SPATIO-TEMPORAL POLLUTION TREND OF BURIGANGA RIVER

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

Farah Ahmed Turin

Dedicated to

My Family

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ABSTRACT

This study focused on the identification of some water quality parameters of Buriganga river adjacent to Dhaka City. In this study, a portion of Buriganga river from Showary ghat to Pagla has been selected as the study reach to assess the existing water quality during the wet season of the year 2022 and dry season of the year 2023. Water samples were collected from twelve monitoring locations along this reach during that period. Different water quality parameters have been assessed in this study including pH, DO, EC, Color, COD, BOD_5, NH_3-N, H_2S and Cl^-. Heavy metals (Chromium, Lead) have been measured during the month of March, 2023. In-situ test was performed for some parameters like pH, DO and EC. Spatial and temporal variation of Buriganga river water quality have been assessed in this study through graphical analysis and comparing with previous studies.

DO concentration was higher in the rainy season than in dry season. Maximum dissolve oxygen in rainy season was found 4.24 mg/L at Posta in October 2022. Minimum DO was found in Showary ghat in March 2023. EC was observed 169 to 185 μS /cm in wet season and 542 to 852 μS /cm in dry season. BOD_5 in the rainy season is lower than dry season. Maximum BOD_5 was found 128 mg/l in March 2023 at Pagla and minimum BOD_5 was found 1.0 mg/l in October 2022 at Showary ghat. COD value was found 8.0 to 42.0 mg/L in the rainy season; whereas in dry season it was much higher from 51.0 to 316.0 mg/L. Average BOD_5 to COD ratio was found less than 0.30, which indicates that the amount of non-biodegradable organic matter is higher than biodegradable organic matter in Buriganga river. Chloride concentration was found lower (9.0 to 17.0 mg/L) in wet season and during dry season the value rises 30.0 to 67.0 mg/L. Other parameters like NH_3-N, H_2S are higher in dry season than rainy season. Pollution load in Buriganga river increases during dry season and washed out during monsoon. Pollution trend from previous data indicates that pollution load has increased during the last 50 years. Minimum DO concentration decreased almost six times during 1968 to 2023 in Buriganga river, Maximum Chloride concentration has increased around 12 times during that period and change of maximum BOD_5 concentration was Observed almost 14 times during last 23 years(2000-2023).

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LIST OF ABBREVIATIONS

ASCE	American Society of Civil Engineers
BMD	Bangladesh Meteorological Department
BOD	Biochemical Oxygen Demand
BWDB	Bangladesh Water Development Board
CBOD	Carbonaceous Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
DoE	Department of Environment
DWASA	Dhaka Water Supply & Sewerage Authority
EC	Electrical Conductivity
ECR	Environmental Conservation Rule
GoB	Government of Bangladesh
GPS	Global Positioning System
IFCDR	Institute of Flood Control & Drainage Research
IWM	Institute of Water Modeling
JICA	Japan International Cooperation Agency
TS	Total Solids
TSS	Total Suspended Solids
US	United States
USEPA	United States Environmental Protection Agency
WWTP	Waste Water Treatment Plant
NPS	Non Point Source
DCC	Dhaka City Corporation
BIWTA	Bangladesh Inland Water Transport Authority

Chapter One

INTRODUCTION

1.1 General

Water is a precious resource for living species on earth. Without water survival is impossible. Other planets have no water like earth so that living species cannot survive there. Out of 100% water on earth, 97% is reserved in Sea and Ocean which is saline and unusable normally. Only 3% water considered as fresh water and out of this 2% is stored as ice and glaciers which also unavailable water (Gray, 2010). The remaining 1% water stored in lake, canals and underground which is the only source of consumption. Proper management and sustainable planning is very much needed to sustain life on earth. Before industrial revolution it was rare to think about water scarcity and water pollution. But after suffering many health hazards due to water pollution it was become prime concern (Akinpelu *et al.,* 2020). In recent years, many developed countries like USA, Japan and South Korea developed efficient technology and national plan to ensure safe water to people. Most of the industries were established on the bank of the rivers. Thousands of tons of waste materials have been releasing into the river water every day (Rahman *et al.*, 2010). There are rules and regulations but they do not obey it properly. Some industries have effluent treatment plant (ETP) but they do not like to run it due to high profit goal (Hossain *et al., 2010*). As a result, river water become toxic for living biota. Agricultural area close to the polluted river are affected as well (Huq *et al.,* 2019). Farmers using this polluted water for irrigation made the toxic materials to enter into the food chain and ultimately come to human. The poor usually use this polluted water for washing and cooking, which is very harmful (Rajonee *et al.,* 2016). Rivers especially surrounding the city are becoming more polluted because of industrialization. Buriganga, Turag, Balu and Sitalakhya are the surrounding rivers of capital city Dhaka, which are in severe condition at present. Buriganga is called a dead river because of the quality of water. During summer season, the physical appearance of the water is dark black like burned Mobil (Islam *et al.,* 2019). Toxic liquids, oils and Mobil's and tons of iron materials were washed into the river water. This toxic water is used as irrigation water in many parts of the lower basin area (Siraj *et al.,* 2013).

Buriganga is one of the most polluted rivers in Bangladesh. A big number of the industries of Dhaka are situated on the banks of the Buriganga or very close to the river system.

Extensive part of urban manure and wastes which are contributed from the domestic level of the Dhaka city is also thrown in the Buriganga river (Moniruzzaman *et al*., 2009). Although Bangladesh is predominantly a plain surface, it is crisis-crossed by a very high density river system. Directly indirectly Bangladesh depends on its river system for various purposes like as fishery, agriculture, sanitation, navigation, drainage, forestry and control of salinity. The river system of Bangladesh contribute to control settlement patterns, domestic water supply, communications and indirectly, in sanitation and health. However, a number of rivers in this country have become biologically and hydrologically dead due to the indiscriminate dumping of domestic and industrial wastes, intrusion by corrupt people (Moniruzzaman *et al*., 2009). Several studies show that the Buriganga is severely polluted comparatively others rivers of the country (Ahmed *et al*., 2011). The pollution is the great and multifaceted problem in country Because of its multi- dimensional nature. Pollution control is the involved multi phenomena such as social, economic and environmental magnitudes which are associated to water pollution management issues that need to be jointly addressed while seeking a sustainable solution (Rahman and Bakri, 2010). Surface waters are more susceptible to influential people are continuously grabbing the contamination due to their easy convenience for dumping river banks (Ali *et al*., 2008).

Buriganga river, the life line of Dhaka city is considerably most polluted among the surrounding four rivers around the city (Sarker, 2005). In recent years, both the width and the flow rate of the river have reduced due to the building up of illegal man-made structures and waste dumping in the banks of the river. The changes in hydro-dynamic properties of the river is also influencing the self-cleansing property of the river. With increasing pollution load, the sign is very alarming for the existence of the river. The most significant sources of wastewater in the river are industries along the bank of the river. There are 627 dying industries located beside the Buriganga river and near 5000 cubic meter effluents are discharged every day from these industries (Ahammed *et al.,* 2016). Previous studies also identified 22 large industrial outlets along the Buriganga river (Rahman and Bakri, 2010). The existing sewerage system is quite old and major northern parts of the mega city Dhaka is still out of sewerage coverage (DWASA, 2014). Lack of adequate sewerage system results in direct discharge of municipal waste into the river or nearby water body which is eventually carried out to the Buriganga river. These untreated wastes are harmful for existing aquatic ecosystem and water quality in the river. The situation is even worse during dry season with reduced water flow and low rainfall flushing. In order to ascertain the overall impact on surface water quality, identification of wastewater sources and characterization of discharge sources are important. In addition, it will be of interest to analyze the distribution of water quality parameters along the river to evaluate the water quality profile of the river stretch and identify pollution zones in the river.

Hydraulically, the Buriganga is not an inaccessible river. Total length of the Buriganga riveris 27 km (banglapedia.org). Mean width of the river is nearly 500 m. (Rahaman and Rana, 1996). The Dhaka city is one of the most densely populated capitals in the world, home to approximately nine million people of which process for pollution control in environment protection less than 25% are served by sewage treatment facility (Kamal *et al*., 2007). Various activities to responsible for polluting Buriganga river most of them are natural and human activities compelled changes in the Buriganga river and the rivers around Dhaka city have in the winter seasons of the last decades caused a complete apprehension about the deteriorating quality of Buriganga deterioration of water quality. Due to the dumping of huge volume of toxic wastes of city's thousands of industrial units and sewerage lines, the river Buriganga is being polluted enormously day and night. This scenario increased unexpectedly day by day (Ahmad *et al*., 2010).

The water quality of the Buriganga river is too poor to be considered as safe for human consumption. Already the minimum dissolved oxygen (DO), the prime indicator of water quality, has been found to be less than the desirable level for certain sections of the Buriganga river. Therefore, all the parameters indicate that the water quality in the Buriganga river is worse than the required standards, particularly in the dry season because of the low dilution factor created by the low flows in the river. During this time, the tidal nature of the flow causes pollutants to movein both directions and leads to a worsening of the problems. The river turns deadly for fish and other organisms during this lean season. Once the level of water quality parameters drops to such an extent and the fish and other aquatic species die, it is almost impossible for the river to recover later on (Hossain *et al* 2010; Alam *et al*., 2007) . Generally, the flow of the Buriganga river is non-tidaland tidal during the wet and dry seasons respectively. The tidal range is between 6.0 and 8.0 m. However, the Buriganga is fed mainly by the Turag river, which receives flows from local rainfall andspill flows from the left bank of the Jamuna river.

Efforts have been made in previous studies to investigate the surface water quality in the Buriganga river to understand seasonal and temporal variation of water quality parameters.

(Rahman and Bakri, 2010; Saifullah *et al.*, 2013; Ahammed *et al.*, 2016; Sarkar *et al.*, 2015). The waste loading from potential sources in the Buriganga river was estimated in the study by Kamal *et al.* (1999) along with the investigation of pollution status in the river. Water has fundamental importance for ecosystems and the environment. The Buriganga river water is not used directly for drinking, but, as a resource for bathing, swimming and washing clothes, it is still widely used. Therefore, it is necessary to monitor the water quality of the Buriganga river to determine whether the water is safe for various uses.

1.2 Objective

The overall objective of this study was to assess the water quality of Buriganga river, particularly focusing on the spatio- temporal variation of water quality. The study focused on assessment of the present status of water quality of the Buriganga river, in terms of selected water quality parameters including pH, DO, BOD_5, COD, Cl^-, Color, EC, NH_3, H_2S, Chromium (Cr) and Lead (Pb) concentration during dry and rainy season and comparing the water quality parameters with previous data from different studies. Specific objectives of the study include:

a) Assessment of spatial variation of water quality of Buriganga river at selected points.
b) Assessment of temporal variation of water quality of Buriganga river at selected points.
c) Assessment of pollution trend of Buriganga river.

1.3 Scope and Methodology

In this study, a certain portion of the Buriganga river from Showari ghat to Pagla were selected as the study reach to assess the existing water quality. In fact, almost all major urban and industrial establishments are located within this reach of the river, and the water quality of the river is affected by the domestic and industrial effluents generated from these establishments. In order to assess spatial variation of water quality, river water samples were collected from four sampling locations of twelve points of Buriganga river during the months of August and October of the year 2022 and January and March of the year 2023. These sampling locations are, Showari ghat, Sadar ghat, Postagola and Pagla. Again, samples are collected from three points along the cross section of each location. In-situ field measurements of dissolved oxygen (DO), pH, temperature and electric conductivity have been carried out at each sampling location. Chemical Oxygen Demand (COD), 5-dayBiochemical Oxygen Demand (BOD_5), ammonia, hydrogen sulfide, color, chromium and lead concentrations have been analyzed in the laboratory following Standard Methods.

This study is very important to provide an up to dated report on the status of water quality of the Buriganga river. This study carries great importance to deliver the information about present state of water quality of the Buriganga river. This is because water quality is the continuous processes, so update data is more useful for maintaining water quality and monitoring. Subsequently this study could be used for creating continuous water quality database. Therefore, a comprehensive experimental research was required to evaluate the present status of the water quality of Buriganga river. In this regard, this study aims to investigate seasonal variation of physiochemical water quality in terms of some selected parameters, along the Buriganga river for both winter (January and March) and rainy (August and October) seasons. The pollution trend of Buriganga river is assessed here by collecting data from different papers, journals, thesis etc. The standard deviation of the water quality test results and mean values were compared in terms of the DoE standards and WHO guidelines. The acquired water quality results were summarized and presented through tabulated form and graphical analysis.

1.4 Organization of the Thesis

This thesis consists of five chapters. Apart from this chapter, the remainder of the thesis has been divided into four chapters.

Chapter 2 provides a brief review of relevant works on the water quality of the Buriganga river and an overview of water quality standards. Theory of water quality parameters, river water pollution, types of pollution, pollution sources, importance of the river have been discussed in this chapter.

Chapter 3 presents the methodology followed in this study, including selection of sampling locations and major point sources, in-situ water quality data collection and water sampling procedure, laboratory analysis of water samples collected from Buriganga river, secondary data collection etc.

Chapter 4 presents the characteristics of Buriganga river based on water quality data assessed in this study. It also shows the spatial and temporal variation of water quality of Buriganga river through table and graphical analysis. Pollution trend of Buriganga river from 1968 to 2023 is assessed. This chapter presents the concentration of heavy metal in selected locations and compare the data with water quality standards.

Chapter 5 Chapter contains the conclusions of the study, recommendations and suggestions for future studies and possible measures of pollution control of Buriganga river.

Chapter Two

LITERATURE REVIEW

2.1 Introduction

The Buriganga river system is located in the southern part of the north central region of Bangladesh, passing through west and south of Dhaka, the capital of Bangladesh. The river receives wastewater from numerous pollution sources along its way, which are discharged as industrial effluents, municipal sewage, household wastes, clinical wastes and oils. Buriganga river, the lifeline of Dhaka city is considerably most polluted among the surrounding four rivers around the city (Sarker, 2005). In recent years, both the width and the flow rate of the river have reduced due to the building up of illegal manmade structures and waste dumping in the banks of the river. The changes in hydrodynamic properties of the river is also influencing the self- cleansing property of the river. With increasing pollution load, the sign is very alarming for the existence of the river. The most significant sources of wastewater in the river are industries along the bank of the river. There are 627 dying industries located beside the Buriganga river and near 5000 cubic meter effluents are discharged every day from these industries (Ahammed *et al.*, 2016).

2.2 Previous Studies on the Buriganga river

JICA (1987) reported the data on water quality analysis for Hazaribagh (1983-85), Chandnighat (1983-85) and Farashganj (1985) on the Buriganga river. The BOD_5 variation was 1-90 mg/l.However, the most frequent range of BOD_5 variation was 3 to 5 mg/l. The DO variation was between 0 to 9 mg/l.

Mohammed (1988) reported a comparison of sampling data of the Buriganga river water near Chandnighat during 1968-80 period. It is apparent from the study that DO level has decreased considerably during 1968-80. While average DO during 1968 was 6.7 mg/l, it came down to 3.3 mg/l during 1980. The average BOD_5 value increased almost fourfold during that period. Number of coliforms also increased considerably during the same period. In February 1987, Mohammed conducted a sampling procedure of the Buriganga river. Six different sampling stations were established along a 10 miles stretch of the river starting from 6 miles upstream of Pagla outfall upto 4 miles downstream. Six samples were taken from different depths at each sampling station.

It was further assumed that the concentrations of BOD_5 and DO were uniform over the cross section of any river station. Since, in most cases, there is daily variations in pollution loads, flows, temperature, oxygen produced by photosynthesis throughout 24 hours etc, the assumption of steady state condition introduces errors.

Azim (1992) reported results of two sampling programs. One during monsoon, when the DO values at different locations were 6 mg/l or above which indicated that there was no problem. During dry season, except two locations, the DO values were all above 6 mg/l. DO value just downstream of the Dholai khal was 1.2 mg/L which is much below than the standard limits set for fishing and bathing. Coliform values were very high during the lean flow period.

The DoE (1992) maintains three monitoring locations along the Buriganga from which samples are collected on an irregular basis. The choice of DoE sampling stations is based mainly on the location of different industrial setups along the river banks mainly to assess the impacts on water quality due to effluent discharges. According to the study, the major rivers in Bangladesh are in good condition and well within the proposed national standards (DoE, 1991) of relevant four parameters. Only the Balu river during the dry season and the Buriganga at the Hazaribagh location are unacceptable in terms of pollution according to the 1990 results. The Buriganga river is comparatively the major polluted river in Dhaka with Hazaribagh station being the most polluting station. The DoE found that the Dissolved Oxygen (DO) concentration at Hazaribagh falls below 2 mg/l in May. Whereas for fish, the DO should be at least around 4 mg/L. Total solids and Chloride were also very high there. The estimated discharge from Hazaribagh into the Buriganga is around 15000 kilograms of BOD per day (Browder, 1992). They mentioned that Hazaribagh main effluent drain discharges wastewater from tanneries which contains high levels of COD in the order of 1100 mg/l and Chromium at around 1.15 mg/L whereas suitable standard for industrial water is around 200 mg/l for COD and 0.5 mg/L for Chromium.

Browder (1992) carried out a comprehensive study regarding the status of pollution of the Buriganga. Two approaches were used by Browder to estimate the mass of pollutants generated and discharged to the outside environment: dry study approach and wet study approach. In the dry study approach, population zones were defined first. Then, using information about population under sewered/unsewered system and the per capita contribution of BOD_5 load, resulting BOD_5 loadings from the zones to the environment were computed. The wet study involved actually measuring the flow and concentration of various pollutants at the discharge point into receiving water bodies. Reasonable estimates were then made based upon the wet and dry study results.

Browder (1992) found that domestic wastewater produces approximately 88% of Dhaka's BOD_5 load while industrial sources account for the remaining 12%. He opined that those figures were consistent with other large South Asian cities which did not have a large industrial base such as Dhaka. The total amount of BOD discharged in Dhaka was estimated by Browder as 182 tons per day. Of that amount, approximately 55 tons were being treated at the Sewage Treatment plant which used to lower the BOD load to approximately 5 tons per day. The remaining 127 tons per day of BOD was being discharged through the storm water conveyance system to receiving water bodies. Browder then estimated that approximately 65 tons of BOD per day, representing about half of the total BOD load, was being discharged to the Buriganga. Contribution form Hazaribagh discharge was estimated to be about 30% of the total load being discharged to the Buriganga. Discharges to the Turag river, which is a tributary of the Buriganga, were estimated approximately 14 tons per day, representing about 10% of the total BOD. Finally, Browder identified that there were four main pollutant discharge routes into the Buriganga: (i) Hazaribagh Tanneries, (ii) City Drains along the river, (iii) Dholai khal, and (iv) Pagla Sewage Treatment Plant.

Browder (1992) described the Dholai khal as the largest source of pollution with an estimated discharge of 35 tons of BOD per day. Hazaribagh was the next largest source of pollution with an estimated discharge of 15 tons per day of BOD. The city drains were considered to account for 10 tons of BOD per day and the Pagla Sewage Treatment Plant discharges approximately 5 tons per day of BOD. Seven monitoring locations along the Buriganga were chosen by Browder. All seven locations were monitored on the same day within a three-hour period in order to get a snapshot of the river. Monitoring was undertaken in the following months: May, July, November and February, 1991- 1992, in order to obtain seasonal data.

Karim (1992) found that minimum DO concentration is higher for the post-embankment period than that of pre-embankment period for the month of June. Situation also improved during post-embankment period with respect to BOD, Chloride and Suspended Solid. He attributed this improvement to the accumulation of pollutants within the embankment area. Ahmed (1993) reported the pollution load from industries in and around Dhaka. The discharges were estimated as 49000 kg/d of polluting load (BOD) in the river.

Ahmed (1993) opined that the polluting industrial load along with anapproximately equal amount of BOD load from domestic sewage and other municipal wastes reaching the river system was responsible for the pollution and degradation of the quality of the rivers around the Dhaka city. Ahmed showed the expected improvement in DO profile after implementation of pollution control measures.
It is seen that pollution control measures including discontinuation of tannery waste discharge in the river and upgrading of DWASA sewage treatment plant significantly improves the DO situation in the Buriganga in lean flow period.

The Institute of Flood Control and Drainage Research (IFCDR) of BUET (1994) carried out a research project entitled "Management of Buriganga river Water Quality under Alternative Scenarios". The main objective of the research work was to formulate appropriate water quality management programs under different scenarios. A hydrodynamic (HD) model, using MIKE 11 river modelling system, was calibrated (for 1989-90 and 1990-91) and verified (1991-92 and 1992- 93) for the Buriganga river system. Calibration and verification showed good matching with observed water level data. The HD model was used for determining hydraulic parameters of the Buriganga river, which were then used for a water quality model. DO profiles were simulated at different levels of flows. When violation regarding water quality standards were detected, then a linear program was run to determine maximum allowable loads. Approximate management program was then suggested. It was assessed that considerable waste load can be assimilated by the river, if they are properly managed, without violating the water quality standards. However, it was remarked that future pollution load would pose considerable water quality problem, and the Pagla Sewage Treatment Plant would need to be expanded to handle extra loading. As a recommendation for future study, an unsteady water quality model has been suggested which is expected to provide further insight into the water quality problem. Also, study on the effect of Nitrogen, Phosphorus and algae on DO has been recommended. In this research work, the HD model was calibrated and verified against observed water levels only. Good matching of simulated water levels with observed values may not ensure the correct volume of flows, i.e. discharge from a model. But, discharge is of prime importance in water quality assessment of a river. Therefore, the discharges considered in the study for various analyses might not be representative of the actual discharges in the Buriganga. Basically, the research opined that, either a treatment plant should be established at Hazaribagh to treat tannery waste or shifting of tannery units to Saver would provide considerable opportunity to properly manage the Buriganga river waterquality.

Rahman and Rana (1995) had studied the management of Buriganga water quality under alternative scenarios. They opined that either a treatment plant should be established at Hazaribagh to treat tannery waste or shifting of tannery units to Saver would provide considerable opportunity to properly manage the Buriganga river water quality.

Kamal (1996) tried to investigate the status of the Buriganga river water quality in terms of some water quality parameters and to simulate the dissolved oxygen (DO) level using a water quality model. He had carried out a data acquisition program from both in situ and laboratory testing. Then he developed a one-dimensional water quality model for the Buriganga river system for a dry period of 1994-95. Different scenarios were then tested to predict the most likely condition of the river by using his model. The results of the model simulations showed a low DO level in the Buriganga. He had shown that an integrated approach would be required to restore the river water quality with regard to biodegradable pollutants.

