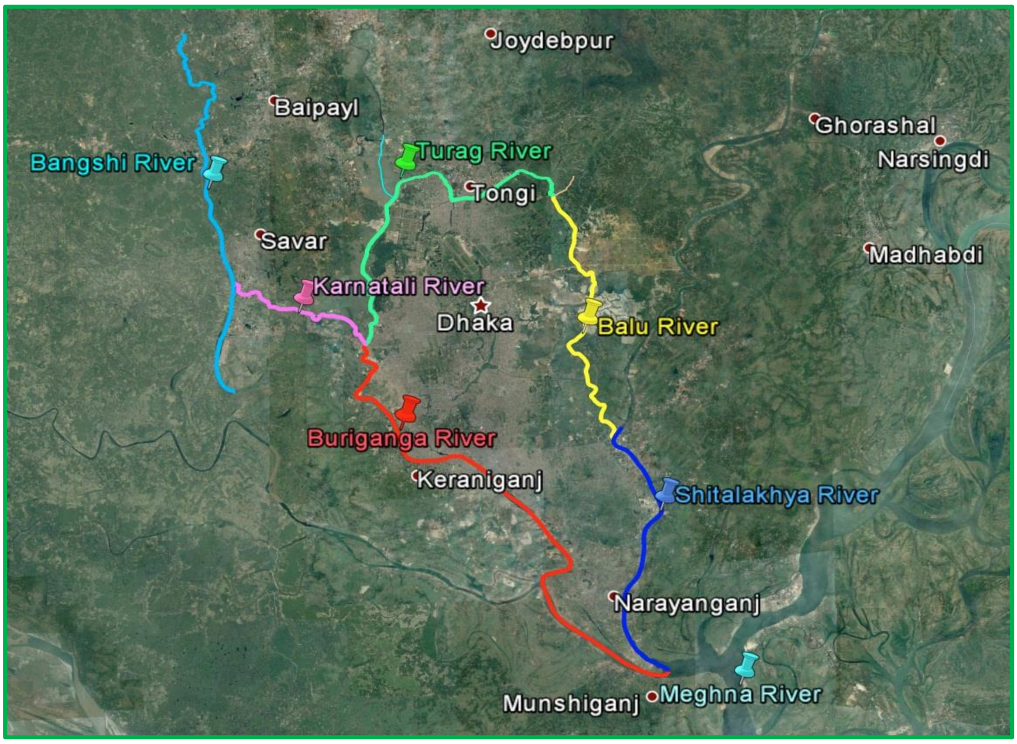
Assessment of river pollution around Dhaka and find out ways to Alleviate Pollution



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VINYL GLOVES


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Preface

This report presents the outcomes of the research '**Assessment of river pollution around Dhaka and find out ways to alleviate pollution**'. The research has been carried out by the Geotechnical Research Directorate of River Research Institute (RRI) funded by Government of Bangladesh (GoB) during the financial year 2014-15 and 2015-16.

With a population of over 15 million Dhaka is one of the most congested cities of the world. This rapidly growing city is surrounded by many rivers and khals namely the Buriganga, the Turag, the Balu, the Bongshi, the Shitalakhya, the Pungly, the TongiKhal and others. The rivers surrounding Dhaka are an advantage to it and essential for the survival of the mega city as these provide drainage system, drinking water, different kinds of fishes and waterways for traveling. However, over the last couple of decades major industrialization and urbanization has been observed in Dhaka. Violating the environment law, tons and tons of untreated industrial effluents are being dumped into these rivers. The rivers have become a dumping ground of all kinds of solid, liquid and other chemical waste. Moreover, encroachment on rivers is a common practice in Dhaka. Under these circumstances this research has been taken.The main aims of the research werei) to assess spatial and temporal variation of water quality parameters including the toxic/heavy metal (T/HM) concentrations around Dhaka, ii) to find out ways to alleviate river pollution and iii) to draw the implication and to recommend for policy approaches to reduce contamination and to improve food security in Bangladesh.

In this research, an integrated approach is followed to understand and solve key problems addressing river pollution involving Physical, Chemical, Biological and Socio-Economic components. It is carried out based on the samples collection from river, in-situ and laboratory investigations of samples, some questionnaire survey from the river bank community. It is found that the Buriganga, Bongshi, Turag, Shitalakha, Balu and Karnatoli rivers are under severe pollution threat in dry season. Water quality parameters are beyond the tolerable limit of DoE in dry season. In post rainy season water quality better than dry season. However, T/HM concentration has greater than standard limit specially Cd and Cr in post rainy season.T/H metal exists in our Food chain as considerable amount of toxic metals like Pb, Cr, Cd, Ni and Cu have found in fish, tomato and red amaranth. Moreover, considerable amount of T/H metals found in different types of fishes in all rivers.

I highly appreciateDirector, Geotechnical Research Directorate of RRI for his guidance, encouragement and cooperation throughout the study period.

I am grateful to Dr. Md. Khabir Uddin, Environment Specialist & Professor, Department of Environmental Sciences, Jahangir Nagar University, Dhaka and Dr. Sultan Ahmed (Joint secretary), Director, Natural Resource Management & Research, Department of Environment, Dhaka for their valuable advices, suggestions and cooperation during the study period.

