CWQI Calculation Table

Table 34 shows the Canadian water quality index (CQWI) results of Buriganga river stations.

Table 4.25 CWQI Results of Buriganga river water

Station	F1 Value	F2 Value	F3 Value	CCME WQI	Category
Postagola Bridge	66.67	44.44	96.2	27.715	Poor
Sadarghat	66.67	61.11	96.58	23.61	Poor
Huzurpara	66.67	63.88	96.34	22.95	Poor
West Hazaribagh	75	63.88	96.55	20.358	Poor
Boshila Bridge	66.67	61.11	96.19	23.77	Poor
Kamrangi Chor Khal	66.67	63.88	97.59	22.43	Poor
Rayerbazar Khal	66.67	61.11	97.92	23.03	Poor

Table 35 shows the Canadian water quality index (CQWI) results of Dhaleswari river stations.

Table 4.26 CWQI Results (Dhaleshwari)

Station	F1 Value	F2 Value	F3 Value	CCME WQI	Category
Hazratpur Bridge	50	50	73.905	40.94	Poor
South Kamarchar	41.67	41.67	93.205	36.3325	Poor
Hazratpur	66.67	61.11	90.59	26.09	Poor
Dhaleshwari River Bridge	58.33	58.33	87.81	49.29	Marginal

4.8. CQWI Graphs

The graph shows the CWQI value of Buriganga river throughout the year based on water quality data of 7 stations of Buriganga river. The value we found was in a range from 20.35 to 27.315. All the values we found was under 44 CWQI value. That means the overall condition of the river was in poor condition throughout the year.

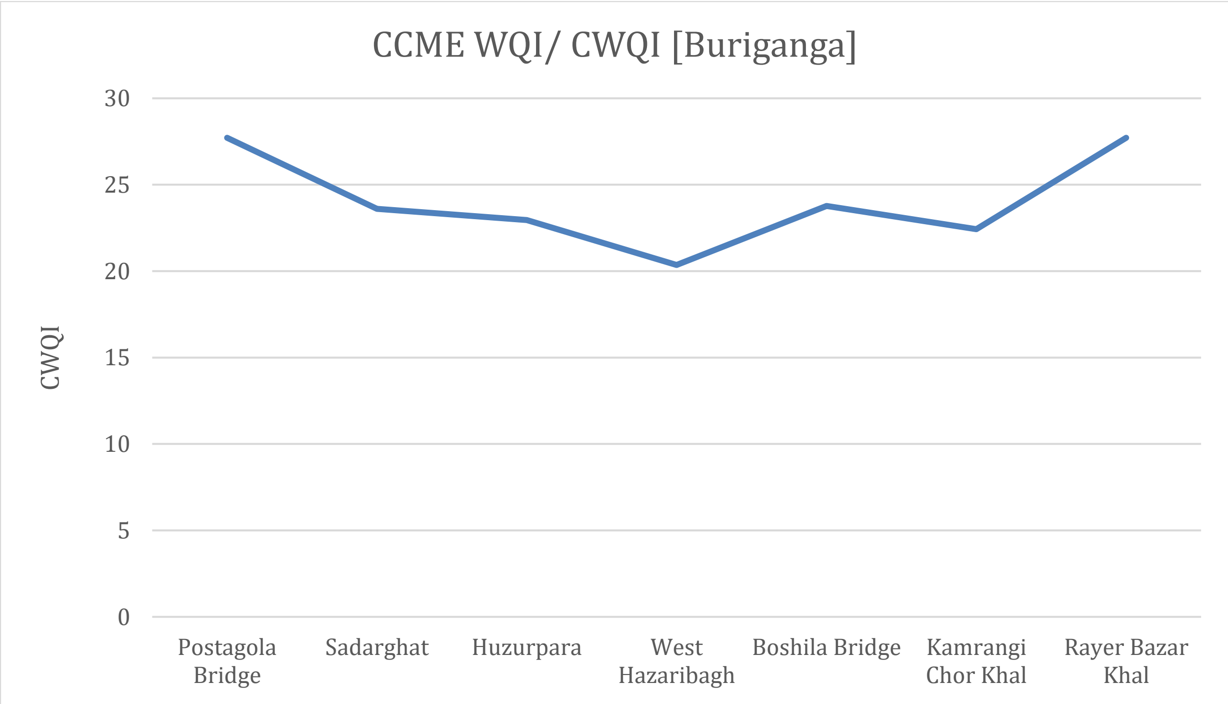

Figure 4.29 CWQI Value [Buriganga]

The graph shows the CWQI value of Dhaleswari river throughout the year year based on water quality data of 4 stations of Dhaleswari river. The value we found was in a range from 26.0911 to 49.2973. Most of the values we found was under 44 CWQI value. That means the overall condition of the river was in poor condition throughout the year.