Alam (2003) reported that the city part of the Buriganga river has become biologically and hydrologically dead because of the indiscriminate dumping of domestic and industrial wastes, encroachment by unscrupulous people, and the negligence on the part of the authority to enforce rules and regulations pertaining to the ecological health of the river. A cleanup program was designed for the Buriganga river to restore its water quality and develop new facilities in and around the river in his research. He found that not only a significant proportion of the respondents are willing to pay for environmental improvements, but also they are willing to contribute in terms of time. It is estimated to be about 60.55 % of the total WTP (Willingness-to-pay) value. The banks of the river have turned into unauthorized industrial districts. There has been unauthorized occupation on bank-side and illegal encroachment into the river.

Magumdar (2005) tried to investigate and assess the water quality in the peripheral rivers of Dhaka city. He reported that Dhaka city is surrounded by a circular river system. The river system includes the Turag river, Buriganga river, Dhaleswari river, Lakhaya river, Balu river and Tongi khal. He pointed out that sufficient quantity of water remains in the rivers during the five months of monsoon season but the flows are practically nil during the dry period except tidal backflow from the Meghna river. The river system receives solid wastes, sewage and wastewaters discharged from domestic, commercial and industrial activities both within and outside the city. This study has put best efforts to give an overview about the present contamination scenario of the peripheral river system around the city including historical trend of the pollution.

The focus of the study of Alam (2008) was to perform a cost-benefit analysis to determine the economic efficiency of the restoration of Buriganga river. He has derived the benefits ofthe restoration program by using market data and employing benefit transfer and contingent valuation techniques. The values generated by this approach are then integrated into the framework of a cost– benefit analysis, which showed a benefit-cost ratio of 4.35. This study demonstrates that the restoration of dying rivers in developing countries is not only an environmental imperative but is also socially and economically justifiable.

Subrata (2008) has focused on the present scenario of water quality, historical trend of water quality and percent increase of BOD_5 loading. Data of water quality analysis in biological and chemical parameters were presented, analyzed in tabular and graphical form in that study. Subrata explored that, the cross-sectional area and depth reduces by tilling waste loads day by day and somewhere increases by unplanned dredging. Shrinking of river bed is found due to the heavy BOD_5 load, sedimentation and bank encroachment. According to his study, from 1968 to 2007 maximum BOD_5 of the river at Hazaribagh area increases from 0.8 to 60 mg/l and DO reaches 6.7 mg/l to zero in most places. BOD_5 loading from industrial origin has increased at all industrial clusters from 1994to 2006. He showed that, increase of BOD_5 load was 37% in Tongi, 82 % in Hazaribagh, and 87% in Narayanganj. In that research, several approaches had been mentioned to restore the water quality of Buriganga river.

Mihir (2009) tried to analyze the bacterial load and chemical pollution level of the Buriganga river. According to his research, anthropogenic effects have seriously affected the physiochemical and biological conditions of the river. By considering this situation and fact, the work was undertaken to determine aerobic heterotrophic and enteric bacteria to the context of biological pollution level along with the physio- chemical properties to reveal an overall status of pollution of the river Buriganga.

This study of Moniruzzaman (2009) was conducted to determine the pollution level of Buriganga river water. Field investigation was started from June 2004 and sample collectionwas conducted six times at an interval of two months up to April, 2005. Different

Water quality parameters such as pH, EC, TDS, DO, Cations (Na^+, K^+, Ca^{2+}, Mg^{2+}, $NH4^+$) and anions ($HCO3^-$, Cl^-, $SO2^-$, $PO3^-$, $NO3^-$) were examined for water of each sampling points to monitor the level of these parameters where it exceeds or within the permissible limit investigation suggested that, Dissolved Oxygen (DO) concentration of water of Buriganga river was very low particularly in dry season (2-3 mg/L). Ammonium ($NH4^+$) and Nitrate(NO_3^-) concentration near Hazaribagh, Sadarghat, Zinzira, Lalbagh, Kotouali and Shutrapur area were very high, which crossed the maximum permissible limit. In dry season the levelof pollution was much high than in wet season. Basically, he tried to show the temporal variation of physio-chemical parameters of Buriganga river water through GIS technology. Rahman (2010) has conducted a study on selected water quality parameters along the Buriganga river. The purpose of his study was to investigate into the impact of the wastewater discharged from tannery industries, municipal sewage, city drains on the riverwater and thus to provide an updated report on the state of water quality of the river. Thewater samples were collected in year 2008-09 during both dry and wet seasons from different points along the river and analyzed for various physiochemical quality parameters,which includes: temperature, pH, EC, DO, BOD_5, COD, PO_4-P, NH_3-N, Pb and Cr. Themean values for the parameters in both dry and wet seasons were then compared with thesurface water quality standards as set by the Department of Environment (DoE) in Bangladesh.

Saha and Hossain (2011) assessed the concentrations of five heavy metals (Pb, Cd, Cr, Cu, and Zn) for sediment from the Buriganga river and for the portion of sediment which passing through the #200 sieve were determined to evaluate their levels and spatial distribution. The ranges of the measured concentrations in the total sediments are as follows: 60.3-105.6 mg/kg for Pb, 0.4-1.6 mg/kg for Cd, 52.8-139.6 mg/kg for Cr, 70-346 mg/kg for Cu and 245-984.9 mg/kg dry weights for Zn and fine portion of sediments contain higher heavy metal concentration compared to total sediments. To assess metal contamination in sediment, US Environmental Protection Agency's (USEPA) guidelines were applied. The concentrations of Pb, Cu, and Zn in all sediment samples were above the EPA guideline for heavily polluted sediment and the concentration of Cd and Cr were fall in the criteria of moderately to highly polluted range. The metals contamination in the sediments were also evaluated by applying Index of geo-accumulation (Igeo), contamination factor (C_f) and toxicity characteristics leaching procedure test (TCLP test).

TCLP test results showed that the Buriganga river sediments are not likely to leach hazardous concentrations of particular toxic constituents into the environment as a result of improper management.

Biplob and Dipok (2013) examined the status of surface water quality of Buriganga river at different locations in Dhaka City. It was apparent from the study that the dissolved oxygen (DO), pH, color, total coliforms, turbidity and ammonia were always very high over the year 2011. The maximum level of DO concentration was 3.4 mg/L, which is below the acceptable limit for surface water. Results also showed that high turbidity and low color values were found in the rainy season while low turbidity and high color values were found in the dry season. Moreover, the values of all parameters were always high at Buriganga near Hazaribagh because of the proximity of industrial sites.

Zoynab (2013) found that the sediments of the Buriganga river were highly polluted with respect to Cu, Pb and Zn; unpolluted to moderately polluted with respect to Cd and moderately polluted to highly polluted with respect to Cr on the basis of USEPA sediment quality guideline. In her research, different types of indices had been used to assess the current pollution status in river sediments of the Buriganga and the Turag rivers. Outcomes were: the Buriganga and the Turag river had a low to appreciable potential ecological risk due to heavy metal contamination according to Ecological Risk Index. As per Sediment Quality Guideline Quotient (SQGQ) the Buriganga river sediments are moderately to highly impacted.

Ahammed (2016) tried to determine the water quality of the selected sections of Buriganga river which passes through Dhaka city. The water quality parameters were sampled during different seasons (summer, winter and autumn) and in 10 different sampling points along the river along the banks of the Buriganga river. The water quality parameters studied were dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), pH, turbidity, conductivity, total dissolved solids (TDS), nitrate and phosphate. The results showed that DO, BOD_5, COD, TDS, turbidity, nitrate and phosphate were present at an alarming level in the Buriganga river.

Fatema *et. al* (2018) assessed the water quality status of the river Buriganga in wet (June-August) and dry (November-January) seasons during the years 2017 and 2018. Temperature and Dissolved Oxygen (DO) of water varied from 22.80 to 31.40 °C and 0.22 to 2.74 mg/l, respectively. Electrical conductivity of water varied from 180 to 598μS/cm while pH ranged from 7.61 to 8.97. Study showed that temperature, DO from 7.61 to 8.97.

Study showed that temperature, DO and Fe were higher in wet season than in the dry season, whereas pH, conductivity were higher in dry season than in the wet season.

Rashidul (2018) investigated a portion of Buriganga river from Boshila Bridge to Postagola Bridge as the study reach to assess the existing water quality during the dry season of the year 2017 and 2018. From the field measurements and laboratory analyses, some improvement in water quality of Buriganga river were found in March 2018 compared to March 2017. Appreciable reduction in BOD_5, electrical conductivity, ammonia, nitrate and orthophosphate concentrations were observed along the river in March 2018 (compared to March 2017). COD values along the Buriganga river ranged from 65 to 140 mg/L during the dry season of 2017, while it ranged from 55 to 85 mg/ L during the dry season of 2018; Ammonia concentration in river water varied from 13.8 to 16.18mg/L in March 2017, while it was found to vary from 10.8mg/L to 13.25 mg/L in March 2018.

Ghosh et at. (2019) illustrated the heavy metal concentration in sediment and fish samples of the Buriganga river for 2017 through a seasonal monitoring. It also focuses on the impact of heavy metal on human health. Each sample was checked by Atomic Absorption Spectrophotometer for the concentration of heavy metals (Cd, Cr, Pb, As, Fe, Mn, Ni, Co, and Hg). Then, the powdered fish sample was further confirmed for the deposition of heavy metals by Scanning Electron Microscopy with Energy Dispersive X-ray spectroscopy (SEM-EDS). It is found that the heavy metals were at an alarming rate in all of the samples. In the end, a health risk assessment was done by Total Hazard Index (THI), Total Target Hazard Quotient (TTHQ) and Carcinogenic Risk (CR) where children were found more vulnerable than adult male and female. THI is greater than 1.0 for children and the adult female. TTHQ is greater than 1.0 for all. Therefore, Carcinogenic Risk is found for Cd, Cr, Pb, and As. Overall, the result revealed a great threat to human health with fish consumption due to the heavy metal concentration of the Buriganga river.

Hafizur *et al.* (2020) investigated the presence of chemical contaminants like hexavalent chromium (Cr^{6+}) in the water bodies surrounding tannery industries and to understand the possible role played by the tannery effluent in contaminating the river water bodies with Cr^{6+}. Result analysis revealed the presence of an amount of Cr^{6+} (ranging from 0.01 mg/l to 3.54 mg/l) in the surrounding water bodies, which was far above the maximum permissible limit of Cr^{6+}(0.05mg/l for surface water), set by the Environmental Protection Agency.

Rukshana *et al.* (2020) investigated the spatial distributions of heavy metals in water at sixteen different sites spread over whole stretch of the Buriganga river (27km). The concentrations of seven metals Cr, Cd, Pb, Ni, Fe, Zn and Cu were analyzed using an Atomic Absorption Spectrophotometer (Thermo-Scientific, 3000 series) in the RRI laboratory. The concentrations were compared with several standard guideline values provided by different organizations like WHO, DoE, FAO and CCME. The visualization of the spatial pattern of individual metal throughout the Buriganga was primed using ArcGIS 10.3 software. The result showed that the surface water of the whole stretch of the Buriganga was severely polluted by these heavy metals in dry season except Cu and Zn. The statistical analysis showed that a wide variation of concentrations among Cr, Cd, Pb, Ni, Fe, Zn and Cu but slightly differed among the locations. The lower concentration of heavy metal was found in post rainy season compared to dry season. Though the concentration were decreased in post rainy season some severe toxic heavy metals like Cr and Cd, concentrations were far above than the safe recommended values.

Md. Jamal Uddin and Yeon-Koo Jeong (2021) showed that urban rivers were in critical condition especially Korotoa, Teesta, Rupsha, Pashur and Padma. The pollutants flowing with water made a severe pollution in downstream areas of rivers. Metals concentrations in river water was found to be higher in dry season. Dissolve oxygen (DO) was nearly zero in Buriganga river and several points in Turag, Balu, Sitalakhya and Karnaphuli river. NO_3^- , NO_2^- and PO_4^{3-} pollution occurred in different rivers. Zn, Cu, Fe, Pb, Cd, Ni, Mn, As and Cr concentration were above drinking water standard in most of the river and some metals was even above irrigation standard in water from several rivers. Sediment data showed very much higher metal concentrations in most of the rivers especially peripheral rivers in Dhaka and Karnaphuli, Korotoa, Teesta, Rupsha and Meghna River. Metal concentrations in sediment was above US EPA threshold value in most of the rivers. Metal concentrations in fish and agricultural crops showed that bioaccumulations of metals had occurred. Theconcentration of metals showed the trend like: water<fish<sediment. Agricultural crops were found to contain toxic metals through polluted water irrigation. The calculated data of daily intake for the non-carcinogenic and carcinogenic showed that consumption of the contaminated foodstuff can cause serious health injuries.

Bader *et al.* (2022) showed that BOD: COD ratio can be used as a good indicator for measuring water pollution, and it can also be used as an indicator to predict the relationship between BOD and COD, as well as knowing the organic matter content in wastewater and industrial water. The results showed that BOD: COD ranged between 0.33-0.89 and seeding is required to treat it biologically.

Kabir *et al.* (2022) focused on quantifying hazardous heavy metals (As, Cd, Cr, Pb, Ni, and Zn) in soil-rice systems near the Buriganga river in Bangladesh to assess their impact on human health and the environment. The mean concentrations of As, Cd, Cr, Ni, and Zn in soil exceeded FAO/WHO acceptable limits, and the metal pollution index (MPI) indicated that all soil samples collected from the rice fields were severely polluted (MPI>30) than water and rice grain samples. According to the sum of pollution index (SPI) by studied metals, rice grains collected from Kamrangirchor (29.36), Dhakauddan (28.75), and Bosila (18.08) were severely polluted. Mean Bio-concentration factors (BCFs) and Transfer factors(TF grain/soil) in rice grains were in the following order: Cd (6.034) > Zn (1.752) > Pb (0.697) > Ni (0.666) > Cr (0.135) > As (0.037), and Cd (1.150) > Zn (0.421) > Ni (0.112) > Pb (0.072) > Cr (0.015) > As (0.034) respectively indicating higher accumulation of Cd in rice grain than others toxic heavy metal.

2.3 Water Quality Standards

For management of water quality of a water body, one has to define the water quality requirements or water quality goal for that water body. As mentioned above, each water use has specific water quality need. Therefore, for setting water quality objectives of a water body, it is essential to identify the uses of water in that water body. Inland surface water quality standard of Bangladesh is shown in Table 2.1 (ECR' 2023).

Table 2.1: Inland surface water quality standard.

Sl. No.	Classification	pH	BOD_5 (mg/l)	COD (mg/l)	DO (mg/l)	Pb (mg/l)	Total Cr (mg/l)
1.	Potable water source supply after bacteriafreeing only	6.5 - 8.5	2 or less	10	6 or above	0.03	0.02
2.	Water used for Recreational purpose	6.5 - 8.5	3 or less	10	5 or above	0.05	0.2
3.	Potable water source supply after conventional processing	6-9	3 or less	25	5 or above	0.03	0.02
4.	Water used for pisciculture	6-9	6 or less	50	5 or above	0.1	0.05
5.	Industrial use water Including chilling andother processes	6.5 - 8.5	12	100	1 or above	0.1	0.1
6.	Water used for irrigation	6.5 - 8.5	12 or less	100	---	0.1	0.1

Note: Maximum Electrical conductivity in irrigation water are 2250-µS/cm (temperature 25^0C); Sodium less than 26%, Boron less than 0.2%. Source: ECR (2023).

2.4 Water Quality Parameters

Chemically pure water is not available in nature and also is not desirable. In order to control the water quality parameters to the extent of international standards of drinking water. All the parameters can generally be grouped in three major heads: (i) Physical, (ii) Chemical and (iii) Bacteriological qualities. Some of water quality parameter with their relative importance in water supply is discussed here.

2.4.1 Dissolved Oxygen

Adequate dissolved oxygen is necessary for the life of fish and others aquatic organisms. The DO concentration may also be associated with corrosively of water, photosynthetic activity and septicity. The solubility of oxygen varies greatly with temperature over the range of interest to environmental engineers. The solubility of atmospheric oxygen in fresh waters ranges from 14.6 mg/l at 0°C to about 7 mg/l at 35°C under 1 atm of pressure. Most of critical conditions related to dissolve oxygen deficiency in environmental engineering practice occur during the summer month when temperature is high, solubility of oxygen is minimum and consuming rate is maximum. In liquid wastes, dissolved oxygen is the factor that determines whether the biological changes arc brought about by aerobic or by anaerobic organisms. Dissolved oxygen measurement arc vital for maintaining aerobic conditions in natural waters that receive pollution matter and in aerobic treatment processes intended to purify domestic and industrial waste waters. Dissolved oxygen determination is used for a wide variety of other purposes. It is one of the most important single tests that the environmental engineers use. In most instances involving the control of stream pollution, it is desirable to maintain conditions favorable for the growth and reproduction of a normal population of fish and other aquatic organisms. Determinations of dissolved oxygen serve as the basis of the BOD_5 test; thus they are the foundation of the most important determination used to evaluate the pollution strength of domestic and industrial wastes.

2.4.2 Biochemical Oxygen Demand

Biochemical Oxygen Demand is a measure of the amount of oxygen demand by living organisms in the water to oxidize organic matter present as food for the organisms. BOD_5 is an empirical test, in which standardized laboratory procedures are used to estimate the relative oxygen requirements of wastewater, effluents and polluted waters. Microorganisms use the atmospheric oxygen dissolved in the water for biochemical oxidation of organic matter, which is their source of carbon. The BOD_5 is used as an approximate measure of the amount of biochemical degradable organic matter present in a sample. The 5-day incubation period has been accepted as the standard for this test. The ultimate BOD_5 of an organic waste is the amount of oxygen required by microorganisms in carrying out the aerobic cycles of carbon, nitrogen, sulfer, phosphorous etc. that is the amount of oxygen needed by bacteria in reducing organic matter to stable compounds. It is considered that a normal sewage has a 5 day, 20^0C BOD_5 of 200 to 250 mg/l. and the value for industrial wastes may be from 3000 mg/l to more than a dozen times that figure, where as a stream fully saturated with oxygen at 20°C contains only 9.20 mg/l of oxygen.

2.4.3 Chemical Oxygen Demand

The chemical oxygen demand test indicates the quantity of oxidizable compounds present in water and will vary with water composition, concentration of reagent, temperature, period of contract and other factors. The concept of chemical oxygen demand is that all organic compounds, with but few exceptions, can be oxidized to carbon dioxide and water. In contrast with the 1300 test, which measures only the biodegradable fraction, COD may measure toxic as well as biodegradable organic compounds. It is therefore applicable to many industrial waste not readily analyzed for water quality factors by the sewage oriented BOD_5 test.

2.4.4 NH_3-N

The compounds of nitrogen are of great interest to environmental engineers because of their importance in the atmosphere and in the life processes of all plants and animals. The chemistry of nitrogen is complex because of the several oxidation states that nitrogen can assumed and the fact that change in oxidation state can be brought about by living organisms. To add even more interest, the oxidation state changes brought by bacteria can be either positive or negative depending upon whether aerobic or anaerobic conditions prevail. The nitrate formed may serve as fertilizer for plants. Nitrates produced in excess of the needs of plant life are carried away in water percolating through the soil because the soil does not have the ability to hold them. This results is relatively high concentration of nitrates in ground water. Under anaerobic conditions, nitrates and nitrites arc both reduce by a process called denitrification. Presumably nitrates arc reduced to nitrites and then reduction of nitrites occurs. Reduction of nitriles is carried all the way to ammonia by a few bacteria, but most of them carry the reduction to nitrogen gas, which escapes to the atmosphere (Maniruzzaman , 2001).

2.4.5 Solids

Solids in water may be found in dissolved or in suspended state. For domestic purposes, the amount of total solids is of importance for the determination of suitability for uses. The idea of solid content is also essential for softening procedure and corrosion control. The usual definition of solid however refers to the mailer that remains asresidue upon evaporation and drying at 103 to 105°C. In potable waters, most of the matter is undissolved form and consist mainly of inorganic salts, small amount of organicmatter and dissolved gasses. The total dissolved solids content of potable water usuallyranges from 20 to 1000 mg/l, and hardness increases with total dissolved solids. The undissolved substances are usually referred to as suspended matter or suspended solids,which is unexpected for water supply (Maniruzzaman, 2001).

Total Suspended Solids (TSS):

Solids suspended in water consist of inorganic or organic particles or of immersible liquids are known as total suspended solids.

Total Dissolved Solids (TDS):

Dissolved materials results from the solvent action of water on solids, liquids, and gassesare known as Total Dissolved Solids.

2.4.6 Turbidity

Water is turbid contains visible material in suspension. From consideration of aesthetic, filterability, and disinfection turbidity is a very important factor in public water supply. In lake or other waters existing under relatively quiescent conditions, most of the turbidity will be due to colloidal and extremely fine dispersions. In glacier fed rivers and lakes most of the turbidity is due to colloidal rock particles produced by the grinding action of the glacier. As rivers descend from mountain areas into the plains, they receive contributions of turbidity from farming and operations that disturbed the soil. As the rivers progress towards the ocean, they pass through the urban areas where domestic and industrial wastewaters may be added (Magumdar, 2005).

2.4.7 pH

Alkalinity and acidity of water, sewage, and sludge are frequently expressed in terms of their pH which is a symbol of hydrogen ion concentration. A pH test determines the strength of the acid or alkali in water, while the chemical tests for acidity and alkalinity determine the amounts of the acid or alkali present. pH values below 7 represent acidity, while pH value above 7 represents alkalinity (Magumdar, 2005).

2.4.8 Electrical conductivity

Electric conductivity is a measure of water's capacity to convey an electric current. This property is related to total concentration of the ionized substance in water and the temperature at which the measurement is made.

2.4.9 Color

The coloring material results from contact of the water with organic debris, such as leaves, needles of conifers, and wood, all in various stages of decomposition. It consists' of vegetable extracts of a considerable variety. Tannins, humic acid, and humates, from the decomposition of lignin, are considered to be the principal color bodies. The lignin derivatives are highly colored and quite resistant to biological attack. Iron is sometimes present as ferric-hamate and produces a color of high potency. Surface waters may become colored by pollution with highly colored wastewaters from dyeing operations in the textile industry and from pulping operations in the paper industry. Color caused by suspended matter is referred to a apparent color. True color is caused by vegetable or organic extracts that are colloidal. Waters containing coloring mater derived from natural substances are not generally considered harmful or toxic properties. The natural coloring materials give a yellow-brownish appearance to the water, somewhat like that of urine, and there is a natural reluctance on the part of water consumers to drink such waters. Waters intended for human use should not have a color exceeding 15 units, the recommended or secondary maximum contaminant level set by the U.S. Environmental Protection Agency (Ahsanuzzaman, 1996).