Special thankis extended to HowladerZakir Hossain, Deputy Secretary, Ministry of Water Resources for providing valuable suggestions to write up this report.

I like to be particular in my appreciation for the research team members who have worked hard for completion of the research within the stipulated time. Sincere thanks are extended to all who have helped us directly or indirectly in connection with this study.

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Abbreviation

AAS	Atomic Absorption Spectrometer
ATSDR	Agency for Toxic Substances and Disease Registry
APHA	American Public Health Association
BOD	Biological Oxygen Demand
BIWTA	Bangladesh Inland Water Transport Authority
$CaCO_3$	Calcium Carbonate
Cd	Cadmium
COD	Chemical Oxygen Demand
CO_2	Carbon di-oxide
Cu	Copper
Cr	Chromium
CSO	Chief Scientific Officer
DCC	Dhaka City Corporation
DEPZ	Dhaka Export Processing Zone
DO	Dissolve Oxygen
DoE	Department of Environment
DAP	Detailed Area Plan
ECA	Environmental Conservation Act
ECR	Environmental Conservation Rules
ESIA	Environmental and Social Impact Assessment
EC	Electrical Conductivity
ETP	Effluent Treatment Plant
EPZ	Export Processing Zone
Fe	Iron
GR	Geotechnical Research
HP	Heavy Metal
Ni	Nickel
NH_3	Ammonia
pH	Potential Hydrogen Ion
Pb	Lead
PSO	Principal Scientific Officer
RAJUK	RajdhaniUnnoyonKortripokkho
SO	Scientific Officer
SSO	Senior Scientific Officer
TDS	Total Dissolve Solid
TSS	Total Suspended Solid
WASA	Water Supply & Sewerage Authority
Zn	Zinc

Executive Summary

Introduction

River environments arise from a massive amount of physical, chemical and biological interactions. The water bodies like rivers, lakes and estuaries are continuously subjected to a dynamic state of change with respect to their geological age and geo chemical characteristics. This dynamic balance in the aquatic ecosystem is upset by humanactivities results in River pollution. Industrialization, urbanization and agricultural practices severely affect water quality and aquatic environment.

Dhaka is one of the most densly populated cityaround the world. It is surrounded by many rivers like the Buriganga, the Bongshi, the Turag, the Balu, the Kornatoli, the Shitalakhya, the Pungly, and others. The rivers surrounding Dhaka are very important for the survival of this city as these provide drainage system, drinking water, different kinds of fishes and waterways for traveling. These rivers are also very important for the survival of eco-system of Dhaka. However, over the last couple of decades major industrialization and urbanization has been observed in Dhaka. Violating the environment law, tons and tons of untreated industrial effluents are being dumped into these rivers. The rivers have become a dumping ground of all kinds of solid, liquid and other chemical waste. Moreover, encroachment on rivers is a common practice in Dhaka and most of the natural drainages disappeared or are in way to due to illegal encroachment. Under these circumstances this research has been taken within the fiscal year 2014-15 and 2015-16.

Aims of the study

The main aims of the research were i) to assess spatial and temporal variation of water quality parameters including the toxic/heavy metal concentrations sorroundings of rivers in Dhaka ii) to find out ways to alleviate river pollution in Dhaka iii) to draw the implication and to recommend for policy approaches to reduce contamination and to improve food security in Bangladesh.

Approaches and methodologies

An integrated approach is followed in this research work to understand and resolve key problems addressing river pollution concerning Physical, Chemical, Biological and Socio-Economic components. It is carried out based on the samples collection from river, in-situ test and laboratory investigations of samples, some questionnaire survey from the river bank community. In-situ tests and samples collections were done in dry season and post rainy season. In the first year, in-situ tests were performed in March 2015 as dry season in Bongshi and Buriganga rivers. Thereafter for extensive research, more rivers namely, Karnatoli, Turag, Balu and Shitalakha were included gradually parallel to Bongshi and Buriganga adjacent to Dhaka. 40 study points along these rivers were selected for this study. For laboratory investigation, water samples were collected from all the locations of five rivers. However, sediment/river bank soil/Crops/vegetables and fish were collected from the most hazardous areas.
In-situ Water quality parameters including dissolve oxygen (DO), pH, temperature, total dissolve solid (TDS), electrical conductivity (EC), ammonia (NH_3), carbon di-oxide (CO_2), chloride, hardness and alkalinity were quantifiedinstantly on the boat using HACH portable Single Input Digital Multi-parameter Meter (30QD) and HACH Portable Freshwater Aquaculture Test apparatus.Heavy/ toxic

metals concentration including Lead (Pb), Copper (Cu), Cadmium (Cd), Iron (Fe), Zink (Zn), Nickel (Ni) and Chromium (Cr) were quantified by atomic absorption spectrometer (AAS) in the laboratory.