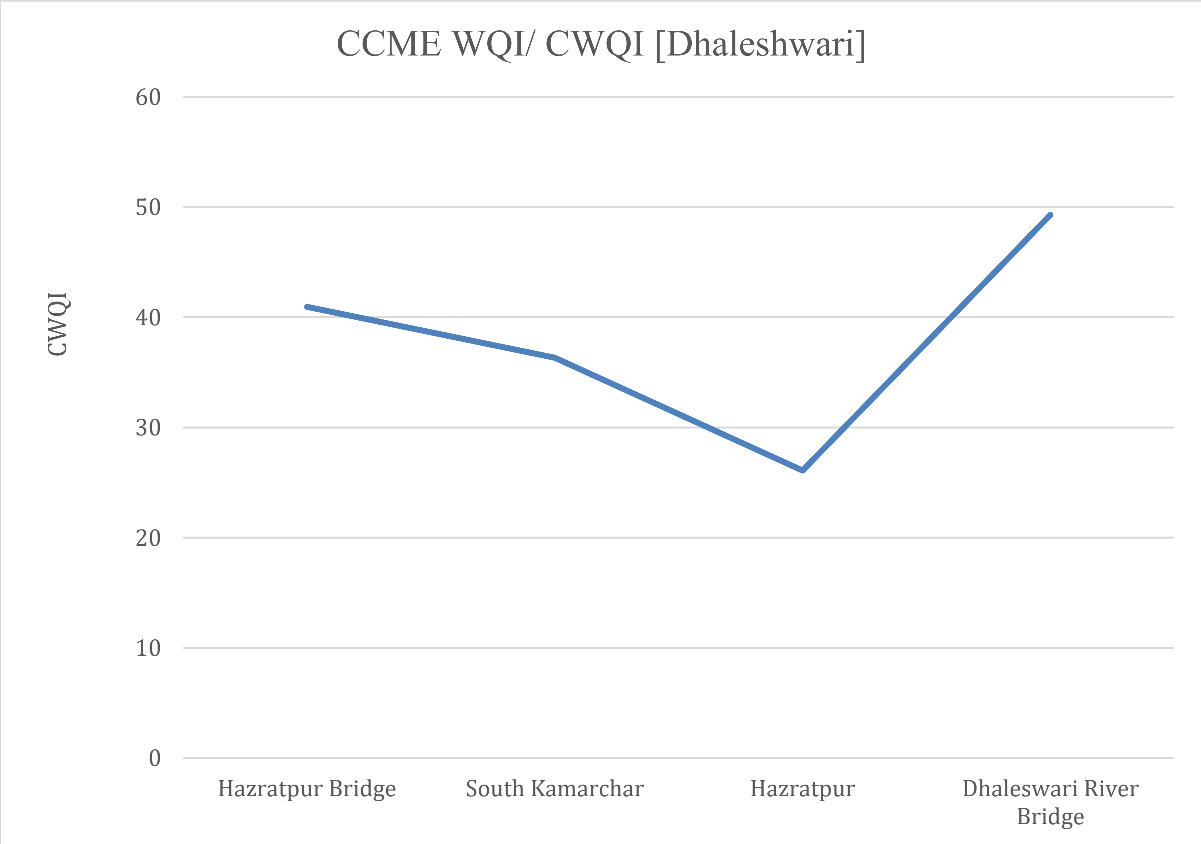

Figure 4.30 CWQI Value [Dhaleshwari]

4.9 Analysis and discussion:

4.9.1. Buriganga river

As samples were collected from 5 distinct locations and 2 canals of the Buriganga river during 3 distinct seasons, we were able to determine several parameters of water quality at those stations. For instance, the BOD value of station 1 ranged from 12.74 to 19.15 mg/L during the three seasons, while the BOD value of station 2 ranged from 15.21-22.5 mg/L and the BOD value of the other stations of the main stream was from 12 to 21.33 mg/L throughout the year. However, the water quality in the canals was considerably worse. Kamrangi Char Khal and Rayer Bazar Khal had BOD values between 19.42 and 45 mg/L. However, based on the BOD value, the overall water quality was significantly improved in 2022-23 than in 2017.