2.4.10 Chromium

Chromium is the 21st most abundant element in Earth's crust with an average concentration of 100 mg/kg. Chromium compounds are found in the environment, due to erosion of chromium containing rocks and can be distributed by volcanic eruptions. The concentrations range in soil is between 1 and 3000 mg/kg, in sea water 5 to 800 μg/l, and in rivers and lakes 26 μg/l to5.2 mg/L. Chromium like zinc, is one of the most abundant heavy metals in the lithosphere with an average concentration of about 69 μg/g and mercury content in carbonate sediments is reported to be 0.03 μg/g (Ahsanuzzaman, 1996). Chromium is moderately toxic to aquatic organisms. Major coastalmarine contributors of chromium are dominated by input from rivers, urban runoff, domestic and industrial wastewaters and sewage sludge. Also, other main sources in the aquatic environment include the waste stream from electroplating and metal finishing industry. Cr(III) occurs naturally in the environment and is found in rocks, animals, plants, soil and in volcanic dust and gases. Cr is used in nuclear and high temperature research, drilling muds, metal-finishing textiles, fungicides, wood leather preservatives, odor agents, leather treatment, industrial water treatment, photo- mechanical processing, dyes and pigments, catalytic manufacture and in the production of chromic acid and specialty chemicals. Anthropogenic sources of chromium include chrome plating, the manufacture of pigments, tanning and treatment of wood products (Harte and Shirley, 1991). Once chromium enters the blood stream, chromium compounds can be distributed to all organs of the body. Cr (VI) is unstable in the body and isreduced ultimately to Cr (III) by many substances like ascorbate and glutathione.

2.4.11 Lead

Lead is a soft, malleable metal, also considered one of the heavy metal. Metallic lead does occur in nature, but it is rare. Lead is usually found in ore with zinc, silver and copper, and is extracted together with these metals. The main lead mineral is galena (PbS), which contains 86.6% lead. Inorganic lead is moderately toxic to aquatic flora and ranks behind mercury, cadmium, copper and zinc in the order of toxicity to invertebrates. The major sources of Pb in natural waters include manufacturing processes, atmospheric deposition. Other sources include domestic wastewaters, sewage and sewage sludge (Ahsanuzzaman, 1996). Lead species are strongly sorbed to Fe/Mn oxides, which are reported to be more important than association with clays and organic materials. The sorption of lead onto Fe/Mn oxides is not affected by aging. The sorption process is pH dependent. As a result, lead is immobile in the aquatic environment and tends to accumulate in sediments close to its point of entry. Lead is reported to be in the 15 - 50 μg/g range for coastal and estuarine sediments around the world with < 25 μg/g in clean coastal sediments (Ahsanuzzaman, 1996).

Lead is toxic and a major hazard to human and animals. Lead has two quite distinct toxic effects on human beings, physiological and neurological. The relatively immediate effects of acute lead poisoning are ill defined symptoms, which include nausea, vomiting, abdominal pains, anorexia, constipation, insomnia, anemia, irritability, mood disturbances and coordination loss. In more severe situations neurological effects such as restlessness, hyperactivity, confusion and impairment of memory can result as well as coma and death (Harte and Shirley, 1991).

2.5 Pollution

Pollutants are generated in and around the city through domestic, commercial and industrial activities. Wastewaters and sewage generated in the city are carried into the river system through numerous outlets. Solid wastes are collected by the city corporation and dumped on the open land. Pollution means addition of much foreign material inorganic, biological and radiological and any other physical change in the natural water which may harm fully and affect the living life directly or indirectly; immediately, after sometime or after a long time.

Major sources of pollutants are;

1. Municipal or Domestic Waste Water
2. Industrial waste water
3. Urban or sub urban runoff.
4. Agriculture.
5. Drainage/leaching of land disposal and solid waste
6. Atmospheric deposition
7. Natural erosion etc.

Categories of pollution:

1. Oxygen demanding waste
2. Pathogens
3. Nutrients
4. Slats
5. Thermal pollution
6. Heavy metals
7. Pesticides
8. Volatile organic compounds
9. Radioactive substances.

2.6 Types of Pollution

Lots of factors are involved in pollution of river water and physical meandering of the river which causes the ultimate pollution in the environment in large context. Human activities those may be essential for their survival create a severe pollution on a river as well as the environment. These include building of dams or embankment, use of fertilizer and insecticide, excavation of riverbed, deforestation in upstream etc. Besides, there are disposal of waste water from the town or city sewer, industrial effluent, disposal ofhuman waste and burned oil by vessels and so on. From the above discussion; it is clear thatwe are polluting the river and its water every time in our daily life. Sometimes which may be inevitable but we have to suffer in the long run of its consequences. However, when we talk about pollution in the river Buriganga, some additional parameters should be discussed. Encroachment of the river banks by the land grabbers which makes the river narrower, intensifies water pollution and break down whole ecosystem of its surrounding areas. Besides, huge volume of industrial (including tannery) wastewater is being disposed without any noticeable treatment. In addition to this waste, Buriganga river is flourished by sewer water of Dhaka city that contains huge quantity of BOD_5 load. There are three types of pollution such as physical, chemical and biological which may affect the quality of the river. The pollutions are discussed below:

2.6.1 Physical Pollution

Physical pollution of river includes sedimentation in the river channel and encroachment of its hanks, which cause river meandering, shrinking of river, river erosion etc, of them encroachment by the land grabbers cause a serious threat in life of river Buriganga. Influential quarters have gone on encroaching and grabbing the river banks on both sides to set up industries there by causing the water more polluted. With bank being burdened with the enormous pressure of pollution and economic activities, the Buriganga today struggles to survive. Thousands of new factories, markets and other establishments have come up along the river and all their wastes are dumped into its water. Motor launches and engine boats grow every day. They release tones of smokes and toxic fluids.

2.6.2 Chemical pollution

Another parameter measuring the pollution range in the water and consequently the river pollution is the chemical compound present in the water. With the rise of population in the city and for Commercial purposes floating vessels in the river has been increased. Effluents from the factories and house are being discharged in the Buriganga without any remedy.

It is turning an outlet of carrying sewage and waste matter of the city. Not only from the tanneries, have waste matter from thousands of latrines on both sides of the river been connected to the low. From the launches and engine vessel in Sadar ghat and Dockyard areas, there are discharges kerosene and mobil oil. There are floating residential hotels in the river. Human excretes from the floating vessel are spilled and the water is turning black and tinted. Thus water is being polluted day by day with the decomposed waste as well as heavy metal from the tannery and other industry situated at Tejgaon area. It is found that there are market metals in dry season as well as wet season and some important water quality parameters are also gradually deteriorating with time. In order to check further degradation of water quality, which may render the water, unfit for beneficial uses, there should be some legal measures against the indiscriminate discharge of sewage effluents, and pollutants from industries and commercial centers located on the banks.

2.6.3 Biological pollution

The third point in measuring the pollution on river is biological quality of the water, prevailing in that river. Biochemical condition is a vital criterion for the living bodies resident in the river ecosystem. The parameters measuring the biological conditions include Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), and used as an index in measuring pollution and their inclination is must when water is polluted.

2.7 Sources of pollution

The various sources of pollution have been identified through reviewing previous studies and from relevant agencies like Department of Environment (DoE), Dhaka Water and Sewage Authority (DWASA), Dhaka City Corporation (DCC), Bangladesh Inland Water Transport Authority (BIWTA), Institute of Water Modelling (IWM) and Bangladesh University of Engineering and Technology (BUET).

2.7.1 Point sources

Rahaman and Rana (1994) state that, the major point sources of pollution in the Buriganga river are a number of industrial installations, municipal wastewater and sewage treatment plants. These are described in the following sections.

Discharge of industrial effluent

Alam (2003) states that, Small to medium sized home-based industries started developing along or near the banks of the Buriganga river since the 1960. The Department of Environment (DoE) conducted a survey in 1998 and identified 249 industries along the banks of the river responsible for water pollution. These industrial installations include tanneries, dyeing industries, aluminium, iron and steel workshops, plastic, pharmaceuticals, battery manufacturing, washing, hardware and cold storage units.

Discharge of municipal wastewater and sewage

The Dhaka Water Supply and Sewerage Authority (DWASA) are responsible for collection, treatment and disposal of municipal wastewater, sewage and storm water in Dhaka City. However, the existing sewerage system of Dhaka City is quite old and inadequate to meet the present demand. SWMC and RPMC reports reveal that, the current sewerage network covers only 110 sq. km of 360 sq. km of the city area, serving only 20 percent of the population. As a result, particularly in areas that are not yet within the sewerage network of DWASA (like the areas adjacent to the Buriganga), there has been a tendency of having unauthorized connection of domestic sewer into the storm water pipes that end into the Buriganga river. This causes discharge of massive amount of untreated municipal wastewater and sewage directly into the Buriganga through the city drains and sewers.

2.7.2 Diffuse sources

Besides the major point sources, there are some diffuse sources including dumping of solid wastes along the banks in a scattered manner by river side dwellers, leakage of oil from floating oil-seller boats and direct disposal of wastes (like residue of food, human excreta). As the runoff moves on the land, it picks up and carries pollutants including polythene bags and dispose them into the river. BIWTA discovered a 3 m layer of garbage including discarded polythene bags on the bed of this river near Sadar ghat launch terminal. Alam (2003) states that, the entire north bank of the river has now become urbanized and very fewagricultural practices take place on the south bank of the river, where some vegetables are only being grown in a few spots, mostly with the use of organic manure. Thus the impact of agricultural runoff in the Buriganga river could be considered insignificant compared to the other sources.

2.8 The importance of the river

Dhaka has celebrated its 400th anniversary as the capital of Bengal proclaimed by the Mughals in the early 17th century. It was a strategic decision by the Mughals considering economic, navigation and security potentials of the perennial river Buriganga. The history, livelihood, culture and heritage of Dhaka City have been largely shaped by this small but important river. Bangladesh Inland Water Transport Authority (BIWTA) has recently submitted a compliance report to the HC saying that there are 68 underground drains and sewerage lines connected to Buriganga river. (The Daily Star, December 03, 2019).

2.9 Water supply

The Buriganga river was once used as the main source of water supply for Dhaka's residents when the Chadnighat water treatment plant (located near Millbarak) was established in 1874, which is currently being operated by Dhaka Water Supply and Sewerage Authority (DWASA). The plant has a capacity to treat a huge amount of water daily from this river which can be supplied to the surrounding urban areas like in Lalbagh and Kotwali for drinking and other domestic usage (Kamal, 1996).

2.9.1 Inland water transportation

The Buriganga river provides an extensive network of inland waterways all over Bangladesh, particularly within the southern districts. Hundreds of launches and thousands of country and engine boats ply on this river daily to transport goods and passengers. The Dhaka Port (locally known as Sadarghat Launch Terminal) located on this river is used by an average of 30,000 people per day. Apart from this major port, there are also several other ports and landing stations on this river such as at Postogola, Pagla, Fatulla, Kholamura and Bosila (Kamal, 1996).

2.9.2 Cleaning and washing

Most of the people who live within the catchment area of the river and directly use the water for washing, bathing and other domestic purposes on a daily basis. Besides these, many people utilize the river for commercial laundry services, washing animals, cleaning polythene bags and plastic containers (for recycling factories).

2. 9.3 Recreation

During the British regime, the bank of the Buriganga river was considered to be the most scenic place in Dhaka for its natural beauty. However, many people still use the river for recreational purposes, such as walking along the river side, swimming and boating. Moreover, still to date occasional cruises on this river take place for visiting dignitaries and for local residents (Kamal, 1996).

2.10 Causes of Buriganga river Pollution

Pollution of Buriganga river began in the Mughal period, since the sewage of the city used to be dumped into the river. Several studies on the Buriganga river have identified many causes for the river's pollution such as sedimentation at the upstream, encroachment, and disposal of solid wastes, sewage and industrial wastes in the river (Kawsar, 2016).

2.10.1 Sedimentation at the upstream

Rahman and Rana state that, because of the sedimentation on the upstream, the flow of Buriganga-Turag system gets cut off, especially during the dry season. This is why no single drop water flows into the river system at that time, states the hydrologists and engineers of Bangladesh Water Development Board (BWDB). During this period of time the system basically carries sewage and industrial effluents.

2.10.2 Population explosion

It is known to all that, every additional person add extra pollution. Sadar ghat is the most familiar point of Buriganga and also in Dhaka. Everyday thousands of people use this point or terminal for their journey. Most of them illiterate and do not know how to use river side area properly. They throw water bottle, paper and other harmful things into the river water.

2.10.3 Encroachment and land grabbing

Over the years, landfills created on the river have narrowed its width at many places near the city. The encroachers have set up platform like structures on the rivers and gradually filled out the bottoms by piling up earth and rubbish. Even multi-storied structures have been built on encroached land. Politically backed influential land encroachers have created illegal structures including houses, bazaars, ghats (port), brickfields etc., on the river thathas created obstacles on the flow of the river (Habib, 2006)

2.10.4 Disposal of solid and domestic waste

Dhaka City dwellers have been dumping domestic wastes and solid wastes into the Buriganga since the Mughal period. According to several studies (Alam ; Rahman and Rana), each day about 900 cubic meters untreated domestic and human waste are discharged into the Buriganga- Turag system. Dhaka WASA’s only one sewage treatment plant at Pagla with a capacity of 0.12 million cubic meters per day, which is only 10 percent of the total disposal of sewage. But, because of mismanagement the treatment plant is using one third ofits capacity.

2.10.5 Sewage and industrial waste

Most of the industrial units around the Buriganga river have no sewerage treatment plants of their own. More than 60,000 cubic meters of toxic waste including textile dying, printing, washing and pharmaceuticals are released into the main water bodies of Dhaka every day.

2.10.6 Tannery waste

There were about 200 leather tanneries in the Hazaribagh area of Dhaka, the capital. Some use modest technology and machinery, but most operate as they did decades ago and used to release untreated toxic chemical waste near residential areas. According to the Department of Environment, the tanneries would discharge 22,000 cubic meters of untreated liquid toxic waste daily into the rivers, gutters and canals that run alongside in the roads of Hazaribagh. Now days due to the shifting of a large number of tannery industries from Hazaribagh some improvement in water quality of Buriganga river is noticed (Islam, 2018).

2.11 Non-point sources of pollution

Degradation of water quality by non-point source (NPS) inputs is an important phenomenon and urgent attention is required in reducing NPS inputs to receiving river waters. The NPS pollution comes from many diffuse sources. It generally results from land run-off caused mainly by rainfall, precipitation, atmospheric deposition, drainage, seepage and hydrologic modification. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into the river and other receiving waters and even the underground sources of drinking water. Urban storm water runoff carries various pollutants washed off from streets, roof-tops and various types of land cover. It is revealed that the city storm runoff with very high pollutant loads is directly discharged into receiving water bodies threatening the natural aquatic environment. However, this is not unexpected considering the developing nature of the city and the poor waste management practices. Although there are separate sewer systems for carrying storm water within Dhaka City, the storm sewers often receive domestic wastewater causing an unwanted deterioration of the storm sewer discharges. Moreover, the existing waste disposal practice and management of wastes are not organized in Dhaka City. Wastes are often disposed of at roadside open dumps which are very likely a number of pollutants in the storm runoff. Many landfills within the city are open and close to drainage (Alam and Khorshed. 2003).

Discharge from construction sites also adds pollutants to the runoff. Pollution by sediments is another concern. Although there is no accurate estimate of sediment discharge to the Buriganga river, it is obvious that the river receives an enormous sediment flow both from its upper catchments and from the city. Experience indicates that sediment concentration/deposition due to human activities (e.g. cutting of trees, lack of vegetation on the top-soil, poor management of construction and digging of roads throughout the years) impacts the Buriganga river. Sediments arc a major source of chemical pollution for the Buriganga due to the close existence of industries, particularly tanneries at the Hazaribagh. Polythene bags have been identified as another hazard for deteriorating environmental quality in and around the Buriganga river. According to various estimates, about six million polythene bags arc used daily in Dhaka City and only twenty percent are properly disposed of. The rest litter the roads, streets and everywhere and finally end up in drains and sewer lines; clogging these and creating seriouswater logging problem and blocked sewer lines in the city. Some of these polythene bags finally end up in the river (Alam and Khorshed. 2003).

The rainfall pattern in Dhaka has important implications for both sanitation and water pollution control. Data shows that Dhaka experiences a typical monsoon climate with high rainfall in the months from June to September and is relatively dry at other times. With regard to water pollution control, during the monsoon period the high flow rates in therivers and flooding in the surrounding low- lying areas provide a large dilution capacity for the river. This reduces the water pollution problems in the monsoon season. Conversely, in the dry season the lack of dilution capacity results in more severe water pollution problems in the Buriganga river. In many countries, agriculture is the leading non-point source pollutant for rivers. Although increased use of fertilizers and agrochemicals have become a concern for river water quality, in the case of the Buriganga, agriculture as a source of pollution has little impact (Alam and Khorshed, 2003).

2.12 Remedies of Buriganga river Pollution

The Buriganga river is burdened with multiple pollutions. It is nothing but a crematory. Environmental experts and water experts give some necessary steps to Bangladesh government to prevent Buriganga river pollution. These prevention techniques are highlighted below.

2.12.1 Population control and creation of public awareness

Huge population explosion of Dhaka is one of the main reasons of Buriganga river pollution. According to several studies, each day about 900 cubic metres untreated domestic and industrial effluents are discharged into the Buriganga-Turag system. An individual person means an extra amount of pollutants. So to prevent the Buriganga river pollution we should make public awareness and stop population growth of Dhaka city.

2.12.2 Increase water flow of Buriganga

During the dry season, the river has a flow of only 50 cubic metre per second (cumec). One solution is to connect the rivers of Dhaka with the Jamuna River which has a minimum dry season flow of around 3500 cumec. This will not only improve the water quality of the peripheral rivers of Dhaka but also will benefit water supply, agriculture irrigation, fisheries and navigation. This is an ideal case of integrated water resources management (Hossain, 2010).

2.12.3 Control disposal of solid wastes

To control disposal of solid wastes into river Dhaka City Corporation (DCC) and BIWTA should work together. BIWTA must force the owners of the vessels and traders on the bank of the river to dump the solid wastes at the fixed places provided by DCC. For any type of construction work within 50 meters of the river bank, clearance from BIWTA should be mandatory. All structures, especially brick fields within 200 meters from the riverbank should be demolished.

2.12.4. River dredging

The government must allocate a budget so that BIWTA can buy sufficient dredgers for routine dredging of the riverbed for smooth navigation.

Chapter Three
METHODOLOGY

3.1 Introduction

This research work aims at assessment of water quality of Buriganga river and show the spatio-temporal distribution of different water quality parameters. The water quality assessment was based on systematic collection of water samples from selected locations of Buriganga river and analysis of the water samples (both in-situ and in laboratory) for important water quality parameters. To find out the trend and present condition of water quality of the Buriganga river needs well organized laboratory facilities. In spite of the remaining of leakage of these facilities an attempt was taken to collection of water sample from different locations in the Buriganga river. Then the data have been analyzed to produce a significant and representative presentation of the water pollution occurrences and ongoing trends of degradation of the Buriganga. Water quality data was generated through collection and analysis of forty eight sets of water samples during August 2022, October 2022, January 2023 and March 2023.

3.2 Study Area

In this study, certain portions of the Buriganga river from Showari ghat to Pagla were selected as the study reach to assess the existing water quality. In fact, almost all major urban and industrial establishments along Buriganga river are located within this reach. In order to assess spatial variation of water quality, river water samples were collected from twelve sampling locations of Buriganga river during the months of August, October of the year 2022 and January, March of the year 2023. These sampling locations Showari ghat, Sadar ghat, Postagola and Pagla. In-situ field measurements of dissolved oxygen (DO) and pH have been carried out at each sampling location. Chemical oxygen demand (COD), 5-day biochemical oxygen demand (BOD_5), ammonia, Chlroride, color, Hydrogen Sulfied have been analyzed in the laboratory following Standard Methods. Heavy metals (Chromium and lead) have been analyzed for the sample collected in the month of March 2023. The latitude, longitude of each point is recorded with GPS. Table, Graphs showing the variance of each parameter seasonally has been plotted using the test results. Figure 3.1 and table 3.1 show the study area and the GPS (Global Positioning System) data of sampling locations, respectively.

3.3 Collection of Water Samples

River water samples were collected from twelve points along the Buriganga river during the wet season of 2022 (August to October) and dry season of 2023 (January to March). These sampling locations were Showari ghat, Sadar ghat, Postagola and Pagla. From each location three samples are collected along the cross section. During the dry season, water quality deteriorates and gets worse due to low river water flow (due to lower upstream flow and low precipitation) and heavy waste load discharging into the river. Sampling in the river was done at the north, mid and south stream of the selected locations.

Water samples were then collected in 2.0L acid washed plastic bottles for further laboratory testing. Before filling the samples, the sampling bottles were rinsed rigorously with the water being collected.

Figure 3.1: Study area showing the sampling locations.

Table 3.1: Global Positioning System data of the sampling locations.

Sl. No.	Sample ID	Latitude	Longitude	Location
1	B-1(North)	23°42'39.19"N	90°23'39.76"E	
2	B-2(Middle)	23°42'36.27"N	90°23'41.17"E	Showari Ghat
3	B-3(South)	23°42'34.17"N	90°23'42.04"E	
4	B-4 (North)	23°42'25.18"N	90°24'24.64"E	
5	B-5 (Middle)	23°42'20.17"N	90°24'22.64"E	Sadar Ghat
6	B-6(South)	23°42'17.23"N	90°24'21.14"E	
7	B-7 (North)	23°41'11.18"N	90°25'48.03"E	
8	B-8 (Middle)	23°41'7.11"N	90°25'41.60"E	Postagola
9	B-9 (South)	23°41'6.14"N	90°25'36.48"E	
10	B-10 (North)	23°39'38.20"N	90°27'21.33"E	
11	B-11(Middle)	23°39'34.17"N	90°27'18.07"E	Pagla
12	B-12 (South)	23°39'28"N	90°27'17.42"E	

Figure 3.2: Present status of the Buriganga river.

In-situ field measurements were done for several parameters (e.g., pH, DO, EC) because real time measurements always offer higher level of accuracy in measurements. Other parameters were measured in the laboratory by following the Standard Methods.

Figure 3.3: Industrial establishment on the bank of the Buriganga river.

Figure 3.4: Collecting river water samples.