Key Findings and recommendations

Investigation reveals that six rivers around Dhaka is severe pollution threat including water, fish, sediment and crops due to the various types of industrial/sewerage/municipal waste directly enter to the water body without treatments. Water quality parameters are beyond the standard limit set by different organizations including WHO (2011), DoE (ECR, 1997) and CCME (2007) especialy level of DO and toxic NH_3 in dry season. As expected, the situation improves in post rainy season. However some toxic heavy metals like Cr, Cd, Pb and Ni were found significant amount in Buriganga, Bongshi and Turag water in post rainy season even though concentration were reduced in this season. These concentrations were two to five times greater than standard value provided by WHO (2011) and DoE (ECR, 1997). Among these metals, Cr and Cd toxicity are severe in Dkahariver's water. The possible reason is the discharge of high amount of Cr concentrated wastewater from the tannery industries and other industries like DEPZ, BEXIMCO etc. which are closely located to these rivers. The tannery industries depend on chrome tanning process and they do not treat Cr contaminated wastewater before discharging to the natural environment.

As heavy metals are non-degradable and not decomposable, it is likely to exist with the flow of water in post rainy season. During July to November, rivers in Dhaka are full of water with high discharge and generally the water seems good in terms of odour and colour.Therefore, it is very alarming that it is polluted with heavy metals during this period too. Usually when volume of water increased contaminant will be diluted, however, these toxic metals still exist in to the environment. That means if water flow can increase in dry season but also toxic metals contamination will be occured. Proper care should be enforced to stop heavy metal containing waste dispose to rivers.

This investigation reveals that heavy metals exists in our food chain as considerable amount of toxic heavy metals like Cr, Pb, Cd, Ni and Cu have found in fish, tomato, pumpkin and red spinach. The heavy metal contamination in vegetables was found in order of red amarangth (lalshak)> tomato> pumpkin and in rice plant root>straw> rice. Toxic metals also found in considerable amount in Taki, balm, Chingri, Kakila, Puti fishes. Cr concentration was the highest contamination in fishes is likely as river water and soils wereseverly Cr polluted. This study reveals that the toxic metals contamination has occur in water, fish, vegetable and rice around Dhaka. People around Dhaka might intake toxic metals through their food including fish, vegetables and crops which indicates they are facing severe toxic threat from daily food intake.

Questionnaire survey showed that river bank community seriously affected by river pollution. All respondents (400 nos.) of Bongshi river bank community opined that they do not use river water in house hold works and all of them use river water in agriculture while all respondents of Buriganga (400 nos.) do not use river water neither in house hold works nor other works. All people around these rivers use groundwater/tap water for different purpose. The most of the Respondent (76.75%) from Bongshi river bank community believed that the untreated waste disposal from industry is the main cause of pollution. On the other hand, 45% of Buriganga river bank community people believe that the main causes of river pollution is industrial waste and 44% thought that pollution comes from municipal & urban wastes and 11% people think that motorized Boat may be responsible for the river pollution. All the respondents of Bongshi and Buriganga river bank community opined that no fish found in dry season especially March and April. Even though some fishes are available in the month of November, December and January (dry season), these fishes are very stinky after cooking. They also opined that River pollution contributed an adverse effect in their social life as well as economic aspect.

The concentration of heavy metals in vegetables, crops and fish will provide baseline data and there is a need for intensive sampling of the same for quantification of the results. Soil, sediment, crops/vegetables, fish and water quality monitoring, together with the prevention of metals enters, is a prerequisite in order to prevent potential health hazards of metals with sewage/ industry-fed water. Industrial plants must be required to set up suitable treatment systems in their facilities or existing industrial plant should be run during operation to reduce pollution and revive the river ecosystem in Dhaka. Otherwise, with the gradual development of industry and discharge of untreated tannery waste/ municipalities/ sewage/might be further exacerbated the situation in coming years. Strict enforcement of industrial and environmental rules and policies, development of phytoremiadation/chemical/biochemical/dilution technique, creation of water flow at upstream in dry season, stop/reduce land encroachment, and increase awareness through selective authority and mass media are also applicable to reduce river pollution.

Implication of this research:

This research will provide a clear idea aboutthe present water quality including toxic/heavy metals status of six rivers around Dhaka which willbe a basis of future research and monitoring activities for preventing river pollution.Thedata generated in this study willhelp to work out in effluent management strategy towards control over effectivetreatment in terms of toxic and heavy metal contents. Moreover, the data from this study will be also usefull for policy approaches to improve food security in Bangladesh. The recommendation generated from this study will help toget better approaches strategies towards management of water resources.

1. Introduction

1.1 Background

River environments arise from a massive amount of physical, chemical and biological interactions. The water bodies like rivers, lakes and estuaries are continuously subjected to a dynamic state of change with respect to their geological age and geo chemical characteristics (Tamiru, 2004). This dynamic balance in the aquatic ecosystem is upset by human activities resulted in River pollution. Industrialization, urbanization and agricultural practices severely affect water quality and aquatic environment (Ayers and Westcot, 2000).