The sample collected from station B2 yielded the greatest concentration of COD, measuring 65.78 mg/L. From 46.45 to 54.66 mg/L, the COD ranged during the first season. In seasons 2 and 3, the COD ranged from 55.31 mg/L to 64.8 mg/L and 60.54mg/L to 65.8mg/L, respectively. Throughout the entire year, the COD concentration was relatively higher in both canals. From 65.32 mg/L to 82.35 mg/L, the COD value of Kamrangi Chor khal. And in Rayer Bazar Khal, the COD ranges between 65.81 and 75.67 mg/L. Which is considerably above the normative values. However, the aggregate chemical oxygen demand was less than in 2017.

The concentration of Ammonium Nitrate in the main stream of the Buriganga river ranged from 7.23 to 11.39 mg/L throughout the year. And the value was considerably less than what we discovered in 2017. However, the concentration of two canals was considerably higher than that of the main stream. The concentration of Ammonium Nitrate ranged from 9.05 mg/L to 13 mg/L at Kamrangi Char Khal and from 9.79 mg/L to 13.40 mg/L at Rayer Bazar Khal.

The annual Nitrate concentration in the main stream of the Buriganga River ranges from 0.50 mg/L to 3 mg/L. In almost every station, the concentration of Nitrate is significantly higher during the summer than during the other seasons. And the concentration ranged from 2 mg/L to 4.50 mg/L for Kamrangi Char khal and from 2 mg/L to 3.50 mg/L for Rayer Bazar khal. The concentration of Nitrate has not changed significantly since 2017.

The typical Orthophosphate concentration in the primary stream of the Buriganga River ranges from 1.35 mg/L to 3.03 mg/L. In nearly every location, the concentration of orthophosphate is substantially higher during the summer than during other seasons. And the concentration varied between 3.02 mg/L and 4.05 mg/L for Kamrangi Char khal and between 3.15 mg/L and 6.17 mg/L for Rayer Bazar khal. The concentration in the canals is considerably higher than that of the main stream.

The temperature of the stream was measured from 23.50 ^{0}C to 25 ^{0}C in season 1. The maximum temperature 25^{0}C was measured from Kamrangi Char Khal. In season 2 & 3 the range of temperature was measured from 20.40 ^{0}C to 22.40 ^{0}C & 23^{0}C to 23.60 ^{0}C respectively. The temperature of the stream was in the limit throughout the year.

In season 1, the electroconductivity of stream water samples ranged from 426.50 (µS/cm) to 540 (µS/cm). And the electroconductivity of the water in two canals was significantly higher.

They had exceeded the limit. In nearly all stations, electroconductivity increased over the next two seasons. In seasons 2 and 3, the electroconductivity ranged from 714.40(µS/cm) to 840(µS/cm) and 838 (µS/cm) to 1200 (µS/cm), respectively.

The pH ranged from 7.35 to 8.15 throughout the course of the year. The pH level was within the acceptable range throughout the entire year. However, the pH level was discovered to be significantly higher in the canals than in the main stream.

In season 1, the TDS concentration ranged from 286.71 mg/L to 325.81 mg/L. The value of TDS found in all stations of the first season was nearly less than the limit. In the second season, TDS values ranged from 439.31mg/L to 571.35mg/L. The Canals' water had a relatively higher TDS concentration. In season three, the value was significantly greater than in seasons one and two. In season 3, the TDS ranged from 510.83mg/L to 625.41mg/L.

Throughout the year, the TSS ranged from 10.72 mg/L to 26 mg/L in the mainstream. The concentration of TSS in the canal was significantly higher. In Kamrangi Char Khal, TSS concentration values ranged between 28.04 and 41.50 mg/L. And throughout the year, the concentration in Rayer Bazar Khal ranged from 27.6 mg/L to 35 mg/L. The concentration was considerably higher than the limit throughout the entire stream.

There was a range of 4.12mg/L to 5.79mg/L for the DO in the majority of the stream. Which is slightly below the acceptable threshold. In season 1, the value of all main stream stations was comparatively higher. Comparatively, the value of the two canals was lesser throughout the year. In Kamrangi Char Canal, the value ranged from 3.75 to 4.25. Throughout the year, the TSS in the general population ranged from 10.72 mg/L to 26 mg/L. The concentration of TSS was substantially higher in the canal. The DO value in Kamrangi Char Khal varied between 3.75 mg/L and 4.51 mg/L. According to the DO value, the Rayer Bazar Khal had the poorest water quality. There was a range of 0.79 mg/L to 4.41 mg/L for the DO value. In contrast, the aggregate DO value has increased significantly in terms of DO concentration.