3.4 In-situ Measurement of Water Quality

At each sampling location the following parameters were measured in-situ during sample collection:

1. pH
2. Dissolved Oxygen (DO)
3. Electric Conductivity (EC)

DO were measured with a portable DO meter. After measuring the DO, water samples were collected from that selected location for other analyses. pH was measured with a portable pH meter and electrical conductivity was measured by using a portable conductivity meter.

Figure 3.5: Measuring Dissolved Oxygen of the river water at a selected location.

3.5 Procedures for Laboratory Analysis of River Water Samples

Laboratory analysis was conducted to determine the following parameters:

1. Biochemical Oxygen Demand (BOD_5)
2. Chemical Oxygen Demand (COD)
3. Hydrogen sulfide (H_2S)
4. Chloride (Cl^-)
5. Color
6. Chromium (Cr)
7. Lead (Pb)

Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Hydrogen Sulfied, Chloride, color were tested in the laboratory following standard laboratory method, Amonia (NH_3-N) was determined by Nessler method. Heavy metals (Chromium and Lead) were determined using Atomic Absorption Spectrophotometer (AAs).

3.6 Secondary Data Collection

Secondary data was collected from different papers (Kamal, 1996; Haque, 2003 and Paul, 2008, Islam, 2018), international journals (International Journal of Emerging Technology and Advance Engineering (2009) etc. to show the pollution trend of Buriganga river. Data from ECR’ 2023 and Department of Environment (DoE) (1991, 1997) were also assessed for the study.

Chapter Four
RESULTS AND DISCUSSION

4.1 Introduction

To assess the water quality status of the river Buriganga the present study was conducted. Sampling areas were divided into four stations which include twelve sampling points. In all the twelve points, physio-chemical parameters were recorded and analyzed over the years. The degradation and seasonal fluctuation of important water quality parameters are analyzed and presented graphically in this chapter. In order to simplify the presentation of data analyses, analysis for some important water quality parameters has been performed separately. While performing analyses on surface water quality, special attention has been given for yearly or seasonal degradation or fluctuation water quality. This Chapter presents an assessment of the water quality of Buriganga river based on analysis of water quality data generated in this study.

4.2 Collection and Analysis of Water Samples

As mentioned in chapter three, water samples of Buriganga river water were collected from twelve sampling locations during the wet season of the year 2022 and dry season of 2023 for laboratory testing. The water samples collected from the Buriganga river were tested for eleven water quality parameters. These parameters were selected because these reasonably describe the status of pollution of a river, when no special type of pollution is to be studied. The water quality parameters tested are:

1. pH
2. Dissolved Oxygen (DO)
3. Electrical Conductivity (EC)
4. Biochemical Oxygen Demand (BOD_5)
5. Chemical Oxygen Demand (COD)
6. Ammonia (NH_3-N)
7. Hydrogen sulfide(H_2S)
8. Chloride(Cl^-)
9. Color
10. Chromium (Cr)
11. Lead (Pb)

4.3 Water Quality of Buriganga river

To summarize the findings of the data analyses, both from in-situ and laboratory testing, monitoring locations from B-1(Showari ghat) to B-12 (Pagla) have been considered to represent the status of the Buriganga river. Collected data shows the characteristics of the water samples collected from the Buriganga river during the month of August, October of the year 2022 and January, March of the year of 2023. These data provided good picture of variation of water quality parameters of Buriganga river over the year.

4.3.1 pH

From the in-situ measurements, it was found that pH value of the Buriganga river varied from 6.8 (Posta –north) to 7.62 (Sadar ghat-middle). In August 2022, pH value ranges from 6.8 to 7.06 along the Buriganga river. During October, slightly increase in pH value was found, ranging from 7.15 to 7.44; In January of 2023, pH ranged from 7.18 to 7.48. Comparatively higher pH value was found during the March, 2023 that ranged from 7.2 to 7.62. Figure. 4.1 to figure 4.3 shows the spatio temporal variations of pH along the Buriganga river.

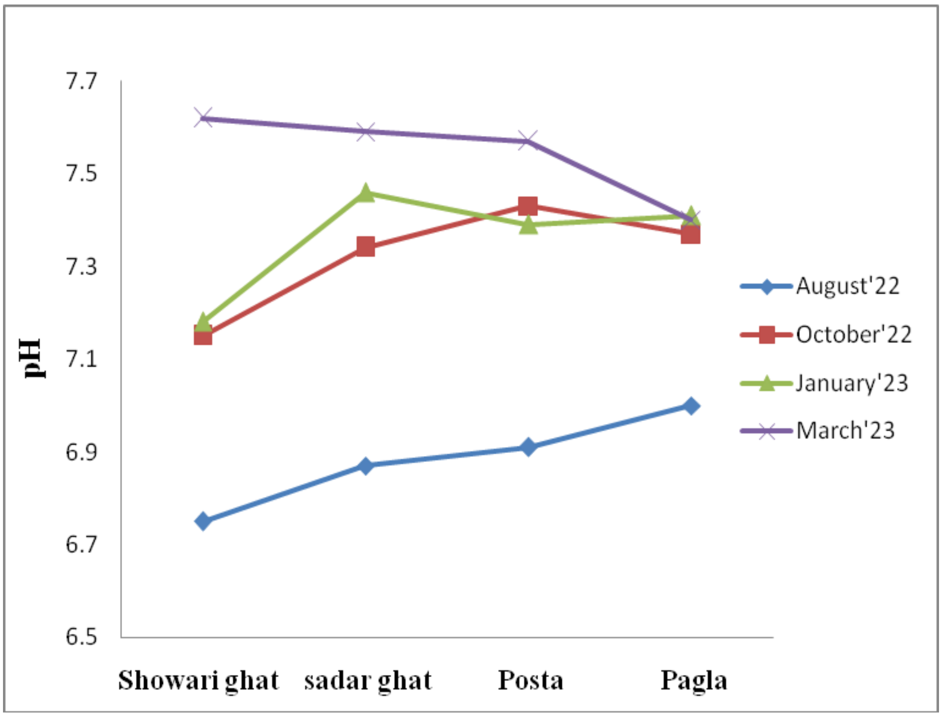

Figure 4.1: pH at north point of each sampling location of Buriganga river at different seasons.

From the figure it was found that highest pH (7.62) was recorded in Sadar ghat during the month of March. According to ECR' 23, pH value for inland surface water should range from 6.5 to 8.5. Therefore, It is identified that all the pH values from different monitoring locations of Buriganga river are almost within the national standards. According to Islam (2018), In the month of March 2017 and 2018 pH were found 7.63, 7.65,7.73 and 7.82, 7.76, 7.71 respectively in Showari ghat, Sadar ghat and Posta.

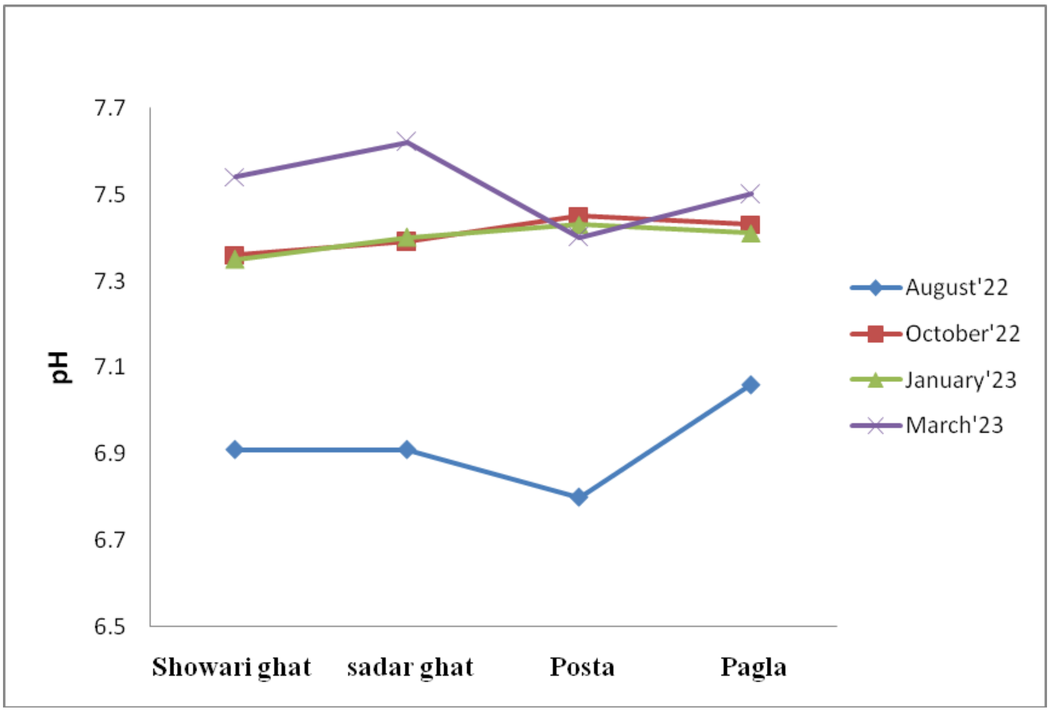

Figure 4.2: pH at mid- point of each sampling location of Buriganga river at different seasons.

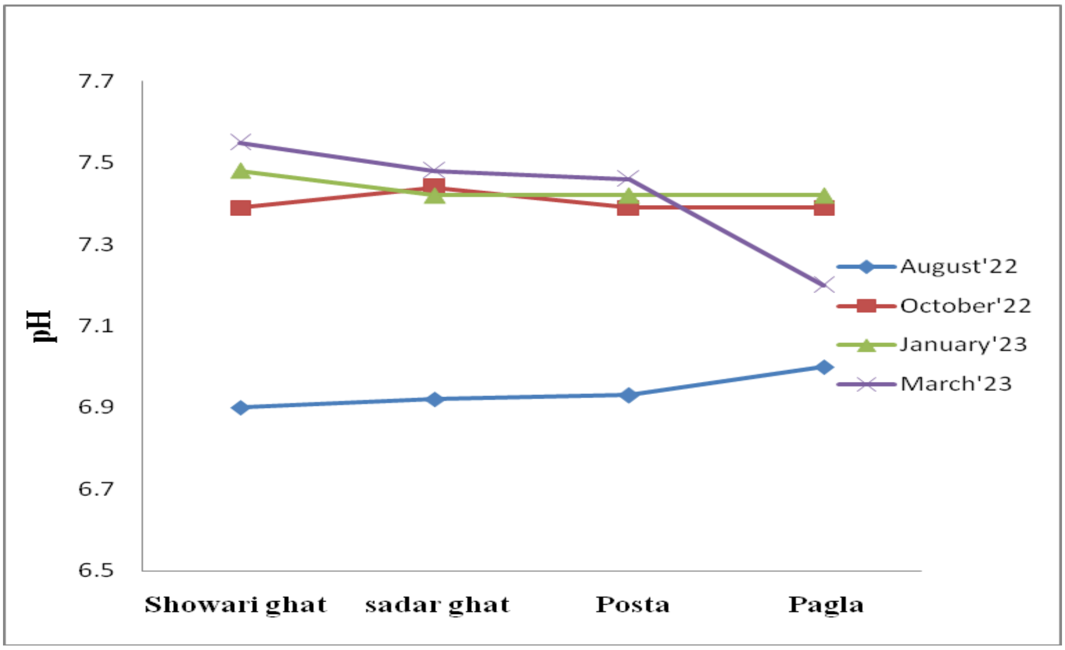

Figure 4.3: pH at south point of each sampling location of Buriganga river at different seasons.

4.3.2 Dissolved Oxygen

Dissolved oxygen is one of the most important parameters in water quality assessment. Its presence is essential to maintain variety of forms of life in the water. Effects of biodegradable waste discharged in a water body are largely determined by the oxygen balance of the system. DO value decreases if oxygen demanding waste are discharged into water.

Along the Buriganga river, DO value has been found around 2.26-4.24mg/L in wet season and 0.23 to 0.43 mg/L in dry season, while minimum 5.0 mg/L DO is essential for the existence of healthy aquatic life in water. Lowest DO values were found in January and March of 2023 as compared to August and October of 2022. Minimum DO value (0.23 mg/L) was found near Showari ghat during dry period. Slight increases in DO values were found during the wet season compared to dry season along the river. Spatio-temporalvariation of DO along the river has been shown in Figure 4.4 to Figure 4.6. These Figures clearly show the variation of DO in wet and dry season.

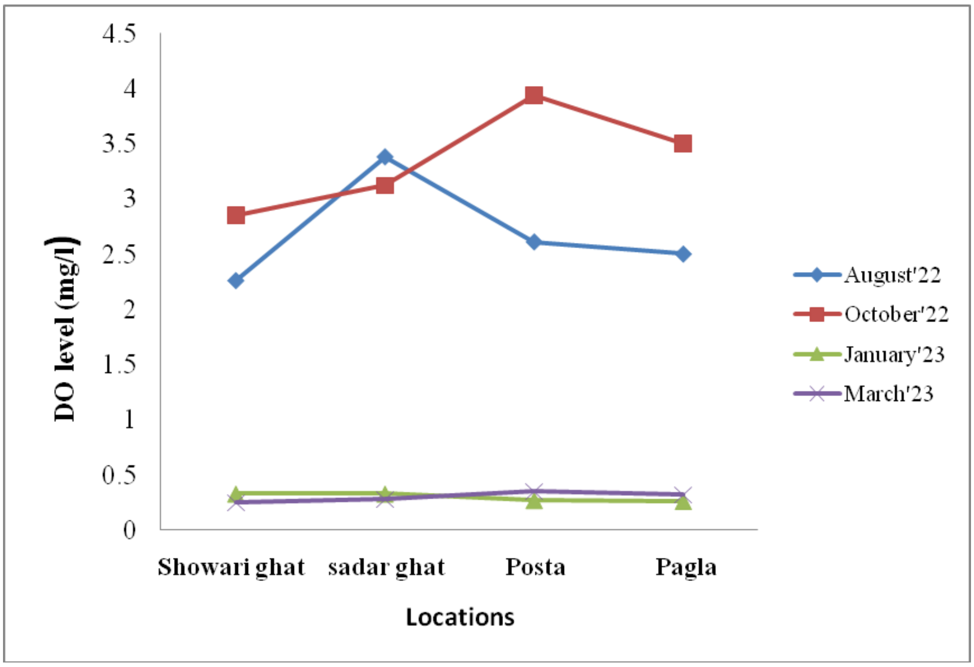

Figure 4.4: DO concentration at north point of each sampling location of Buriganga river at different seasons.

According to ECR' 23 allowable DO concentration for potable water source supply after bacteria freeing is 6 mg/lL or above, for recreational and fishing 5mg/L or above, for industrial uses including chilling and other purposes is 1.0mg/L or above. So it can be said that DO concentration of Buriganga river water is not safe for potable water source, fishing, and recreational uses in terms of DO according to ECR' 23. However, this can be used for industrial purposes in rainy season. DO concentration is very much lower in dry season because of low dilution factor created by the low flows in the river. During dry season the tidal nature of the flow causes pollutants to move in both directions and leads to a worsening of the problems (Alam *et al*. 2007; Ahmed and Bakri 2010).

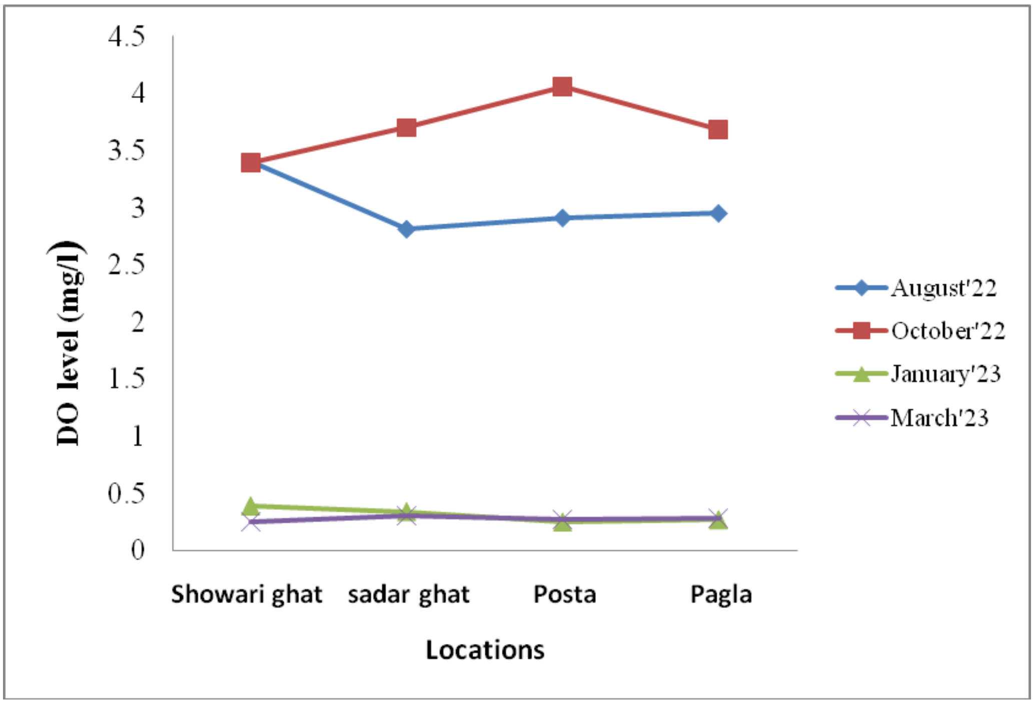

Figure 4.5: DO conc. at mid -point of each sampling location of Buriganga river at different seasons.

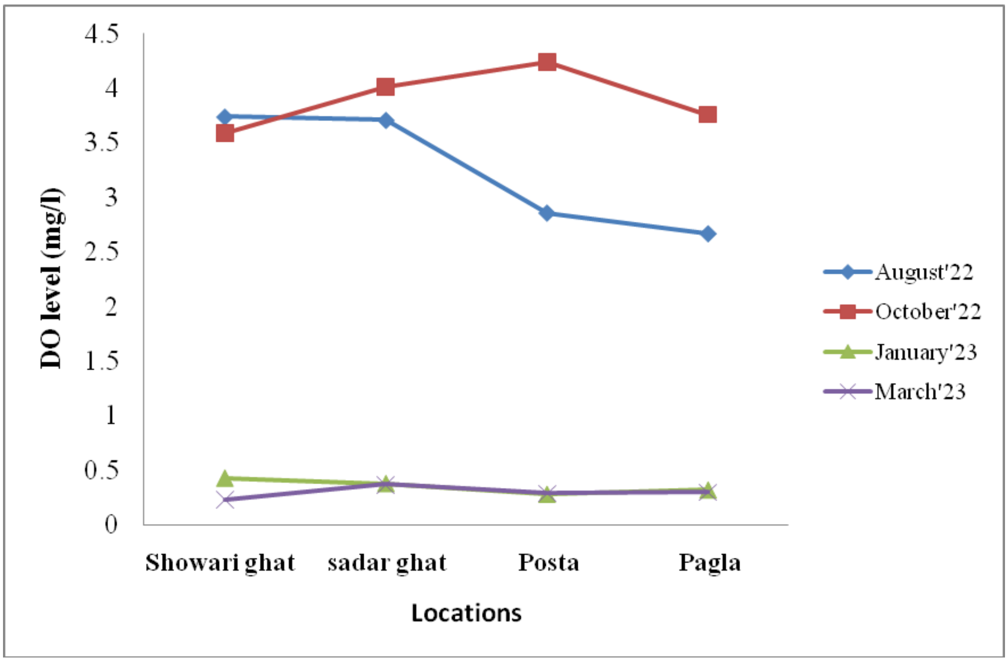

Figure 4.6: DO conc. at south point of each sampling location of Buriganga river at different seasons.

According to Ali et al. (2008), average DO concentrations in the Buriganga river ranged from 6.1 and 6.4 mg/L. Rahman and Bakri (2010) also measured DO in 5 different locations and found that that DO concentrations (0.9-2.8 mg/L) are much lower than the DoE standard DO concentrations below 5 mg/L, create stress for aquatic biota in the river ecosystem. Furthermore, fish kills might be expected if DO concentrations remain below 1- 2 mg/L for several hours (Reza and Yousuf, 2016).

4.3.3 Electrical Conductivity

Electrical conductivity was found 167 to 185 µS/cm in Buriganga river during the month of August and EC ranged from 173 to 185 µS/cm in the month of October' 22. In dry season of the year 2023 EC increases rapidly ranged from 542 to 568 µS/cm in January and 746 to 852 µS/cm in March. Figure. 4.7 to Figure. 4.9 shows the seasonal variation of EC along the river.

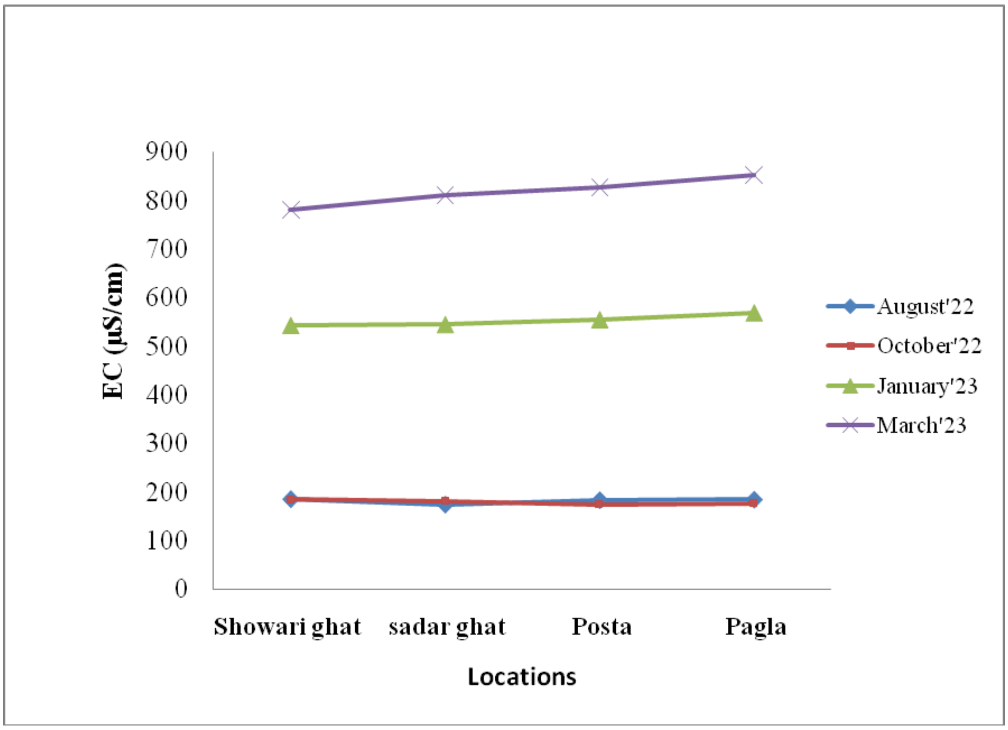

Figure 4.7: EC conc. at north point of each sampling location of Buriganga river at different seasons.