Bangladesh is a country renowned for the countless rivers that create an intricate network across Bangladesh. These rivers are what make Bangladesh a very unique country of the South East region of the globe. Dhaka city with a population of over 15 million is one of the most crowded cities around the world. This rapidly growing city is bounded by many rivers and khals. The Buriganga, Bongshi, Karnatoli, Turag, Balu and Shitalakhya rivers are very important for the survival of eco-system of Dhaka. The rivers surrounding Dhaka are an advantage to it and essential for the survival of the mega city as these provide drainage system, drinking water, different kinds of fishes and waterways for traveling. However, the city has been developed haphazardly without considering its physical and social diminution. As a result, the environmental consequences originating from rapid increase of population along with the increase of polluting effluents from industries, and municipal as well as other waste are having profound negative impacts on rivers around Dhaka city. In turn, the polluted waters of the rivers are posing increasing threats to the living organisms including humans residing by the rivers.

Over the last couple of decades major industrialization has been observed in Dhaka, especially in dyeing, washing and textiles sectors. Estimation reveals that there are over 7,000 industries in Dhaka metropolitan area located. However, among all these the dyeing factories and tanneries are the main polluters of the rivers. Waste from these industries is usually connected to the sewerage system that directly follows to the rivers around the city.

Dhaka city has been growing without much of plan and the city lacks systematic waste management system as well. Dhaka generates around 0.4 to 0.7 kilograms of solid waste per capita per day but the Dhaka City Corporation (DCC), the main agency responsible for collection, transportation and disposal of the waste cannot manage the task properly with its existing limited logistics. The per capita waste collected in Dhaka per day is 0.2 kilograms. The waste which is not managed by the DCC is dumped into the rivers by the people living near the river banks.

The rivers, which perform the task of natural drainage for Dhaka, are also being polluted as rain water sweeps into them all the waste dumped here and there of the city. Furthermore, liquid waste produced in the city is being poured in the rivers untreated. Moreover, Dhaka WASA utilizes the existing canals and sewerage pipes to collect waste water from different residential areas and depose, most of it, into surrounding rivers without any treatment. Apart from domestic and industrial waste, oil and other chemicals which are spilled into the rivers from launches, steamers, and trawlers are also polluting river water. Besides, due to lack of improved sanitation facilities in Dhaka, contamination of water is occurring from also human excreta.

Encroachment on rivers is a common practice in Bangladesh. Most of the natural drainages of Dhaka City disappeared or are in way to due to illegal encroachment. Encroachment on the rivers through unauthorized construction and dumping of solid waste in clearance of regulations to prevent encroachment making it difficult to drain out the runoff and the pollutants i.e., added particles remaining in the rivers keep polluting the environment. Moreover, due to river encroachment and dumping of solid waste into the rivers the rivers are losing their natural flow.

Moreover, water level in the dry season is low and practically no/very small water flow in the rivers, and therefore river water pollution increase in dry season due to the lean water flow.
Heavy metals (HMs) accumulation and distribution in soil, water and environment are increasing at an alarming rate causing deposition and sedimentation in rivers, and affecting aquatic life. Heavy metals contamination in aquatic environments is critical concern, due to toxicity of metals and their accumulation in aquatic habitats. Trace metals in contrast to most pollutants, not bio-degradable, and they undergo a global ecological cycle in which natural water are the main pathways. Of the chemical pollutants, heavy metal being non-biodegradable, they can be concentrated along the food chain, producing their toxic effect at points after far removed from the source of pollution. Rivers are a dominant pathway for metals transport and HMs become significant pollutants of riverine systems. The World Health Organization as well as the Food and Agriculture Organization of the United Nations state that monitoring elements like Cd, Pb, As, Hg, Cu, Zn, and Fe are obligatory and others are suggestive in aquatic life specially fish. HMs concentrations in the fish should be within respective maximum permissible limits established by law in order to ascertain whether this food could be considered suitable for human consumption.

Polluted water flowing around the greater Dhaka city is posing serious threats to public life as it is unfit for human use. People living near the rivers, having no other alternative, are forced to use polluted river water. Some also use the water because they are unaware of the health risks. This causes spread of water borne and skin diseases. Solid waste and different effluents dumped into the rivers make it difficult for fishes and other sub-aquatic organisms to live. When solid waste and effluents run into the river, the Biological Oxygen Demand (BOD) in the water rises, creating oxygen crisis for the sub aqueous life. As the dissolved oxygen (DO) content of the river water is decreased below the critical level posing threats to bio-diversity in and around the rivers.

Key pollutants in the water systems are typically pathogens arising from human waste (bacteria and viruses), heavy metals and organic chemicals from industrial waste. Ingestion of pathogens through drinking contaminated water or with food prepared using contaminated water is the most common pathway. Eating fish from contaminated waters can be risky, since they can absorb and concentrate both pathogens and toxics such as heavy metals and persistent organics. In addition, human health may be affected by crops that take up pollutants from contaminated water used for irrigation or from land flooded by polluted rivers.

Physical properties such as color, odor and temperature, and biochemical properties such as pH, dissolved oxygen (DO), carbon-di-oxide (CO_2) total dissolved solid (TDS), electrical conductivity (EC) and hardness are important water quality parameters. Any abnormalities in their properties indicate decline of water quality which results getting worse in aquatic life. In order to utilize fresh water bodies successfully for aquatic life including fish production and human consumption, it is very important to study the biochemical properties which influence the aquatic environment.