4.9.2. Dhaleshwari river:

BOD: The BOD values were collected from four stations of Dhaleshwari river. During three seasons, the BOD value of station 1 changed a little and fluctuated between 5.43mg/L and 6.13 mg/L, while the BOD value of station 2 fluctuated between 9.95 mg/L and 8.32 mg/L. In station 3, the BOD value ranged from 14.1 mg/L to 16.5 mg/L and in station 4, the BOD value fluctuated from 13.94 mg/L to 13.74 mg/L throughout the year.

COD: Similarly, COD tests were done in four stations of Dhaleshwari. The COD value of station 1 fluctuated between 28 mg/L and 33.8 mg/L over the course of the three seasons, whereas the COD value of station 2 fluctuated between 29.73 mg/L and 39.76 mg/L. Throughout the year, the COD concentration ranged from 89.48 mg/L to 104.71 mg/L at station 3 and from 98.75 mg/L to 81.65 mg/L at station 4.

Ammonium Nitrate: Throughout the seasons, the Ammonium Nitrate concentration at station 1 varied between 2.34 mg/L and 2.57 mg/L, while the COD concentration at station 2 varied between 5.35 mg/L and 5.73 mg/L. Throughout the year, the COD concentration ranged from 13.22 mg/L to 16.7 mg/L at station 3 and from 6.91 mg/L to 6.43 mg/L at station 4.

Nitrate: In these three seasons, the nitrate concentration at station 1 varied between 0.00 ppm and 0.20 ppm, whereas the nitrate concentration at station 2 varied between 0.40 ppm and 0.5 ppm. Throughout the year, the nitrate concentration ranged from 3.5 ppm to 4 ppm at station 3 and from 1 ppm to 1.5 ppm at station 4.

Orthophosphate: Throughout the three seasons, the orthophosphate concentration at station 1 varied between 0.95 mg/L and 1 mg/L and the concentration at station 2 varied between 1.03 mg/L and 1.27 mg/L. Throughout the year, the concentration at station 3 fluctuated between 3.35 mg/L and 3.90 mg/L, and the concentration at station 4 fluctuated between 2.27 mg/L and 2.40 mg/L.

Temperature: During the three seasons, the temperature at stations 1 and 2 fluctuated slightly between 22 and 23 degrees Celsius, whereas the temperature at station 3 fluctuated between 27.2 and 30.2 degrees Celsius, and at station 4, the temperature fluctuated between 23.6 and 27 degrees Celsius.

Electroconductivity: The EC value of station 1 fluctuated between 254.91 S and 273.66 S over the course of three seasons, while the EC value of station 2 fluctuated between 470.62 S and 492.31 S. Throughout the year, the EC value at station 3 varied between 1007.30 S and 1042.60 S, and the EC value at station 4 fluctuated between 813.21 S and 943.61 S.

Salinity: The salinity value of station 1 varied from 0.20% to 0.60% over the course of three seasons, while the EC value of station 2 fluctuated between 0.30% and 0.60%. Station 3 had similar value as station 1 and station 4 had a salinity value ranging from 0.10% to 0.60% over the course of the year.

pH: The pH value of station 1 fluctuated between 6.90 and 7.20 over the course of three seasons, while the pH value of station 2 fluctuated between 6.90 and 7.30. Throughout the year, station 3's pH ranged between 7.84 and 8.30, and station 4's pH varied between 7.50 and 7.70.

TDS: In station 1, TDS was found between 151.32mg/L and 159.04 mg/L. In station 2, TDS varied from 201.35mg/L to 239.88 mg/L. In station 3, TDS fluctuated between 463.09 mg/L and 561.73 mg/L and TDS varied from 403.81mg/L to 492.19 mg/L.

TSS: In station 1, TSS varied from 6.47 mg/L to 7.05 mg/L and in station 2, TSS was found slightly changed throughout the seasons and the values fluctuated between 9.30 mg/L and 9.95 mg/L, while TSS values ranged from 24.61 mg/L to 36.41 mg/L in station 3 and in station 4, TSS value varied from 19.00 mg/L to 25.93 mg/L.

DO: In station 1& 2, DO was found varied from 6.22 mg/L to 6.35 mg/L and from 4.51 mg/L to 5.54 mg/L respectively, while in station 3, DO ranged from 1.00 mg/L to 1.30 mg/L and in station 4, the values varied from 2.75 mg/L to 3.20 mg/L.

4.9.3. DoE (Malaysia) Water Quality Index:

DoE WQI value was gradually improving at Buriganga since the relocation of tannery industry. Though even now in 2022-23 Buriganga water is classified as polluted as per Doe WQI but the number is getting better day by day.