Maximum EC (852 µS/cm) was found in Pagla during March 2023. In wet season, as the flow of the river increases dilution leads to lowering of EC values, while in the dry season, the flow of the river decreases, as a result the EC increases.

Higher EC values Indicate higher ionic concentration in water. Discharge of waste water containing dissolved substances, chemicals, and minerals; even a small amount of dissolved salts and chemicals can heighten the conductivity of receiving river water. According to ECR’ 23 allowable limit of EC for irrigation water is 2250 µS/cm at 25ºC temperature.

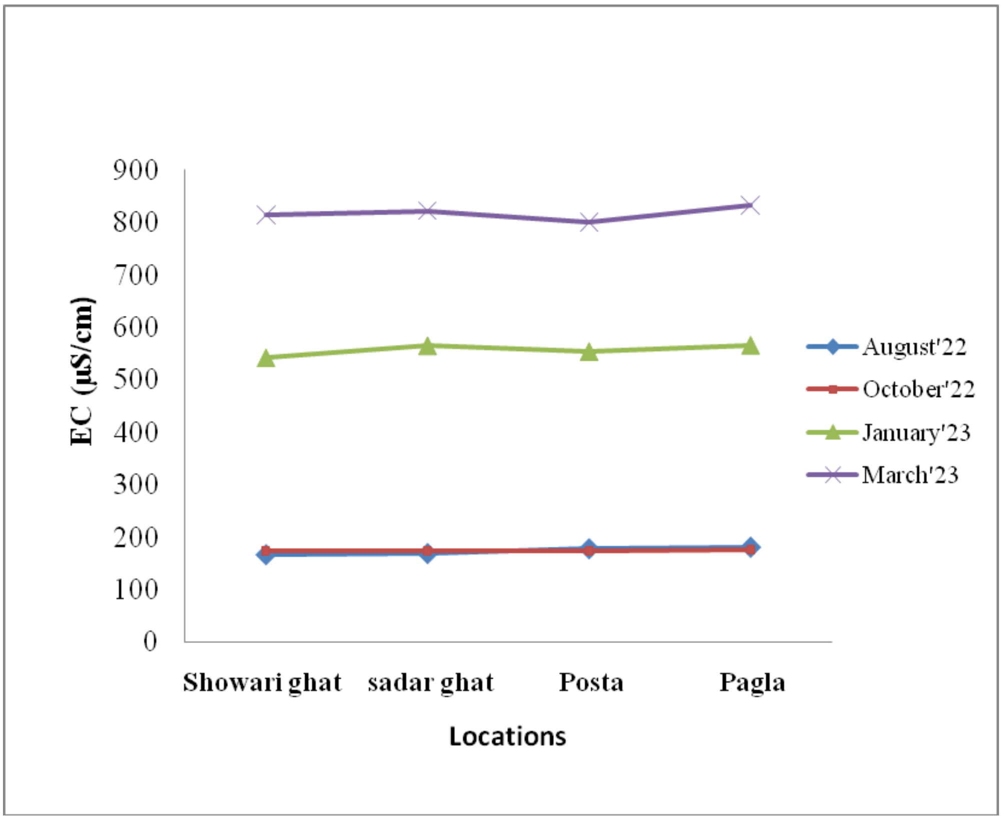

Figure 4.9: EC at mid point of each sampling location of Buriganga river at different seasons.

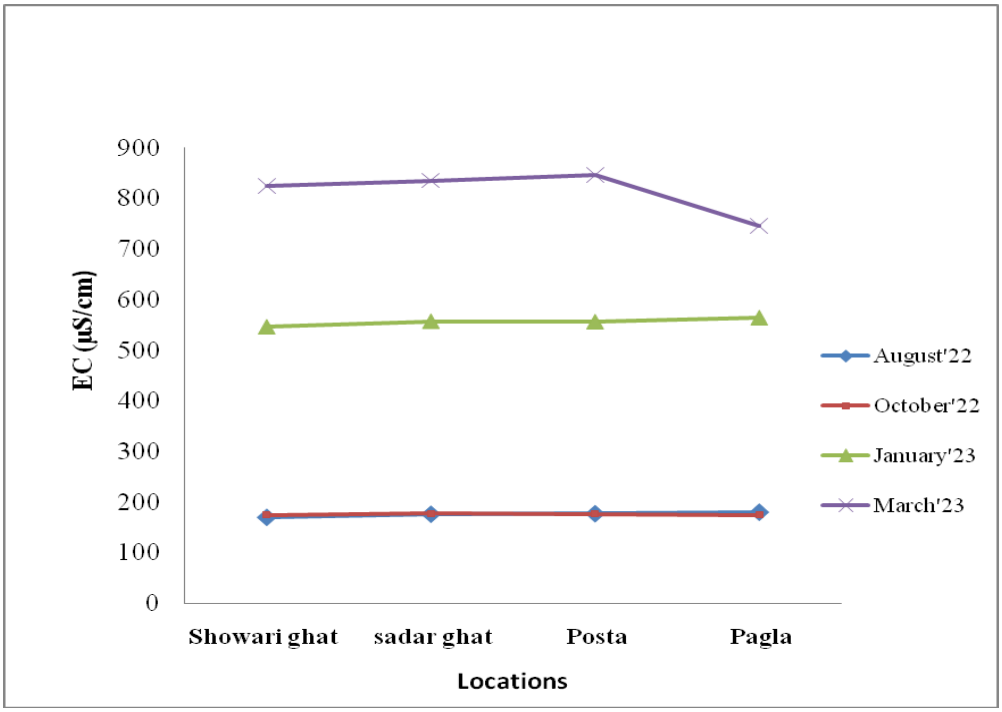

Figure 4.9: EC at south point of each sampling location of Buriganga river at different seasons.

4.3.4 COD and BOD_5

Chemical Oxygen Demand (COD)

In this study, COD values along the Buriganga river ranged from 7 to 42 mg/L during the wet season of 2022 in the month of august and October; during the dry season of 2023 COD values ranges from 51 to 316 mg/L. It should be noted that the standard of COD for potable water source after freeing bacteria and recreational uses is 10 mg/L, for fishing purpose the standard is 50 mg/L and for irrigation and industrial uses it is 100 mg/L. From the study it is clear that the Buriganga river water is not suitable for drinking water source and recreational uses in terms of COD according to ECR' 23. However, during rainy season it can be used for irrigation and industrial purposes. Figure 4.10 to figure 4.12 shows the seasonal variations of COD along the river over the years.

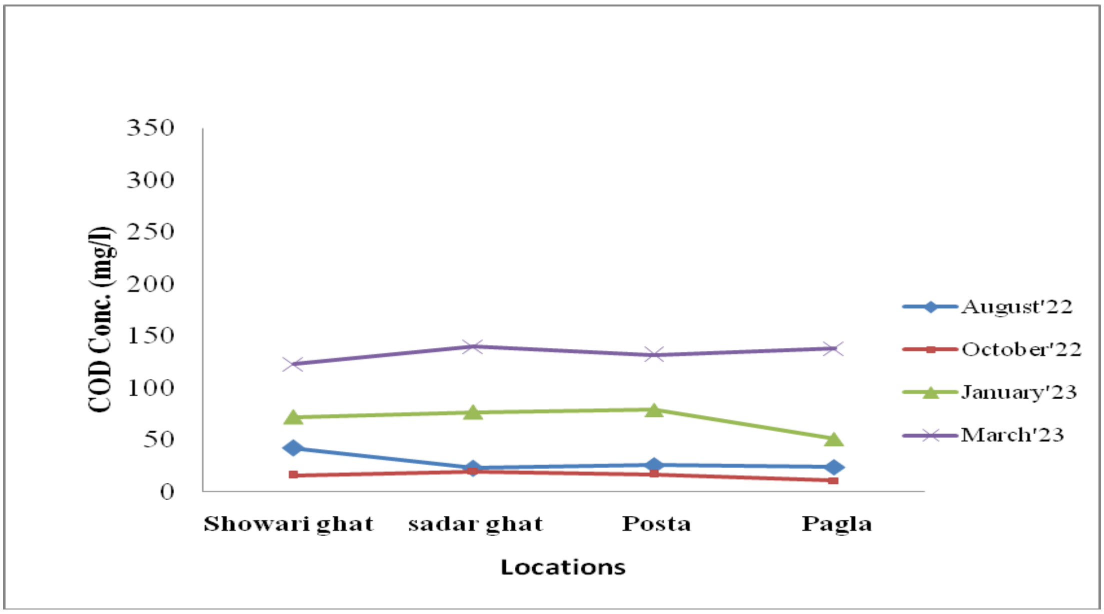

Figure 4.10: COD conc. at north point of each sampling location of Buriganga river at different seasons.

It was found from the study that COD values of water samples in the month of March 2023 were much higher than the other values. Maximum COD value was found at Pagla in March 2023. According to Rahman and Bakri (2010), COD concentrations in the Buriganga river are 4-15 times higher than the standard. COD concentration in Showary ghat, Sadarghat and Posta were 138mg/l, 111mg/l and 96mg/l respectively in March' 2017 (Islam, 2018). COD content remains high normally in February and March in each year. (Paul, 2008).

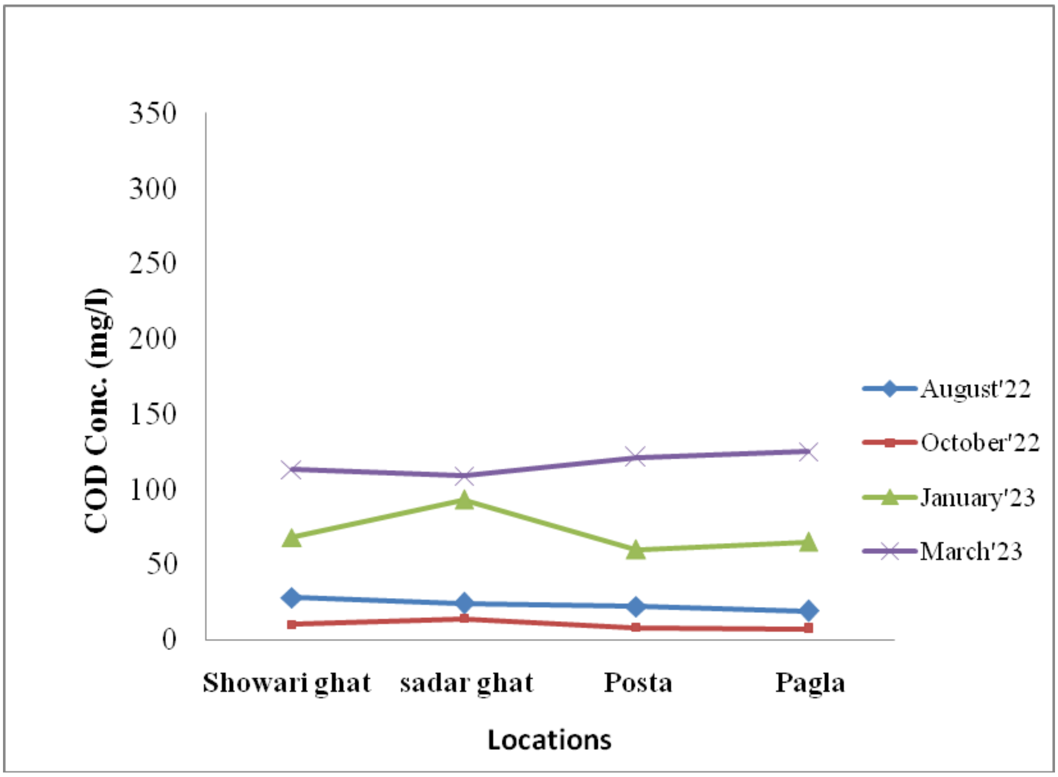

Figure 4.11: COD conc. at mid point of each sampling location of Buriganga river at different seasons.

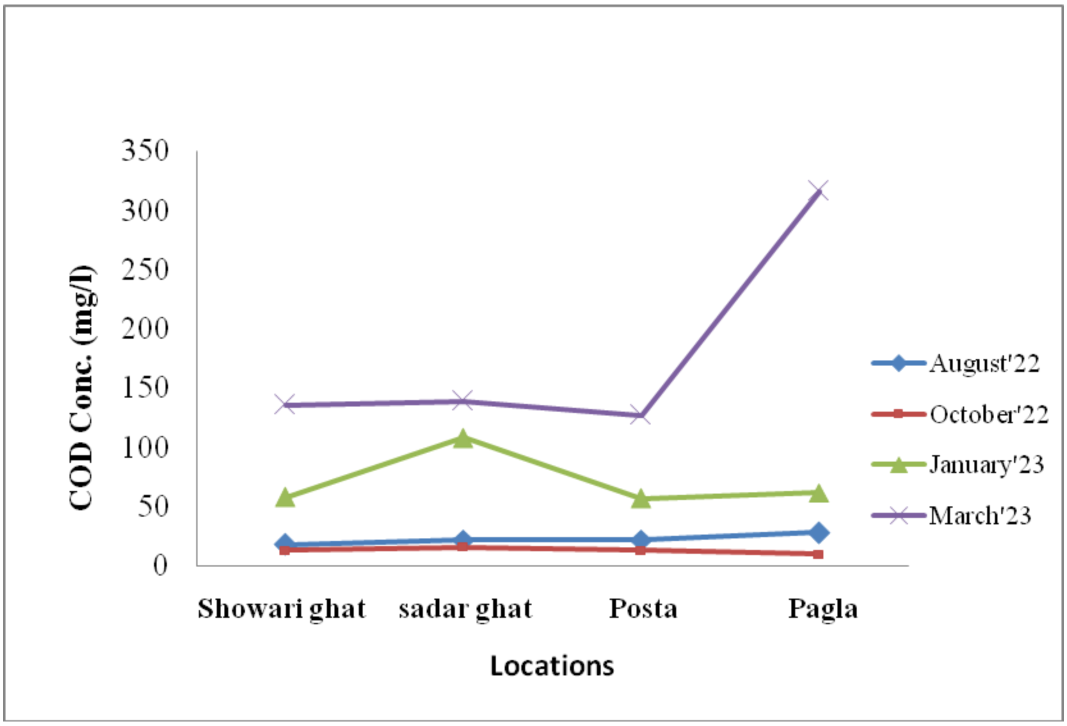

Figure 4.12: COD conc. at south point of each sampling location of Buriganga river at different seasons.

Biochemical Oxygen Demand (BOD_5)

The BOD_5 is a measure of the amount of oxygen that bacteria will consume in five days at 20°C while decomposing organic matters under aerobic conditions. High level of BOD_5 indicates the presence of excessive amount of biodegradable organic matter in the water. The DoE standard for BOD_5 in surface water body varies from 2.0 to 12.0 mg/L, depending on intended uses (drinking water source, recreation, fishing, irrigation etc.) of the water. Variation of BOD_5 along the river has been shown in Figure 4.13 to Figure 4.15.

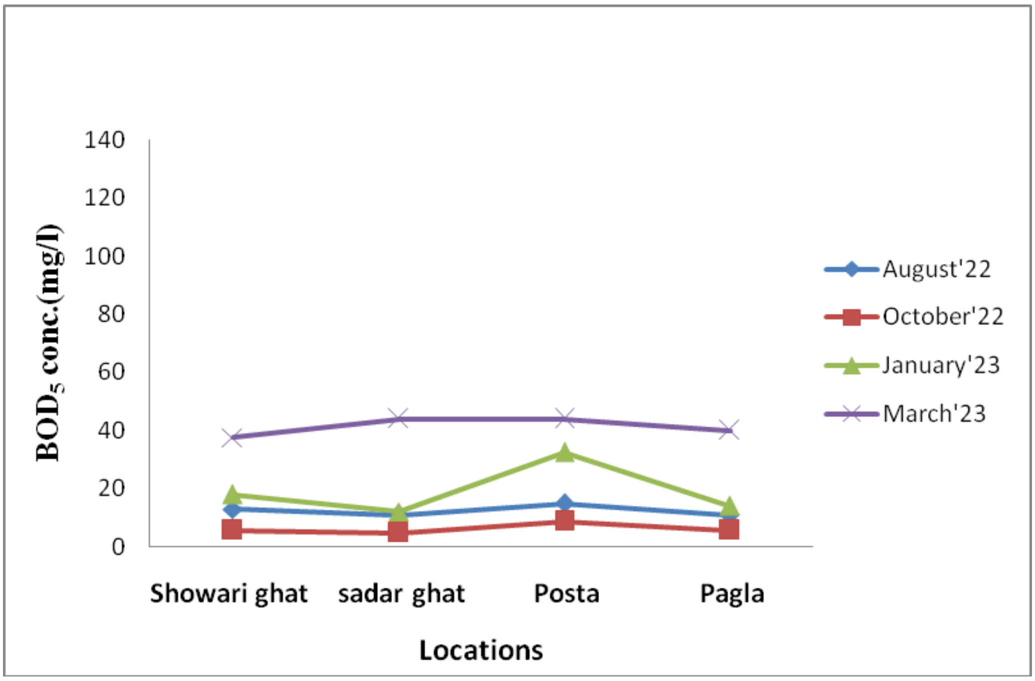

Figure 4.13: BOD_5 conc. at north point of each sampling location of Buriganga river at different seasons.

Along the river, BOD_5 varied from 4.8 to 13.0 mg/L in august 2022 and 1.0 to 8.8 mg/L in October 2022. Maximum value for wet season was found on Showary ghat. Higher BOD_5 values were found in the dry season in the month of March 2023 and it was 128 mg/L. Allowable limit of BOD_5 for potable water source after bacteria freeing is 2.0 mg/L or less, for industrial and irrigational uses 12.0 mg/L. Buriganga river water is not safe as a potable water source and for fishing in terms of BOD_5 according to ECR' 23. However, during rainy season the water can be used for industrial and irrigational purposes.

Maximum BOD_5 was found in Pagla during dry season which indicated that pollution load was high in dry period. However, pollution load decreases in monsoon. In the month of October 2022 BOD_5 ranges from 1.0 to 8.8 mg/L which is much less than any other value.

This may occur due to the heavy rain on that time flow of the river was high. Therefore, it can be concluded that during pre-monsoon pollution has been accumulated in the river and during monsoon pollution load has been washed out from the river.

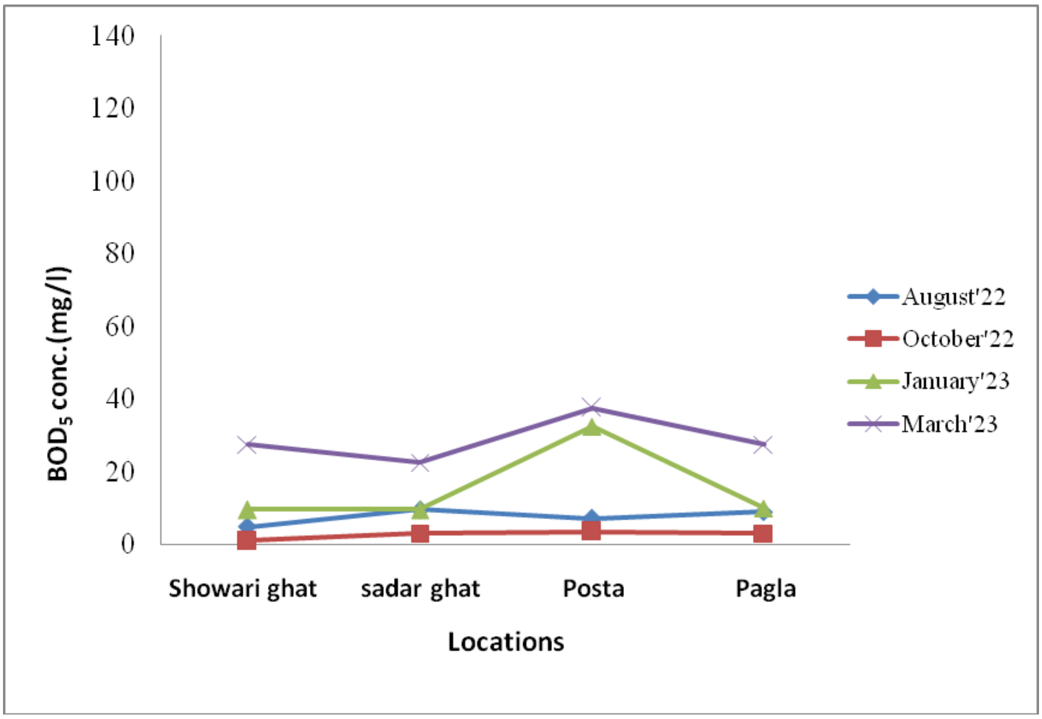

Figure 4.14: BOD_5 conc. at mid -point of each sampling location of Buriganga river at different seasons.

Figure 4.15: BOD_5 conc. at south point of each sampling location of Buriganga river at different seasons.

According to Rahman and Bakri (2010), BOD_5 standard is often exceeded in Buriganga river water and in their study BOD_5 was found 34.5 mg/L in 2010. Due to the discharge of organic matter and industrial fertilizer wastes (containing high amounts of nitrogen (N) and phosphorus (P)), BOD_5 increase in the Buriganga river (Arif and Yousuf, 2016).

Relation between DO and BOD_5

Average DO and BOD_5 value of every sampling locations shows a downward trend which means that with the increase of BOD_5, dissolve oxygen (DO) decreases and from the test data it was found that DO in dry season was much lower than rainy season. However, pollution was accumulated during dry period and decreased during monsoon as dilution occurs in monsoon and pollution washed out during that period. Figure 4.16 shows the relation between minimum DO between maximum BOD_5. DO concentration increases with the decrease of BOD_5.