Now-a-days river pollution in Dhaka is a burning issue. Some research has been carried out and also recommendations have been forwarded to protect the rivers from pollution. At the government level several rules, regulations, policies and strategies have been formulated to save the rivers from pollution. Government's interest in protecting the rivers from pollution has also been reflected in the ECA (Environmental Conservation Act)-1995 and the ECR (Environmental Conservation Rules)-1997. However, the implementation and enforcement of the policies and the regulations have so far been very ineffective, leading to poorer river water quality and further pollution. In addition, in many cases the policies and strategies are seemingly far from being practical in terms of implementation.

In this regard, an integrated approach will be followed in this proposed research to understand and solve key problems addressing river pollution involving Physical, Chemical, Biological and Socio-Economic components.

1.2 Aims

- To determine spatial and temporal variation of water quality parameters including the toxic/heavy metal concentrations around Dhaka
- To draw the implication and to recommend for policy approaches to reduce contamination and to improve food security in Bangladesh
- To fnd out ways to alleviate river pollution in Dhaka

1.3 Specific objectives

- To determine the intensity of river pollution by inventorying water quality parameters including the toxic/heavy metal concentrations around Dhaka.
- To identify the causes and sources of river pollution around Dhaka.
- To compare the river pollution among the rivers around Dhaka
- To detect toxic/HMs contaminated areas in respect of aquatic life especially fish culture around Dhaka city rivers in Bangladesh.
- To detect HMs concentration in water, sediment, fish and crops of the selected rivers.
- To identify potential health hazards due to river pollution.
- To identify the vulnerability of vicinity of river bank people especially health hazards and crop production.
- To recommend for policy approaches to improve food security in Bangladesh.
- To draw the implication and to provide the suggestions for actions to reduce contamination.

2. Literature Review

2.1 River pollution in Bangladesh perspective

All sectors in Bangladesh like industry, agriculture, sewerage, energy, transportation, construction, and consumers generate wastes. Industrial wastes are usually generated from different industrial processes, as a result the amount and toxicity of waste released from industrial activities varies with theindustrial processes. In general, these untreated industrial and sewerage wastes dispose to the rivers in Bangladesh.

2.1.1 River water pollution due to tannery waste disposal in Dhaka

Tannery effluents are the highest pollutants among all the industrial wastes (Azom *et al.,* 2012). Hazaribagh tanning industrial zone situated in the capital of Bangladesh, Dhaka, constitute 90% of the tanneries in the country. Approximately 15000 m^3 of untreated chemical wastes are disposed to the low-lying areas, natural canals and other water bodies such as the Buriganga and Turag rivers, which are major sources of water supply for agricultural, livestock and fishing activities (UNIDO, 2000). Human Rights Watch (2012) reported that about 21,600 m^3 of environmentally hazardous liquid waste is released every day from the tanneries located in Hazaribagh which include hazardous chemicals such as chromium, sulphur, ammonium, salt and other chemicals. Chrome tanning is the most common type of tanning where large amounts ofchrome powder and liqueur are used (Gain, 2002). Many other studies have been carried outpointing out the pollution state of the Hazaribagh area (Kashern and Singh, 1999, Zahid *et al.,* 2004; Shams *et al*., 2008). Water quality of the rivers increasingly deteriorates and these exert asignificant threat to our limited water supply by changing taste and odor, growth of aquatic weeds, aquatic life and wild life (Zahir and Ahmeduzzaman (2012). According to Huq (1998), various chemicals are used during the soaking, tanning and post tanning processing of hides and skins. The main chemical sused include sodium sulphite and basic chromium sulphate including non-ionicwetting agents, bactericides, soda ash, CaO, ammonium sulphide, ammoniumchloride and enzymes. Others are sodium bi-sulphate, sodium chlorite, NaCl sulphuric acid, formic acid, sodium formate, sodium bicarbonate, vegetabletannins, syntans, resins, polyurethane, dyes, fat emulsions, pigments, binders, waxes, lacquers and formaldehyde. Various types of processes and finishing solvents and auxiliaries are used, as well. It has been reported that only about 20% of the large number of chemicals used in the tanning process is absorbedby leather, the rest is released as waste. Hazaribag which is the largest tannery region in Bangladesh consists of more than 200 tanneries generate 7.7 millionliters of liquid waste and 88 million tons of solid waste every day. The directdischarge of these wastes has contaminated the ground and surface water withdangerously high concentrations of chromium, as well as cadmium, arsenic, and lead. The contamination of rivers also allows these pollutants to accumulate in common fish and shellfish species, which are used as local food sources. Chowdhury (2011) mentions that some chemicals such as sodiumsulfide, sodium meta sulfide, formic acid etc. are used in tannery industry. He also mentions that these chemicals are harmful to both the workers and the surrounding residential people. A group of experts said that emitted wastages from tannery industry make a threat for both environment and human beings. A scientific conference of the Nigerian Institute of Science and Technology at Universityof Ibadan, 1998 pointed out that eventually the effluents and sludge from these operations are discharged onto land and into water bodies. The high sulphide content of tannery sludge, apart from being toxic, poses serious odour problems in the environment. The dissolved and suspended solids of the effluent would affectthe quality of nearby streams, in addition to reduced clarity.