On the other hand, Dhaleswari River water quality index is rapidly worsening. Dhaleswari Water Quality Index decreases more than 100% at some places. It's alarming and dangerous for both human and aquatic life.

4.9.4. Canadian Water Quality Index (CWQI)

Based on our analysis, the CCME WQI values for the Buriganga river range between 20 and 28. This indicates that nearly all of the stations are in poor condition and that the overall water quality of the river remains poor. In the majority of cases, BOD, COD, Ammonium Nitrate, TDS, and DO values exceeded the annual threshold throughout the entire year. By modulating and decreasing the values of these parameters, water quality can be enhanced. The majority of the time, the pH, nitrate, temperature, and TSS values were within the acceptable range.

According to our analysis, the CCME WQI ranges between 26 and 50 for Dhaleshwari river. Therefore, the water quality of the river Dhaleshwari is also subpar, but it is still superior to that of the river Buriganga. Throughout the majority of the year, BOD, COD, Ammonium Nitrate, TDS, and DO values exceeded the annual threshold. The water quality can be improved by modulating and reducing the values of these parameters. pH, nitrate, temperature, and TSS values were typically within the acceptable range.

4.9.5. River Pollution Index

The river pollution index (RPI) values of Buriganga river stations have been found to be variant throughout the year. RPI value indicates the water quality of a water source. Station 1 has RPI value ranged between 5 and 6.73 throughout the year. On the contrary, in 2017, the value was higher than that which is 8.25. The RPI value of station 2 was 6 in season 1, in season 2 &3, the value was equal to each other which is 6.75. In station 3, in 1st two seasons RPI value were 5 & 6. On the other hand, in 2017, the value was 6.75. The RPI value of station 4 was 5 in season 1 and 6.50 and 7.25 in season 2 & 3 respectively. But in 2017, the value was 8.25. Station 5 has RPI value of 5 in season 1 and 6.50, 7.25 and 8.25 in season 2, 3 & 2017 respectively. The RPI value of station 6 varied from 6 to 8.25. The RPI value of station 7 ranged from 7.25 to 8.25. So, most of the time the RPI value was higher than 6 and it indicates that the water was severely polluted.

The RPI value ranged between less than 2 to 8.25 in Dhaleswari river stations. The RPI values of recent times are much higher than that of 2017. In recent times, most of the stations have severely polluted water whereas, the water of the stations was unpolluted or negligibly polluted in 2017.

CHAPTER 5. CONCLUSISONS AND RECOMMENDATIONS

5.1 Conclusions

Major conclusions from this study may be summarized as follows:

- It is revealed that the BOD values indicate that the water of both rivers was heavily polluted and the water quality in the two canals (Kamrangi Char Khal & Rayer Bazar Khal) of Buriganga was noticeably worse than the other part of Buriganga. However, based on the BOD value, the overall water quality was significantly improved in 2022-23 than in 2017.
- The highest value of COD was found in Dhaleshwari river bridge which was 98.75 mg/L. But the aggregate chemical oxygen demand (COD) of Buriganga was less than in 2017.
- It is found that Ammonium Nitrate concentration value was considerably less than what we discovered in 2017.
- It is revealed that the nitrate concentration has not changed much than 2017. The concentration value ranged from 0.50 to 4ppm in Buriganga whereas, it was varied from 0 ppm 3.5ppm in Dhaleshwari.
- The orthophosphate values ranged from 1.35mg/L to 6.17 mg/L in Buriganga and from 0.95mg/L to 3.90mg/L in Dhaleshwari.
- The electroconductivity values varied from 426.50 µS/cm to 1200 µS/cm in Buriganga and from 254.91 µS/cm to 1042.60 µS/cm in Dhaleshwari.
- The pH ranged from 7.35 to 8.15 throughout the course of the year in Buriganga and it fluctuated between 6.90 and 8.30 in Dhaleshwari.
- Most of the river pollution index values of both rivers are higher than 6 which indicates that the water of these rivers is severely polluted.

5.2. Recommendations

The recommendations for the future study are given below

- The water samples can be collected from more stations in both of the river.
- The water samples can be collected a few more times of a year to understand the real condition of the water quality of the river more precisely
- A few more tests can be conducted like color, turbidity, fecal coliform, or heavy metal tests to understand the actual water quality.
- Some more indices like Heavy Metal Pollution Index, NSF WQI can be done to identify the impact of relocation tannery industries in both rivers.

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