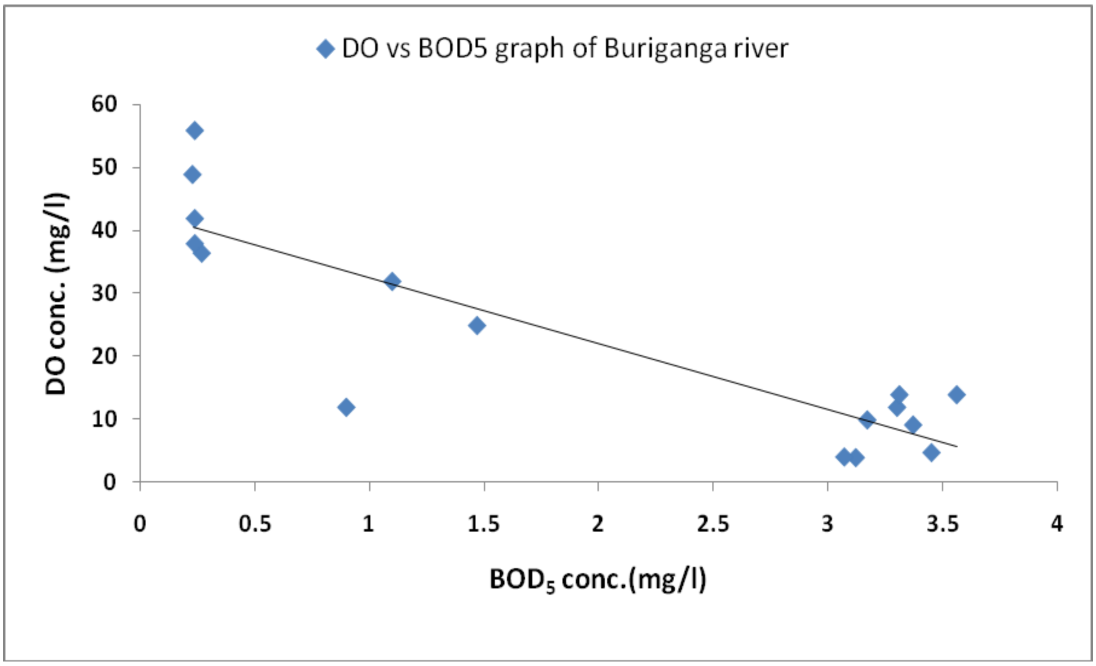

Figure 4.16: Relationship between minimum DO vs maximum BOD_5 in Buriganga river.

Average BOD_5/COD value

Organic matters are usually quantified as BOD_5 (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand). BOD_5 and COD are important measurements to determine the extent of water pollution (Mouri, Takizawa, 2011). The ratio of BOD_5 to COD indicates the biodegradability of wastewater, the higher value of BOD_5/COD means high biodegradability of water (Papadopoulos *et al.*, 2001). When the ratio of BOD_5 to COD is less than 0.1, which means the presence of high organic matter and is it difficult to biodegrade, and it can be toxic (Andrio *et al.*, 2019) The lowest ratio of BOD_5 to COD for water to be easily biodegradable is 0.4 (Lee and Nikraz, 2015) and that the best value is greater than 0.5 (Samudro and Mangkoedihardjo, 2010). From the collected data the average ratio of BOD_5 to COD have been assessed here for all the sampling location during the study period.

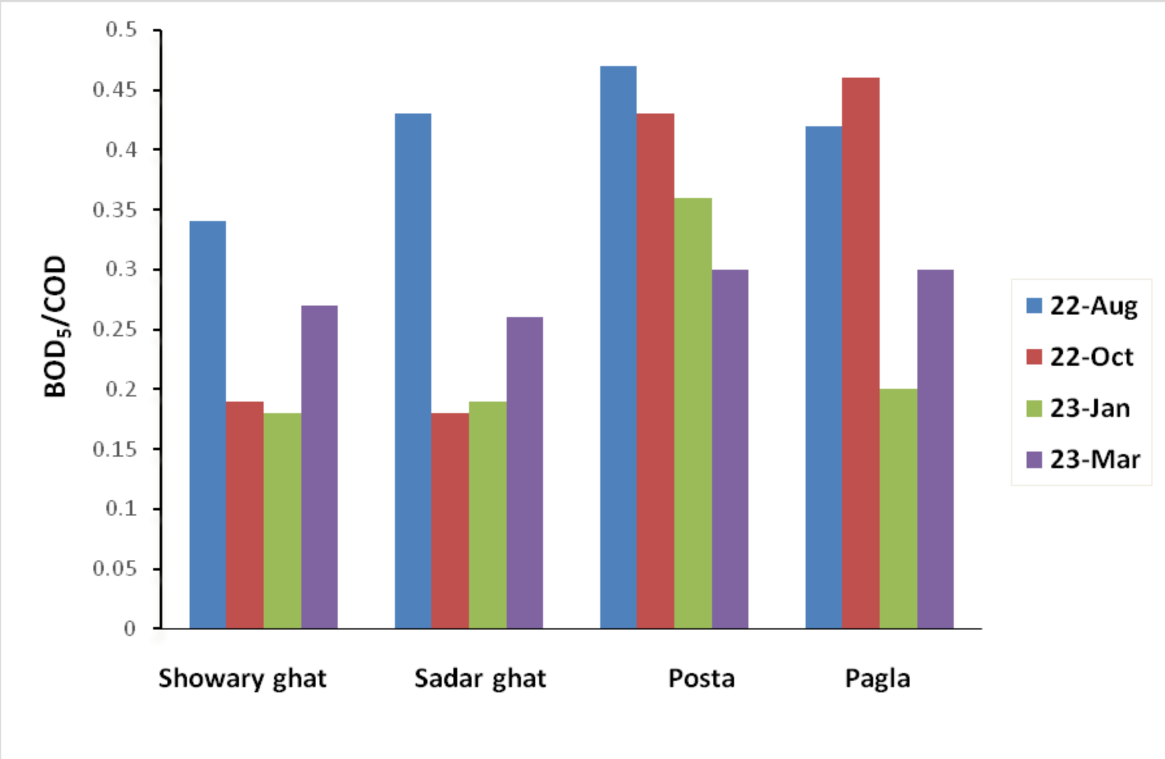

Figure 4.17: Average BOD_5/COD value of water samples collected from Buriganga river.

It is found that the average BOD_5/COD value is greater than 0.30 in August 2022 which thatthe water is easily biodegradable. In the month of October the BOD_5/COD value for Showary ghat and Sadar ghat is less than 0.30 which indicate the presence of high amount of non-biodegradable organic matter in the water. The BOD_5/COD value for the month of January and March of 2023 also indicate the presence of more non-biodegradable substances than biodegradable in all the sampling locations of Buriganga river. Figure 4.17 shows the average BOD_5/COD value along the Buriganga river. Average BOD_5/COD value of all value collected from Buriganga river is 0.29 which indicates the presence of high amount of non-biodegradable organic matter than biodegradable organic matter in the Buriganga river water.

4.3.5 NH_3-N Concentrations

Along the Buriganga river, total ammonia concentrations varied from season to season. In wet season in the month of August and October of 2022 NH_3-N concentration is found nearly 1.00 or less than that. In January 2023, small increase in NH_3-N concentrations was found, with concentration varying from 4.7 to 7.4 mg/L. maximum ammonia concentrations were recorded in March 2023 along the river as compared to all other sampling times. Highest NH_3-N (21.25 mg/L) was found at Pagla near the industrial establishment. However, the standard of NH_3-N for potable water source after bacteria freeing is 0.10 to 0.30 mg/L according to ECR' 23. For industrial uses the limit is 2.7 mg/L and for irrigational uses it is 1.5 mg/L. The concentration of NH_3-N found in Buriganga river was significantly higher than the acceptable level in almost all the sampling locations. Figures 4.18 to Figure 4.20 shows the variation of NH_3-N along the Buriganga river.

Figure 4.18: NH_3-N conc. at north point of each sampling location of Buriganga river at different seasons.

In June, 2007 NH_3-N concentration in Buriganga river for Sadar ghat was found 2.0 mg/L in March 2017 NH_3-N concentration in Buriganga river for Showary ghat, Sadar ghat and Posta were found 16.4 mg/L, 15.95 mg/L and 16.15 mg/L respectively (Islam, 2018).

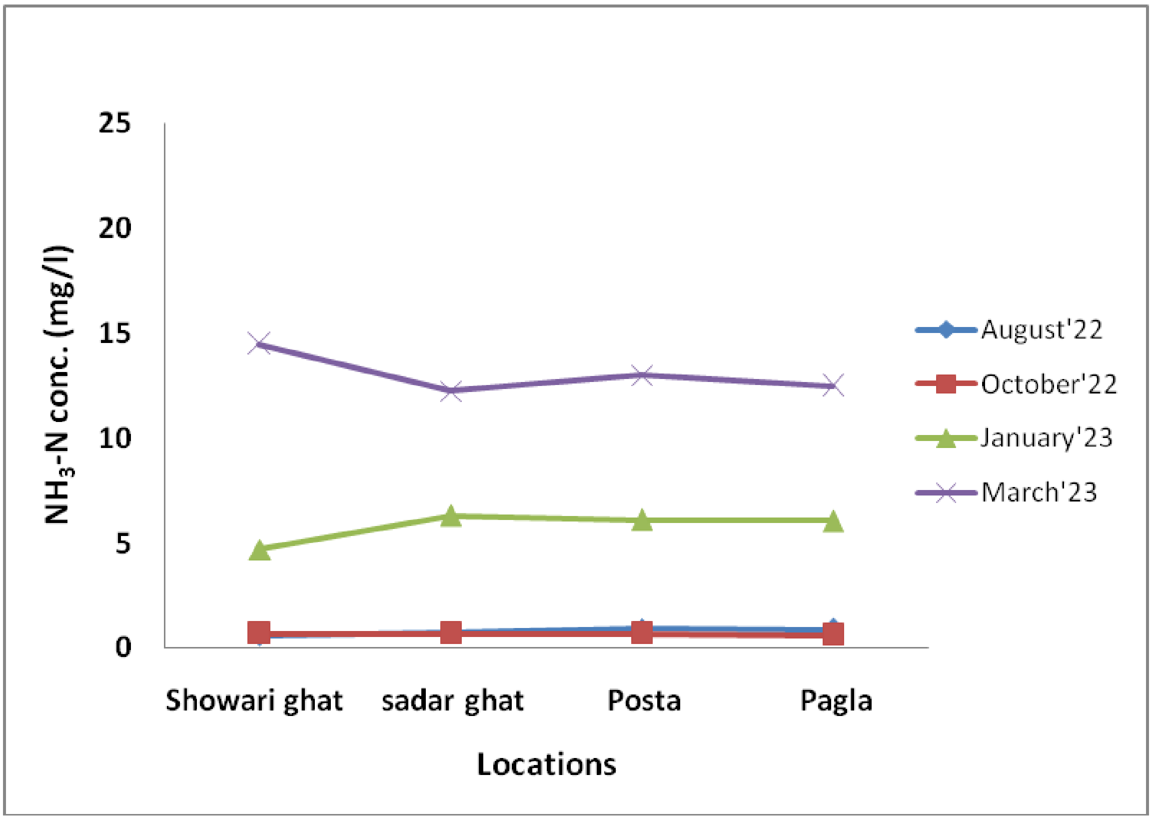

Figure 4.19: NH_3-N conc. at mid-point of each sampling location of Buriganga river at different seasons.

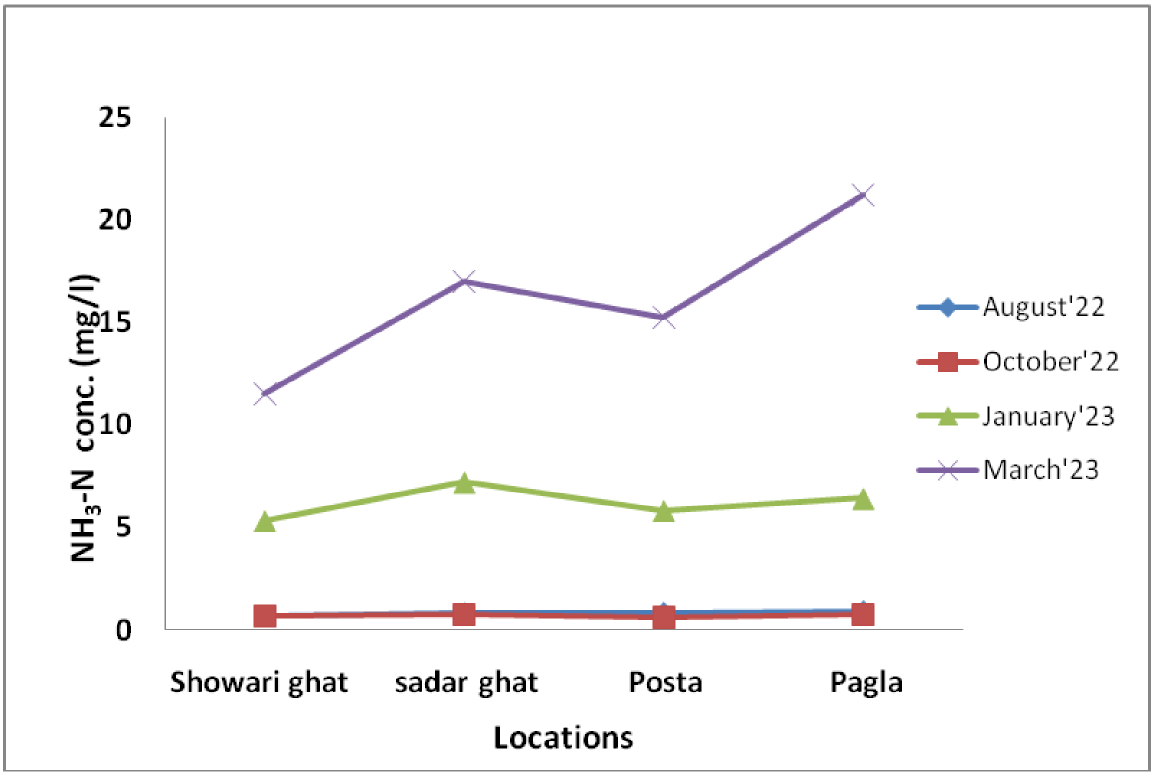

Figure 4.20: NH_3-N conc. at south point of each sampling location Buriganga river at different seasons.

4.3.6 Chloride Concentrations

Along the Buriganga river, the concentrations of Chloride varied from season to season. In wet season the concentration is low than the dry season. In the month of August it ranged from 9 to 17 mg/L where in October of 2022 chloride concentration was found nearly 10.00 to 12.0 mg/L. In January 2023, the concentrations were found higher, with concentration varying from 30 to 35 mg/L. In March 2023, maximum chloride concentrations were recorded along the river as compared to all other sampling times. Highest chloride (67 mg/L)was found at Pagla near the industrial establishment. There is no standard of chloride for inland surface water in ECR 2023. Figure 4.21 to Figure 4.23 shows the variation of chloride along the Buriganga river.

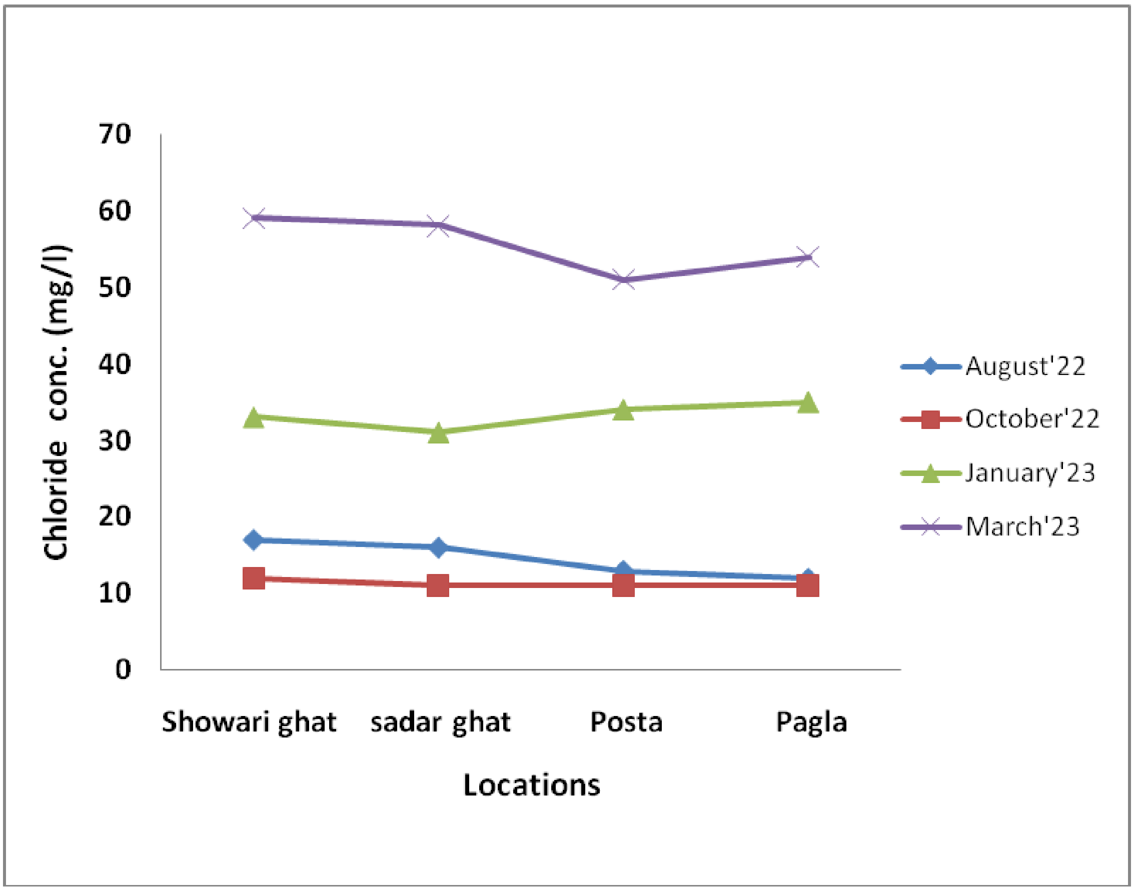

Figure 4.21: Chloride conc. at north point of each sampling location of Buriganga river at different seasons.

Maximum chloride concentration in Buringanga river was found 30 mg/L in 1980 (Haque, 2003). According to Uddin et al. (2016), Chloride concentration in Buriganga river was found 0.4 to 1.12 mg/L.

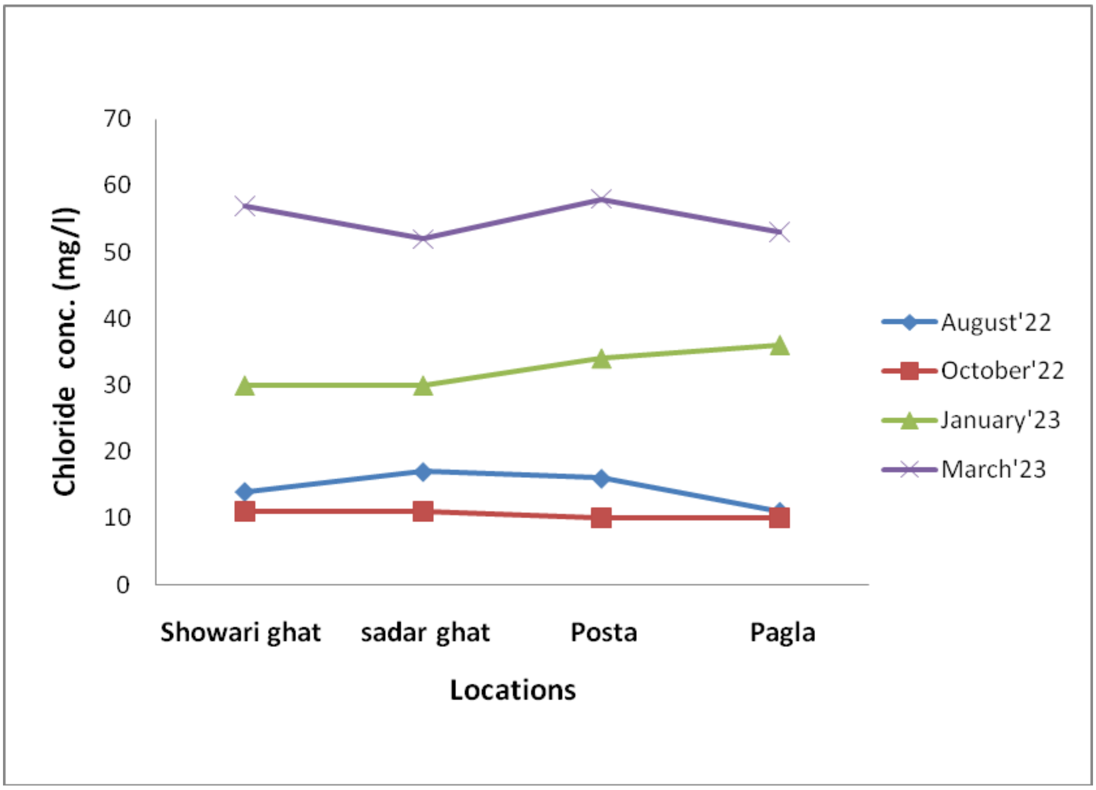

Figure 4.22: Chloride conc. at mid-point of each sampling location of Buriganga river at different seasons.

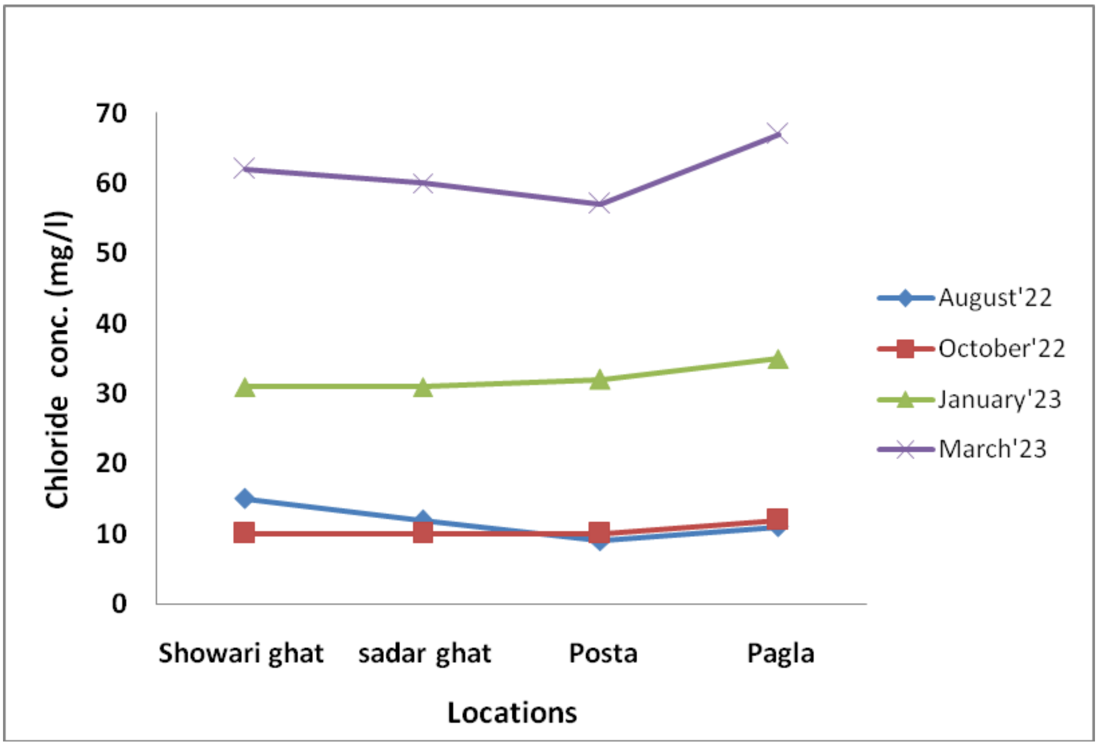

Figure 4.23: Chloride conc. at south point of each sampling location of Buriganga river at different seasons.