The dumping of untreated liquid tannery wastes from tannery industries at Hazaribag, Dhaka is the major source of pollution of Buriganga. The chromiumreleased from the Hazaribag tannery industries has been contaminating the water of the river Buriganga for the last 45 years (Azom*et al.,* 2012). A statistics available from the Department of Environment (2001) revealed that 95 per cent of the tannery industries have been built in unplanned way at the congested places of Hazaribag during the last fifty years. According to a recentestimate, about 60,000 tons of raw hides and skins are processed in the tanneries every year, which release nearly 95,000 liters of untreated effluents into the open environment daily, resulting into the dead river Buriganga.The Buriganga, an attractive river is now highly polluted with different chemical residues released from different industries. There are plenty of industries that are spontaneously polluting our rivers. About 1172 industrial polluting entities are polluting the Buriganga and the tanneries of Hazaribagh is the main source (Anonymous, 1997).

2.1.2 Changes in water quality due to industrial wastes

A study revealed that tannery effluents heavily pollute the river water, so muchso that the dissolved oxygen in the river water was found to be nil during the dry season and no fish or other aquatic animals were found living, up to 500 m downstream of the sluice gate (Chowdhury *et al* .1996). The environment and livelihood of people being hampered by the reaction of this poisonous effluent wastes. Waste and effluent from the tanneries causegreat harm to the environment. The highly toxic nature of the waste water causes soil pollution at the same time fresh water pollution (Schirado*et al.,*1996). Anonymous (2003), reported that most of the industries of Dhaka have been set up on the bank of the river. The color of the water and the river bank soil has been changed with the industrial wastes and effluents being continuously in-the river and the surrounding areas, oil were floating on Mack greenish water. Earth on the river bank is equally blackish in color. With the increase in human population and rapid urbanization alongwith industrialization in, a country, there is progressive increase in industrial, wastes and effluents. The pollution from agrochemicals, organic and inorganicsubstances that enter into the food chain have public health implications. Most of the industries of Dhaka have been set up on the bank of the Burigangariver. The color of the water and river bank soil has been changed because industrial wastes and effluents being continuously released in the river, and the surrounding areas, oil was floating on greenish water. Earth on the river bank is equally blackish in color (Anonymous, 2003).

Bhuiyan *et al.* (2010) conducted an experiment to evaluate the heavy metalpollution level of tannery effluent affected lagoon and canal water in the south western Dhaka, Bangladesh. The study had provided the evidence thateffluents discharged from the tannery and auxiliary industries and urban sewage system were the main sources of heavy metal pollution in the lagoonand canal water system in the Hazaribagh area of southwestern Dhaka. Nanda and Tiwari (1999) observed that the-quality of water deteriorate ssignificantly after the discharge of industrial effluents into the river. Ogbonna *et al.* (1998) reported that the wastes from the leather industry consist of tanned and untanned solids, waste waters (effluent) including the sludge and waste gases. The sludge derived from the treatment of tannery effluent varies incomposition but usually contains water (65-98%), lime, Cr, hydrate oxide, residual sulphides and organic matter (proteins, hair, grease, etc.).

In the soaking and liming process many chemicals are used to clean the salt,dirt, blood, hair etc. which create solid and liquid wastes and in the tanning process chromium oxide, ammonium, sulphate, formic acid, sulphuric acid etc. are used which create solid and liquid wastes (Huq, 1998). It has been estimated that about 13.5 million pieces of hides and skins from all over the country are brought to Hazaribagh every year for processing. In chrome tanning, raw hides and skins normally go through a process calledpickling, with sulfuric acid and common salt, after which they are treated withsolutions of basic chromium salts (Khatun and Huq, 1994).

Das *et al.* reported lower pH (7.2) and DO (1.77±0.67 mg/l) level in the surface water of Buriganga in dry season Alam e*t al.* studied TSS content of major rivers of Bangladesh and found TSS in Buriganga river (near Hazaribagh) ranging from 0.01 to 0.03 g/l during dry season and 0.1 g/l in rainy season, while TSS near Badamtoli was 0.01 to 0.04g/l in dry season and 0.3 to 0.6 g/l in rainy season. Das *et al.* also found the EC of tannery effluent was 10455 ± 2722.36 µS/cm and in Buriganga and Karnatoli river was 614.5 ± 275.0 and 175.6 ±82.5µS/cm, respectively. Alam *et al.* found the concentration of Cl in rainy season from 196.4 to 470.0 mg/l and in dry season from 98.0 to 107.6 mg/l in Buriganga river water. Alam *et al.* found that the NO concentration of Burigangariver ranged from 5.0 ±0.05 to 7.0 ±0.04 mg/l in rainy season and 0.01 ± 0.01 mg/l in dry season. However, Alam *et al.* found that the concentration of NO_3 in Buriganga river ranged from 8.0 ±0.5 to 12.2 ±0.4 mg/l in rainy season and 8.0±0.5 to 12.2 ± 0.4 mg/l in dry season.

Rahman *et al.* studied various water quality parameters and showed that the Buriganga river water quality is not acceptable from the aquatic ecosystem perspectives view for the parameters such as DO, BOD, COD, NH_4 -N and Cr during both dry and wet seasons and for EC during the dry season. On the other hand, the study has also concluded that the riverwater is still acceptable in both dry and wet season's interms of parameters such as temperature, pH, PO -P andPb. They reported the overall meanvalues (average of all the sampling stations) of parametersfor the river Buriganga were temperature: dry-20.86°C, wet-29.82°C; pH: dry-7.41, wet-7.42; EC: dry-660.56, wet-82.6; DO: dry-0.85, wet-2.8; BOD : dry-34.5 mg/L, wet-2.5; COD: dry-60.12, wet-17.2; PO -P: dry-0.53, wet-0.64; NH -N: dry-4.12, wet-3.28; Pb: dry-0.006, wet-0.0008 and Cr: dry-0.056, wet-0.074.

Water quality parameters in Turag river decreasing over years (Saha, 2010). Mobin et al. (2014) reported that the temperature of water was within an average value of 28.39°C which indicates standard temperature (20 to 30°C) for aquatic medium. The average value of pH was 6.83, which indicates that the value was within the standard limits (6.5 to 8.0) for aquatic organisms. The values of DO water were within the range of 0.6 to 3.9 ppm with an average value of 2.25 ppm indicating low DO value from standard level (4.0 to 6.0 ppm for domestic and 5.0 ppm for fish culture). The values of BOD were within the average value of 1.15 ppm indicating lower condition compared to standard value of BOD (6.0 ppm for fish culture and 10.0 ppm for irrigation). The average value of TDS was 340.86 ppm which indicates low TDS condition. The EC values were ranged from 35 to 150 µS/cm with an average value of 56.30 µS/cm which indicate lower condition than the standard value. The average value of transparency was 28.39 cm. The average value of hardness was 106.79 ppm which indicates near to the standard level. The average alkalinity was 237.66 ppm indicating very lower condition than the standardlimit (2000 ppm for irrigation).

Islam *et al.* (2012) showed that the color of water was light to dark black and emitted noxious smell due to the industrial effluents. The upstream water was slightly alkaline with comparatively high DO content while low concentration of other parameters. The minimum and maximum values of pH, EC, TDS, DO and BOD were 7.24-7.61, 425-2277 µS/cm, 239-1349 ppm, 1.22-3.66 ppm and -2.44-0.86 ppm, respectively. The continuous dumping of waste materials resulted in a marked increase in the concentration of metals in the river water varied in the order of Fe > Zn >Pb> Cu > Cd. Rahman *et al.* (2012) recorded the pH ranged from 6.6 to 7.98 and Electrical Conductivity (EC) from 160 to 1107 µs/cm. The recorded dissolve oxygen (DO) varied from 0.11 to 6.8 mg/L and biological oxygen demand (BOD) ranged from 10 to 180 mg/L while chemical oxygen demand ranged from 21 to 220 mg/L and free CO_2 value from 5 to 22 mg/L. The concentration ranges of heavy metals and arsenic in ppb were as follows: Zinc (Zn) (0.04 to 0.4), cadmium (Cd) (0.043 to 2), arsenic (As) (1.15 to 4.8), (lead) Pb (2.29 to 18.62) and mercury (Hg) (0.12 to 1.45).

Halder *et al.* recorded the maximum recorded values of pH, color, turbidity, biochemical oxygen demand (BOD_5), hardness, total dissolved solids (TDS), chloride (Cl-), carbon-di-oxide (CO2) and chemical oxygen demand (COD) were7.1 mg/L, 625 ptcu, 97.2, 4.65 mg/L, 1816 mg/L, 676mg/L, 5 mg/L, 15.5, and 78 mg/L, respectively. The maximum concentration of turbidity, BOD, hardness, TDS, and COD found in the Turagriver is much higher than the standard permissible limit.

Hossain *et al.* conducted a study on the water quality of Bongshi River. Their results revealed that the pH and DO values of all the sampling points were exceed the standard limit set by the Department of Environment (DoE). In case of the COD and BOD, the results were significantly above the surface water quality standard declared by the DoE. But in case of salinity, TDS, and EC the results showed some variable patterns like near the industrial establishment the samples contained higher value than the other sampling points. The untreated industrial effluents with high pollution load discharged into the river caused the deterioration of the water quality. The results were also varied in different sampling points. But overall concentrations of heavy metals were below the detection limit and some were within the standard limit set by the DoE.

Some of the previously reported studies described only the physicochemical properties and biochemistry of the river water Bhuiyan *et al.* (2011), Sikder *et al.* (2012, 2013), Ali et al. (2008), Moniruzzaman *et al.* (2009)] and a few others have dealt with the seasonal and spatial distribution of heavy metals Alam et al. (2003), Ahmad et al. (2010).