4.3.7 H_2S Concentrations

Along the Buriganga river, the concentrations of H_2S varied from season to season. In wet season the concentration is low than the dry season. In the month of August it ranged from 13 to 22 mg/Lwhere in October of 2022 H_2S concentration was found nearly 8.0 to 10.0 mg/L. In January 2023, the concentrations were found higher, with concentration varying from 18 to 28 mg/L. In March 2023, maximum H_2S concentrations were recorded along the river as compared to all other sampling times (24-30 mg/L). Figure 4.24 to Figure 4.26 shows the variation of H_2S along the Buriganga river.

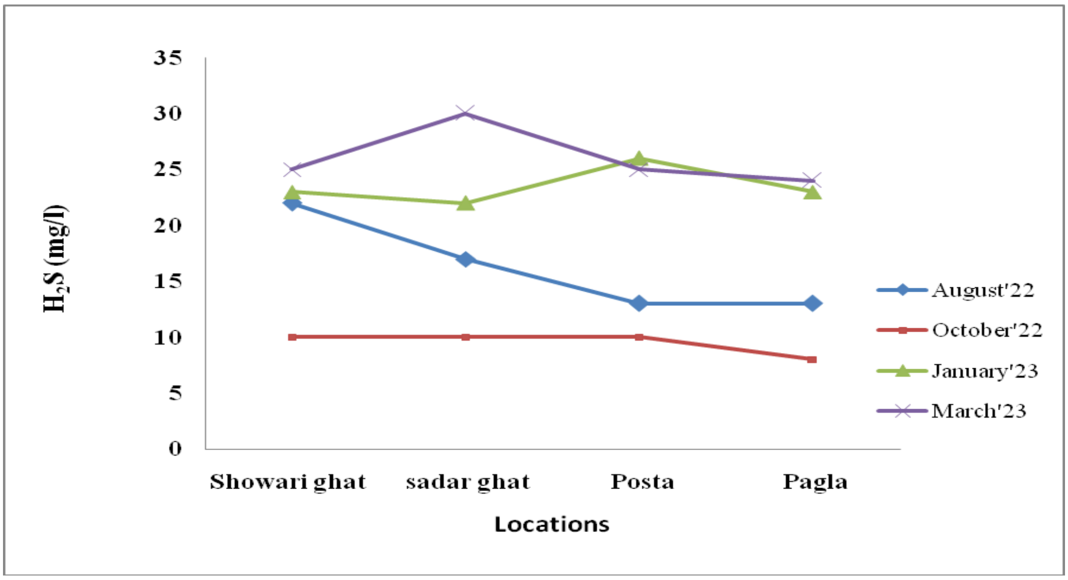

Figure 4.24: H_2S conc. at north point of each sampling location of Buriganga river at different seasons.

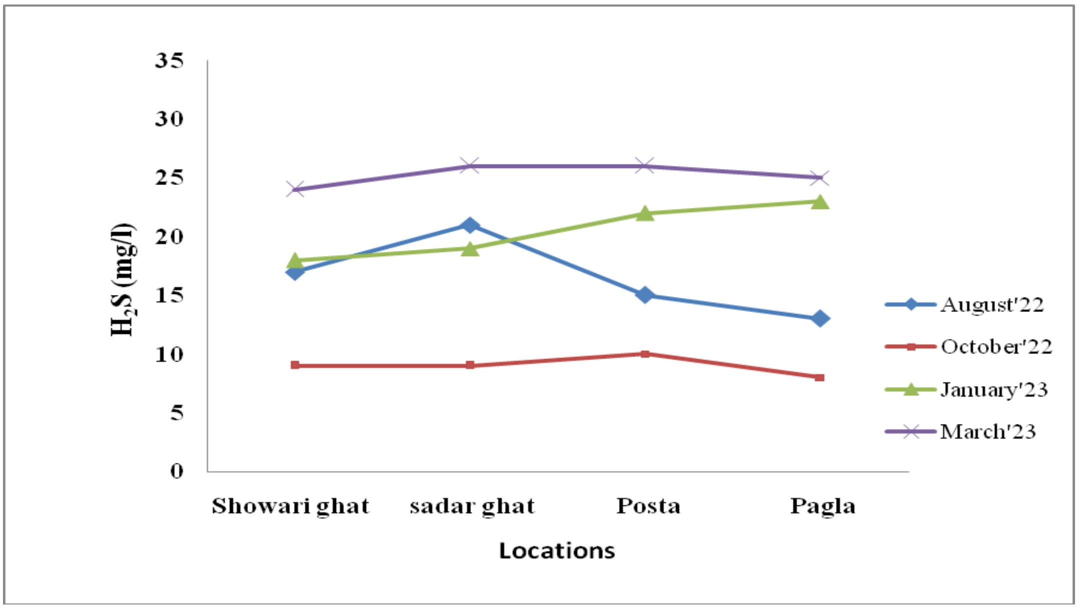

Figure 4.25: H_2S conc. at mid- point of each sampling location of Buriganga river at different seasons.

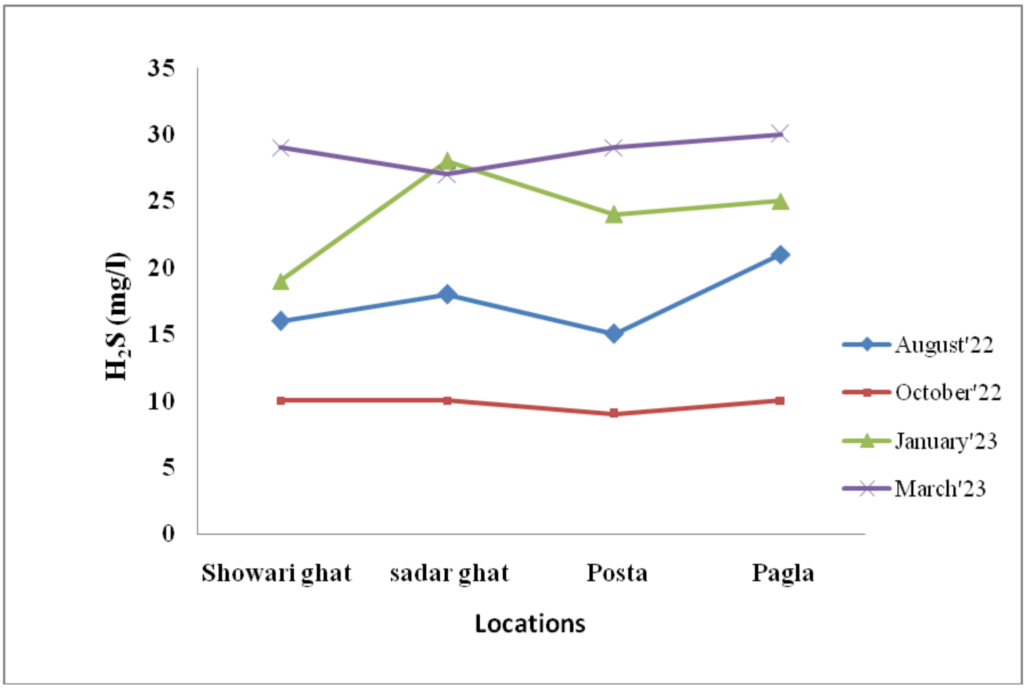

Figure 4.26: H_2S conc. at south point of each sampling location of Buriganga river at different seasons.

4.4 Pollution trend of Buriganga river

Dissolve Oxygen

From previous studies the minimum concentration of DO at Sadar ghat point is assessed here. Available data from 1968 to 2023 are plotted and it shows an overview regarding DO concentration at Buriganga river over the years. Figure 4.27 shows the DO concentration trend of Buriganga river.

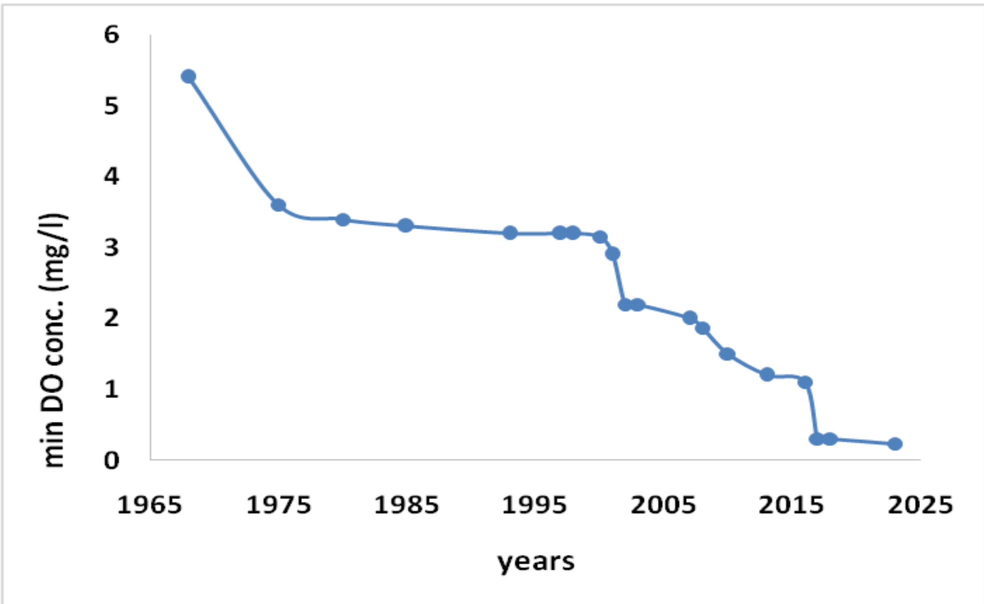

Figure 4.27: Change of minimum DO conc. at Sadar ghat in the Buriganga river over the years.

From the figure it is clear that minimum DO concentration of Buriganga river is decreasing over time. During the period (1968 to 2023) the DO concentration was decreased almost six times which indicates a high pollution load of Buriganga river. Data were collected from different papers (Kamal, 1996; Haque, 2003 and Paul, 2008, Islam, 2018) and international journals (International Journal of Emerging Technology and Advance Engineering, 2009).

Biochemical Oxygen Demand

Biochemical Oxygen Demand (BOD_5) data of previous years from different papers, journals, thesis are assessed here to show the BOD_5 pollution trend of Buriganga river. Figure 4.28 shows the change of maximum BOD_5 concentration over the years.

From figure 4.28 a tremendous increase of maximum BOD_5 concentration was found during the period 1968 to 2023. A sharp increase was obtained during 2015 to 2023; within this eight years the pollution increased almost ten times. Higher BOD_5 concentration indicates a high pollution load of Buriganga river. This occurs due to indiscriminate discharge of untreated industrial and household waste into them. Every day a large amount of BOD is dumped into the Buriganga from industrial and domestic sources through several drainage outlets.

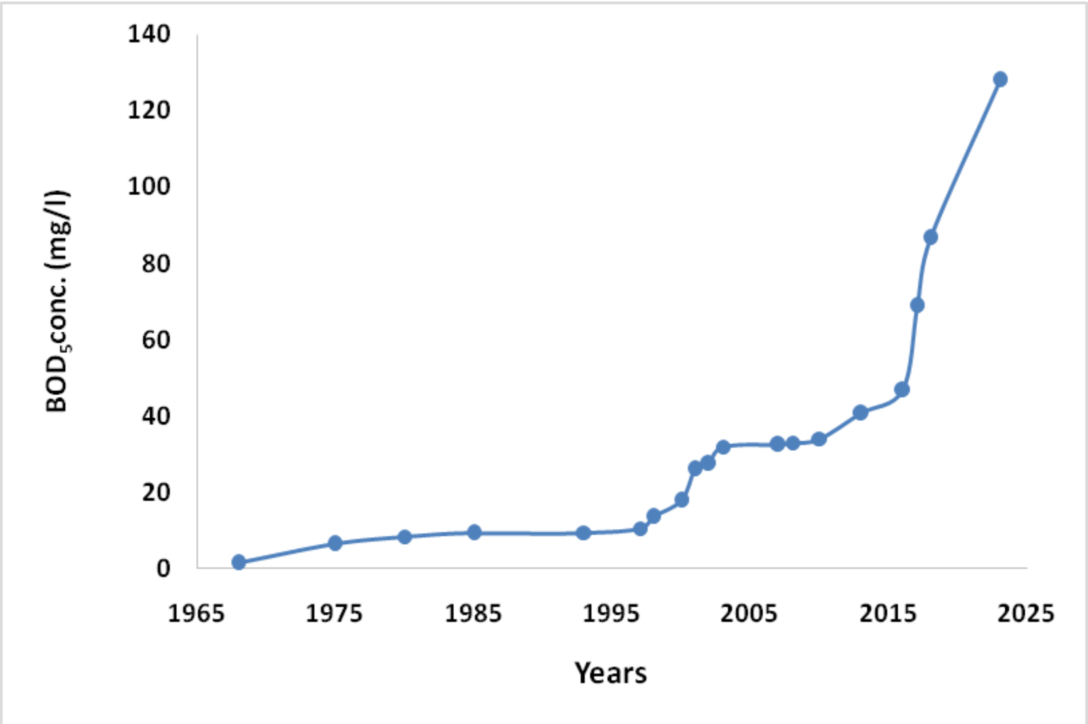

Figure 4.28: Change of maximum BOD_5 conc. in the Buriganga river over the years.

Chloride

Maximum Chloride concentration data of previous years from different papers (Kamal, 1996; Haque, 2003 and Paul, 2008, Islam, 2018) and international journals (International Journal of Emerging Technology and Advance Engineering, 2009) are assessed here to show the Cl^- concentration of Buriganga river. Figure 4.29 shows the change of maximum Cl^- concentration over the years. Chloride concentration increases almost 12 times during last 55 years.

Chloride concentration is increasing in Buriganga river day by day. This indicates the intrusion of seawater and discharge of industrial wastewater from the chemical, petrochemical, chemical pharmaceutical, paper, cement, soap, textile, paint, pigment, food, machinery manufacturing, and leather-tanning industries.

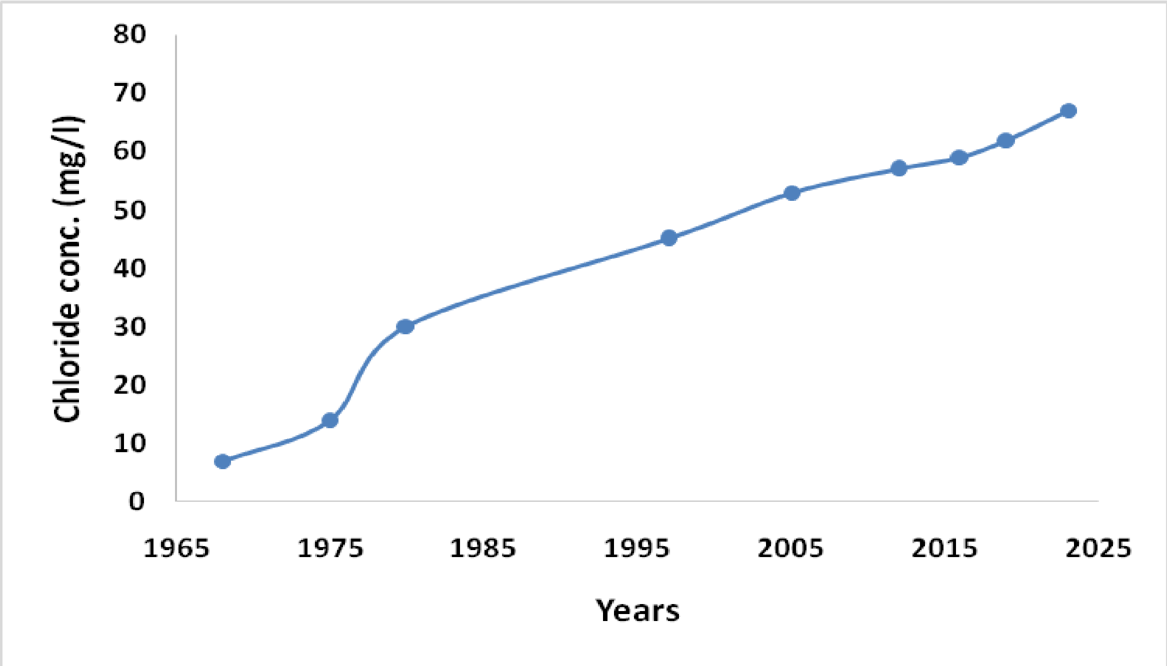

Figure 4.29: Change of chloride concentration (maximum) in the Buriganga river over the years.

4.5 Heavy metal (Chromium, Lead)

In this study Chromium and Lead have been tested for dry season in March 2023.Table 4.1 shows the concentration of Chromium and lead.

Table 4.1: Concentration of Chromuim and Lead of each sampling location of Buriganga river in March, 2023.

Locations		Chromium,Cr(ppm)	Lead,Pb(ppm)
Showari-ghat(N)	B1	<MDL	0.019
Showari-ghat(Mid)	B2	<MDL	0.015
Showari-ghat(S)	B3	<MDL	0.019
Sadar Ghat(N)	B4	0.002	0.019
Sadar ghat(Mid)	B5	0.002	0.017
Sadar ghat(S)	B6	0.002	0.015
Posta(N)	B7	<MDL	0.019
Posta(mid)	B8	<MDL	0.021
Posta(S)	B9	<MDL	0.024
Pagla(N)	B10	<MDL	0.029
Pagla(mid)	B11	<MDL	0.021
Pagla(S)	B12	<MDL	0.040

4.5.1 Lead

The major sources of Pb in natural waters include manufacturing processes, atmospheric deposition. Other sources include domestic wastewaters, sewage and sewage sludge (Ahsanuzzaman, 1996). Lead is toxic and a major hazard to human and animals. Lead has two quite distinct toxic effects on human beings, physiological and neurological. The relatively immediate effects of acute lead poisoning are ill defined symptoms, which include nausea, vomiting, abdominal pains, anorexia, constipation, insomnia, anemia, irritability, mood disturbances and co-ordination loss.

In this study maximum lead concentration was found 0.04 mg/L near Pagla in the month of March 2023. Lead concentration in other locations were found less than 0.04mg/L, which apparently shows that the lead concentrations were below the allowable limit according to ECR"23 (0.1mg/L). Figure 4.27 shows the concentration of lead at the sampling locations of Buriganga river.

In 2003 and 2004 lead concentration at pagla was found less than 0.001 mg/l (Source; WSP International,1998; IWM, 2005 Khan *et al.* (1998) found that the concentration of Pb ranged from 0.012 to 0.43 μg/mL, which are much lower than the current study. Alam *et al.* (2003) found that in the Buriganga river Pb concentration varied between 0.1 and 0.7 μg/l

In rainy season, and 5-14.4 μg/L in dry season, which are also much lower than the present study. Rahman and Bakri (2010) measured the concentration lead (Pb) to assess the heavy metal toxicity in the Buriganga river and found that Pb concentrations were 0.006-0.008 mg/L which are lower than the permissible standard 0.01 mg/l.

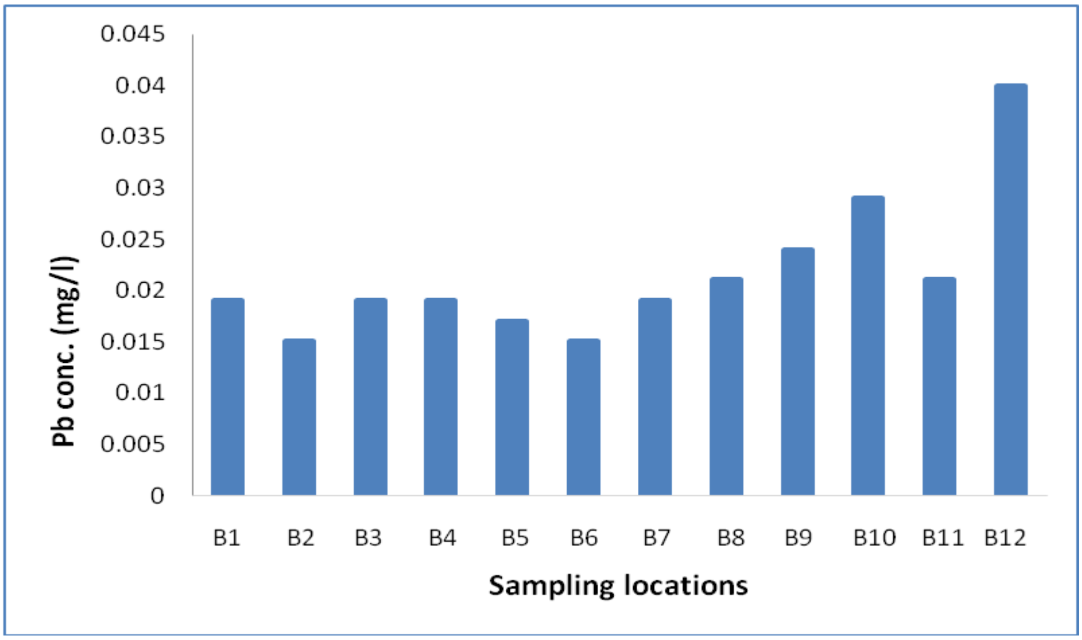

Figure 4.30: Lead (Pb) concentration at the sampling locations of the Buriganga river at March, 2023.

4.5.2 Chromium

Chromium is found zero in almost all sampling location except Sadar ghat. In Sadar ghat chromium is found 0.002 mg/L which is quite low than the allowable limit of Bangladesh guideline value. According to ECR' 23 allowable chromium concentration for drinking water source is 0.01 mg/L, for recreational purpose 0.2 mg/L, for fishing is 0.05 mg/L, for industrial uses 0.10and for irrigation the limit is 0.10 mg/L.

Alam et al. (2003) found higher concentration of Cr in rainy season (3-13 μg/L) than the concentration of dry season (1.2-8 μg/L) in Buriganga river. Rahman and Bakri (2010) measured the concentration of chromium (Cr) to assess the heavy metal toxicity in the Buriganga river and found that Cr (VI) concentrations were 0.06-0.07 mg/L which are higher than the allowable limit of drinking water source (0.01 mg/L) according to ECR'23. High concentration of Cr (VI) is often associated with the leather industries (used in the tanning process) and discharge of untreated wastewater (Rahman and Bakri, 2010).

Chapter Five
CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The Buriganga river receives solid wastes, sewage and wastewater which contain biodegradable materials and industrial effluent are being disposed indiscriminately in the Buriganga river. These pollutants constantly deplete the most important parameter, Dissolved Oxygen (DO). The water quality of the Buriganga river is deteriorating over the years. The increase of domestic and industrial pollutant loads can be attributed to the rapid increase of population, industries and subsequent increase of people without proper sanitation facilities. Low flow of water, lack of rainfall and increase in temperature during dry season also contribute to the pollution status of the Buriganga river. This study focused on the identification of some water quality parameters of Buriganga river adjacent to Dhaka City. In this study, a portion of Buriganga river from Showary ghat to Pagla has beenselected as the study reach to assess the existing water quality during the wet season of the year 2022 and dry season of the year 2023. Water samples were collected from twelve monitoring locations along this reach during that period. Different water quality parameters have been assessed in this study like PH, DO, EC, Color, COD, BOD_5, NH_3-N, H_2S, Cl^- etc.Heavy metals (chromium, Lead) have been measured during the month of March, 2023.

5.2 Conclusions

The outcomes from this analysis of Buriganga river water quality are as follows:

i) Buriganga river water is not suitable for potable water source, irrigational and industrial uses as pollutant concentration is higher than allowable limits. However, during rainy season the water is suitable for industrial uses according to ECR' 23.

ii) Appreciable reduction in BOD_5, COD, Electrical Conductivity, Ammonia, Chloride concentrations have been observed along the river during the wet season (August to October of 2022) compared to dry season (January to March of 2023) as the dilution rate has increased.

iii) The presence of non-biodegradable organic matter is higher in Buriganga river than biodegradable organic matter as the BOD_5/COD value is found below 0.30.

iv) Pollution trend analysis for selected parameters of last 50 years has shown that pollution is increasing in Buriganga river water. DO concentration has been found too low than the required standard. BOD_5 and Chloride are increasing at an alarming rate in Buriganga river over the years.

5.3 Recommendations for further studies

This study was undertaken to bring out the scenario of present Buriganga river water by showing seasonal variations of water quality and the collected data will help to assessed different water quality models.

i) Only for some selected stations on the Buriganga river, this study has been conducted. Therefore, a complete observation from more locations is essential for better understanding of actual condition of water quality in the river system.

ii) Other heavy metals (Ni, Fe, Al, Hg, Cd) and other parameters such as organic content, total organic carbon, sediment oxygen demand and moisture content so on and so forth may be considered for further analysis and in-depth research.

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Appendices

Table A.1: Characteristics of water samples collected from Buriganga river during August, 2022.

Parameters	Locations along the Buriganga river											
	Showari Ghat			Sadar Ghat			Posta			Pagla		
	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12
pH	6.75	6.91	6.9	3.97	6.91	6.92	6.91	6.8	6.93	7	7.06	7
DO (mg/l)	2.26	3.74	3.4	3.38	3.71	2.81	2.61	2.9	2.91	2.5	2.67	2.95
Color(pt-co)	118	91	92	93	110	102	75	90	90	75	77	116
EC (µS/cm)	185	167	170	174	169	176	183	178	177	184	181	180
COD (mg/l)	42	28	18	23	24	22	26	22	22	24	19	28
BOD_5 (mg/l)	13	4.8	10	11	9.6	10	15	7.2	12	11	9	10
NH_3 -N (mg/L)	1.12	0.59	0.7	0.82	0.7	0.84	1.02	0.9	0.86	0.96	0.87	0.93
H_2S (µg/l)	22	17	16	17	21	18	13	15	15	13	13	21
Chlroride(mg/l)	17	14	15	16	17	12	13	16	9	12	11	11
BOD_5/ COD	0.31	0.17	0.56	0.44	0.40	0.45	0.57	0.32	0.54	0.45	0.47	0.35

Table A.2: Characteristics of water samples collected from Buriganga river during October, 2022.

Parameters	Locations along the Buriganga river											
	Showari Ghat			Sadar Ghat			Posta			Pagla		
	B-1	**B-2**	**B-3**	**B-4**	**B-5**	**B-6**	**B-7**	**B-8**	**B-9**	**B-10**	**B-11**	**B-12**
pH	7.15	7.36	7.39	7.34	7.39	7.44	7.4	7.45	7.39	7.37	7.43	7.39
DO (mg/l)	2.85	3.59	3.39	3.12	4.01	3.7	3.9	4.24	4.06	3.5	3.76	3.68
Color(pt-co)	57	59	62	65	55	62	66	64	60	48	49	57
EC (µS/cm)	185	173	174	182	174	177	175	174	176	178	176	174
COD(mg/l)	16	10	13	20	14	16	17	8	13	11	7	10
BOD_5 (mg/l)	5.6	1	1.6	4.8	3	1.6	8.8	3.5	4.8	5.6	3	4.8
NH_3 -N(mg/l)	0.8	0.67	0.68	0.92	0.67	0.75	0.7	0.68	0.62	0.64	0.61	0.76
H_2S(µg/l)	10	9	10	10	9	10	10	10	9	8	8	10
hlroride(mg/l)	12	11	10	11	11	10	11	10	10	11	10	12
BOD_5/COD	0.35	0.10	0.12	0.24	0.21	0.10	0.51	0.43	0.36	0.50	0.42	0.48

Table A.3: Characteristics of water samples collected from Buriganga river during January, 2023.

Parameters	**Locations along the Buriganga river**											
	Showari Ghat			Sadar Ghat			Posta			Pagla		
	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12
pH	7.18	7.35	7.48	7.46	7.4	7.42	7.4	7.43	7.42	7.41	7.41	7.42
DO (mg/L)	0.33	0.43	0.39	0.33	0.38	0.34	0.3	0.28	0.25	0.26	0.32	0.27
Color(pt-co)	132	113	114	131	148	162	144	129	137	133	136	124
EC (µS/cm)	542	542	546	544	565	557	554	554	556	568	566	564
COD(mg/l)	72	68	58	77	93	108	79	60	57	51	65	62
BOD_5(mg/l)	18	9.6	10	12	9.6	37.5	33	32.5	7.5	14	10	12
NH_3 -N (mg/l)	5.25	4.7	5.3	5.3	6.3	7.2	6.5	6.1	5.8	5.95	6.05	6.4
H_2S(µg/l)	23	18	19	22	19	28	26	22	24	23	23	25
hlroride(mg/l)	33	30	31	31	30	31	34	34	32	35	36	35
BOD_5/COD	0.25	0.14	0.17	0.15	0.10	0.34	0.41	0.54	0.14	0.27	0.15	0.19

Table A.4: Characteristics of water samples collected from Buriganga river during March, 2023.

Parameters	**Locations along the Buriganga river**											
	Showari Ghat			Sadar Ghat			Posta			Pagla		
	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12
pH	7.62	7.54	7.55	7.59	7.62	7.48	7.57	7.4	7.46	7.4	7.5	7.2
DO (mg/l)	0.25	0.23	0.25	0.28	0.37	0.3	0.35	0.29	0.27	0.32	0.3	0.28
color	462	327	427	458	444	460	461	453	457	445	426	489
EC (µS/cm)	780	814	825	810	822	835	827	800	846	852	833	746
COD(mg/L)	123	113	136	140	109	139	132	121	127	138	125	316
BOD5(mg/l)	37.5	27.5	40	44	22.5	40	44	37.5	36	40	27.5	128
NH3 -N (mg/l)	13	14.5	11.5	14	12.25	17	14.5	13	15.25	13.75	12.5	21.25
H 2S (µg/l)	2590	2465	2960	2420	2355	2540	2140	2100	2310	2485	2200	3060
Chlroride (mg/l)	59	57	62	58	52	60	51	58	57	54	53	67
Alkalinity(mg/l) as CaCo3	316	301	301	317	307	312	295	288	310	298	285	362
BOD_5/COD	0.30	0.24	0.29	0.31	0.20	0.28	0.33	0.30	0.28	0.28	0.22	0.40

Table A.5: Average BOD_5/COD value of water samples collected from Buriganga river.

period	Showary ghat	Sadar ghat	Posta	Pagla
August 2022	0.34	0.43	0.47	0.42
October 2022	0.19	0.18	0.43	0.46
January 2023	0.18	0.19	0.36	0.20
March 2023	0.27	0.26	0.30	0.30

Table A.6: Water quality in Buriganga river in the year of 2007 (Paul,2008)

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Table 2: Concentration of physicochemical parameters of the Buriganga river in the winter (January) and rainy (August) season

Sampling Point	Temp. (0C)		TDS(mg/L)		TSS (mg/L)		pH		Eh (mV)		DO (mg/L)		BOD (mg/L)		COD (mg/L)		Cl-(mg/L)	
	winter	rainy	winter	rainy	winter	rainy	winter	rainy	winter	rainy	winter	rainy	winter	rainy	winter	rainy	winter	rainy
A1	21	22	9.72	4.68	2.56	3.8	8.1	6.8	25	-34	2.9	6	0.6	1	256	116.67	0.1	0.1
A2	24	22	4.04	5.56	1.64	1.8	7.3	6.9	-3	-20	4	6.4	1	1.8	256	320	0.3	0
A3	23	22	3.76	7.64	1.52	4.8	7.6	7.1	12	-7	3	5	0.3	1	336	280	0.1	0
B1	21	22	4.92	6.88	1	5	7.5	7	2	11	1.6	5.5	0.6	0.3	296	106.67	0.3	0
B2	21	22	9.08	5.04	1.2	3.4	8.3	7.1	25	-5	1.2	9.2	0.4	3.8	336	146.67	0.2	0.1
B3	18	21	4.24	3.88	1.44	3	7.4	7.2	-17	4	0.8	7.9	0.1	1.8	216	413.34	0.3	0.2
C1	22	18	4.56	5.08	1.96	1.2	7.7	7.2	9	3	3.3	6.7	0.5	2.3	296	186.67	0.1	0.1
C2	22	23	3.2	6.52	2.2	3.4	7	7.3	-27	5	2	5.2	0.3	2.6	240	126.67	0.3	0
C3	22	21	6.68	5.08	1.76	3.4	6.8	7.4	-33	9	3.2	5.5	0.5	0.6	280	247.62	0.2	0
D1	21	21	6.4	3.88	5.24	1.1	7.7	7.1	5	7	1.8	5.5	0.6	0.6	248	325.67	0	0.1
D2	21	22	6.32	4.28	4.96	0.1	8.8	7.3	17	3	2	4.4	0.3	3	296	78.75	0	0
D3	23	23	4.08	1.8	3.24	1.1	7.8	7.1	-3	-5	4.2	5.4	1.9	4.2	248	134.57	0.3	0.1
E1	24	21	3.96	3.76	1	1.9	7.6	6.9	-7	-20	3.1	3.5	0.5	1.7	256	192.85	0	0.3
E2	21	18	4.68	3.2	2.96	1.3	7.8	7	4	5	3.8	4.6	0.6	2.2	248	112.5	0.1	0.3
E3	18	24	3.32	2.76	1.32	0.4	7.4	6.8	-10	-24	3.4	4.5	0.6	2.5	272	268.58	0	0.2
F1	22	22	5.28	6	3.56	1.8	7.8	6.6	-3	-37	3.8	3.9	0.6	1.1	216	126.67	0	0
F2	18	22	5.24	5.32	3.4	0.5	7.6	6.8	-3	-26	4.8	4.8	0.4	1	264	47.85	0	0.1
F3	20	22	5.68	4.8	4.16	0.3	7.85	7.02	19	-11	3	5	1.7	3.9	216	163	0.1	0.4
SD	1.83	1.5	1.81	1.47	1.34	1.55	0.46	0.2	16.18	15.36	1.1	1.39	0.47	1.2	36.12	99.6	0.11	0.12
DoE	20 to 30°C		1000		≤ 30.0	-	6.5 to 8.5		5		>2.00		4	0.05				

Table A.7: Water quality in Buriganga river during 1968-1980 (Haque,2003).

Table 4.1: Water Quality in Buriganga River during 1968-1980 (Source: Haque, 2003)

Parameters	BUET 1968			DPHE 1975			Study Team 1980		
	min	max	Ave.	min	max	Ave.	min	max	Ave.
EC(μΩ/cm)	150	332	207	325	650	-	282	512	-
PH	7.1	8.2	-	7.1	8.5	-	7.1	7.7	-
Chloride (mg/l)	1	7	-	14	62	-	28	30	29
DO(mg/l)	5.4	8	6.7	1.55	10	-	2.4	4.6	3
BOD(mg/l)	0	1.5	0.8	1.4	6.5	-	1.6	8.4	3
Nitrate (mg/l)	0.1	0.6	0.3	2.6	6.2	-	0.1	1.9	-
Coliform(#/100 ml)	268	600	1450	200	20000	-	-	> 20000	-

Table A.8: Water quality in Buriganga river over the years.

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Table 1. Compilation of physicochemical characteristics of the Buriganga River from various studies and Department of Environment (DoE) standards.

Parameter	Ali et al. (2008)[1]	Begum et al. (2010)[2]	Rahman and Bakri (2010)[3]	DoE Standards for aquatic ecosystem
Temperature (°C)	20-29	24-26	21-30	20-30
pH	7.1-7.9	6.9-7.6	7.4	6.5-8.5
DO (mg/L)	6.1-6.5	3.2-5	0.9-2.8	5
BOD_5 (mg/L)	-	-	2.5-34.5	2
COD (mg/L)	-	-	17.2-60.1	4
PO_4-P (mg/L)	12-39	-	-	6
NH_3-N (mg/L)	2.2-2.6	-	3.2-4.1	0.5
Pb (mg/L)	-	-	0.006-0.008	0.05
Cr (mg/L)			0.06-0.07	0.05

[1]study period: Sep'07-Dec'07; [2]study period: Dec'04-Jan'05; [3]study period: Dec'08-Mar'09

Table A.9: Water quality parameters from International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 8, Issue 6, June 2018).

Table 1.
BOD values of samples collected fromdifferent locations

Location	DO_0	DO_5	BOD(mg/l)
Hazaribagh	11.75	6.5	87.5
Mitford Ghat	11	6.3	78.33
Sadarghat	10.9	5.7	86.67
Postogola	11.5	5.8	71.67

Table A.10: Water quality standard according to DOE 1991.

Table 2.2: EQS of some relevant water quality parameters, (DOE 1991)

Parameter	Drinking water (BSTI)	Recreational	Fishing water	Industrial water	Irrigation water
Dissolved Oxygen mg/l	6	4-5	4-6	5	5
Temperature °C	20-30	20-30	20-30	20-30	20-30
Turbidity (FTU)	5	10	50		
TDS mg/l	500			1500	2000
BOD mg/l	0.2	3	6	10	10
COD mg/l	4	4		10	
pH	6.6-8.5	6-9.5	6.5-8.5	6-9.5	6-8.5
Total coliform /100 ml	2	200	5000		1000

Table A.11: Water quality standard according to ECR’ 2023

Sl.	**No. Classification**	**pH**	**BOD (mg/L)**	**COD (mg/l)**	**DO (mg/L)**	**Pb (mg/l)**	**otal Cr (mg/l)**
1.	Potable water source supply after bacteria freeing only	6.5 - 8.5	2 or less	10	6 or above	0.03	0.02
2.	Water used for recreation purpose	6.5 - 8.5	3 or less	10	5 or above	0.05	0.2
3.	Potable water source supply after conventional processing	6-9	3 or less	25	5 or above	0.03	.02
4.	Water used for pisciculture	6-9	6 or less	50	5 or above	0.1	0.05
5.	Industrial use water Including chilling and other processes	6.5 - 8.5	12	100	1 or above	0.1	0.1
6.	Water used for irrigation	6.5 - 8.5	12 orless	100	---	0.1	0.1

Note: Maximum Electrical conductivity in irrigation water is 2250-µS/cm (temperature 25$_0$C); Sodium less than 26%, Boron less than 0.2%. Source: ECR (2023).

Table A.12: Water quality of Buriganga river (Kamal 1996).

Table 4.3: Seasonal variation of Dissolved Oxygen (DO) in Buriganga

Year	**Hazaribagh** Min. DO (mg/L)		**Chandighat** Min. DO (mg/L)		**Pagla** Min. DO (mg/L)	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
1980	6.8	3	1.5	3.1	-	-
1983	3.45	1.4	2.75	1.7	-	-
1984	4.3	4	3.2	2.8	-	-
1985	3.3	4.5	2.5	4.5	-	-
1987	-	6.4	-	4.8	-	-
1988	5	4.3	4.7	1.7	5.1	5.9
1989	5.3	5.7	4.7	4.9	4.9	5
1990	6.1	6	6	6	6	6.1
1991	6	2	5.4	5.1	6	6
1992	5.3	5.7	5.3	5.5	5.6	5.3
1993	5.4	5.7	5.5	5	5.1	5.7
1994	3.3	6	3.2	4.3	-	-
2000	3.1	3	3.4	5.5	3.1	5.4
2001	1.5	2.8	2	6	3.2	4.6
2002	1	5.2	1.1	6.3	1.2	6

Note: “-” indicates that data is not available

Table A.13: Water quality standard according to DOE, 1997.

Table 2.3: EQS of some relevant water quality parameters (DOE 1997)

Parameter	Recreational	Fishing	Irrigation
pH	6.5-8.5	6.5-8.5	6.5-8.5
BOD(ultimate),mg/l	≤ 3	≤ 6	≤ 10
DO,mg/l	≥ 5	≥ 5	≥ 5
Coliform(total),Nos./100ml	≤ 200	≤ 5000	≤ 1000
Ammonia Nitrogen(N),mg/l	-	≤ 1.2	-
Electrical Conductivity(μmho/cm)	-	-	2250

Table A.13: Water quality of Buriganga river (Kamal, 1996)

Table 4.9: Analysis of historical data on BOD_5 (at 20^0C) at Pagla

Year	BOD_5 concentration (mg/L)		BOD_5 concentration (mg/L)		Data range mostly vary between
	Min. value	Occur in	Max. Value	Occur in	
1988	1.9	Nov	4.1	Dec	2 - 2.5
1989	1.1	Feb	3.2	Jan	2 - 3
1990	1	Feb	2.8	Mar	1.5 - 2.5
1991	2	Aug, Nov	3.5	Dec	2 - 3
1992	2	Sep	4.4	Nov	2 - 4
1993	2.8	Sep	3.9	Aug	3.3 - 3.9

Table A.14 Water quality in Buriganga river in the year of 2007 (Paul, 2008)

Table 4.2: Measured water quality parameter in June, 2007

Location / Parameters	Chandi-ghat	Fotulla	Pagla	Farashganj	Sadar-ghat	Kamranghir-char	Hazaribagh
DO(mg/l)	1.65	1.49	1.10	0.20	0.15	0.57	1.65
pH	6.8	6.7	6.6	6.6	6.4	6.5	6.7
EC(micro S/cm)	11.34	142.4	13.75	8.93	14.79	9.74	14.25
Cr(ppm)	0.010	<0.001	0.001	<0.001	0.001	0.051	0.074
Cd(ppm)	0.0013	0.0008	0.0008	0.0014	0.0009	<0.0004	0.0002
Pb(ppm)	0.004	<0.002	0.007	0.003	0.007	0.007	0.013
BOD_5	24	22	21	17	44	30	60
COD	50	44	41	42	107	40	145
NO_3-N (mg/l)	0.3	0.4	0.5	0.2	0.3	0.2	0.6
NH_3-N (mg/l)	0.97	0.7	0.75	0.91	0.89	2.05	0.36
Turbidity (NTU)	18.3	14.3	16.5	20	25	14.7	34
PO_4^{3-}(mg/l)	0.6	0.54	1.35	0.53	1.67	0.09	2.36

Table A:15 Water quality of Buriganga river(Kamal, 1996)

Table A5: Continued

Station/River	Month/Year	Terbidity(NTU)	DO(mg/l)	BOD5 at 20 oC(mg/l)	COD (mg/l)	pH	T .Alkalinity
Sadarghat	Jan-00	28	5.3	2.4	8	7.2	146
Buriganga	Feb-00	30	3.2	23		7.4	178
	Mar-00	32	3.1	18.5		7.4	169
	Apr-00	30	4	16		7.3	162
	May-00	30	5.5	4.2		6.8	64
	Jun-00	28	6.2	3.2		6.98	54
	Jul-00	95	7.5	2.1		7.08	56
	Aug-00	90	7.2	2.4		7.1	49
	Sep-00	36	5.7	1.7		6.95	54
	Oct-00	38	5.8	1		6.95	54
	Nov-00	30	6	2		7.12	74
	Dec-00	25	5.2	2.1		7.15	86
	Jan-01	28	5.3	2.4	8	7.2	146
	Feb-01	28	2.1	10	74	7.35	100
	Mar-01	9.8	5.8	3		7.13	72
	Apr-01	11	5.2	4		7.1	72
	May-01	9.8	5.8	3		7.2	70
	Jul-01	10	6.1	4.1		7	74
	Aug-01	12	7	4.6		6.95	46
	Sep-01	8	7	4.2		7.15	56
	Oct-01	8	5.5	2.8		7.2	60
	Nov-01	5	6.1	3.4		7.2	24
	Dec-01	8	4.6	6		7.25	30
	Jan-02	6.5	1.6	10		7.18	74
	Feb-02	4.9	1.1	12		7.15	72
	Mar-02	8	1.1	14		7.2	72
	Apr-02	10	2.6	12		7.28	76
	May-02	8.5	6.4	3.8		7.12	66
	Jun-02	12.5	6.1	3.5		6.98	52
	Jul-02	12	6.9	3.8		6.96	46
	Aug-02	10	6.8	3.6		6.95	54
	Sep-02	10	6.8	3.4		7.14	52
	Oct-02	8.5	6.4	3.1		7.14	56
	Dec-02	6	6	2.8		7.14	72
	Jan-03	4.5	2.8	8		7.18	74
	Feb-03	4.5	2.6	8		7.21	78
	Mar-03	4	2.4	14		7.26	90