Since 1989, the DO concentration in the Balu River has been much below the critical level of 4 mg/l (DoE/BEMP, 2003). High Aluminum and Cadmium were also detected in the water samples collected from the BaluRiver. IWM (2003) reported that very low DO levels (as low as 0.1 mg/l) have been detected in the Balu river. Upstream of the confluence with the Balu river, much higher values were recorded (5.8 mg/l and 7.7 mg/l. In April 2003, recorded ammonia concentration in the Balu river was 1.6 mg/l (DoE/BEMP, 2003). However, recorded ammonia level in the Noraikhal was much higher; 5 mg/l in November 2003 (post-monsoon) and 13 mg/l in April 2003 (DoE/BEMP, 2003).

Monitoring data of the DoE demonstrated that the concentration of dissolved oxygen in the river Sitalakhya beside the fertilizer factory varies between 2.1 to 2.9 mg/l during low tide (Saad, 2000). Monitoring data of the Surface Water Modeling Centre (SWMC) on the same river, showed a degrading trend for water quality in the dry season.The Bangladesh Center for Advanced Studies analyzed that TDS of Sitalakhya river cross the limit and TDS rised 216 to 446mg/l from 1980 to 1998.

Hasan *et al.* showed that the highest average values of EC, Turbidity, DO, BOD and TDS were 715.1µS/cm,18.87 NTU, 1.04 mg/l, 8.06 mg/l and 87.3 mg/l respectively in dry period. While in rainy period, the highest average values of EC, Turbidity, DO, BOD and TDS were 118.6µS/cm, 11.13 NTU, 2.77 mg/l, 6.56 mg/l and 69.81 mg/l respectively. The river was found unsuitable for drinking, domestic, irrigation and industrial purposes. Poor river water quality impacts the ecosystem and aesthetic features very negatively. Whereas Roy *et al.* recorded the minimum and maximum values of pH, TDS, DO and NH_4 were 6.89-7.33, 982-1308 ppm, 0.33-2.12 ppm and 6.79-89.76 ppm, respectively.

2.1.3 Effect of river water pollution on human health

Huq (1998) reported that Tannery workers are the worst sufferers and endure ahostile environmental condition. Workers usually handle chemicals with openhand and do not wear any gloves. The workers suffer from various healthproblems and illness like skin diseases, diarrhea, jaundice, fever, kidney problems etc. The residential areas close to the tanneries are susceptible to different environment related problems. Residents near the Hazaribagh tannery are exposed to higher morbidity and mortality compared to people living 2 to 3 km apart. Human Rights Watch (2012) stated that Past and present tannery workers described and displayed a range of health conditions including prematurely aged, discolored, itchy, peeling, acid-burned, and rash-covered skin; finger scorroded to stumps; aches, dizziness, and nausea, and disfigured or amputated limbs. Although Human Rights Watch is not aware of any epidemiological studies on cancer among tannery workers in Bangladesh, some anecdotal evidence suggests that cancer rates are indeed elevated among workers dealing with chemicals.

Azom*et al.* (2012) stated the chromium-laced solid wastes from tanneries areoften converted into poultry feed as is the case in areas of Bangladesh-and canthus impact livestock and humans. According to the WHO, over 8,000 workers in the tanneries of Hazaribag suffer from gastrointestinal, dermatological, and other diseases, and 90% of this population dies before the age of 50. Tannery effluent also threatens the groundwater under Hazaribagh, although there is no research showing negative effects on human health from this potential route of exposure. However, the issue is particularly significant given that an estimated 95 percent of Dhaka city's water supply (used for bathing, cooking and cleaning by an estimated 14 to 15 million people) is derived from various groundwater supplies (Human Rights Watch, 2012). Many common health problems that tan workers face-such as skin and respiratory diseases-result from repeated exposure to a hazardous cocktail of chemicals when measuring and mixing them, adding them to hides in drums, or manipulating hides saturated in them (Human Rights Watch, 2012). Higher concentration of these metals in the natural environment may lead an excessive accumulation of metals, thereby might become toxic to plants which may cause animal and human health hazards. Industrial pollutants with high concentrated heavy metals may cause water borne diseases including diarrhea, cholera, jaundice, hepatitis, dysentery, skin diseases etc. On the other hand, pollution and contamination of the river, lake and pond water have impacts on the aquatic resources. The fish resources have drastically decreased due to metal contamination of the river, lake and pond water. The presence of arsenic in ground water has been increasing scarcity of safe drinking water causing health complications like skin lesion, disorder of the respiratory organs, stomach, heart and circulatory, system, kidney and fiver complications gangrene lung and urinal cancer etc. (Breckle and Khale 1992; Trivedi andErdei, 1992).

A study of 1997 compared the self-reported health problems in 112 house holds in Hazaribagh with those from 100 households in a nearby Dhaka neighborhood (with similar socio-economic characteristics but located further from the tanneries). Respondents in Hazaribagh reported 31 percent more cases of skin diseases, 21 percent more cases of jaundice, 17 percent more cases of kidney related diseases, 15 percent more cases of diarrhea, and 10 percent more cases of fever than the residents in the other neighborhood (Haque*et al.,* 1997).

Dr.Z. Karim, Dr. Saleemul Haque, Md. Mahiuddin Ahmed, MasudNabi Khan worked on water pollution. Their findings showed that polluted water may damage living beings partially or fully. They classified pollutants in four classes e.g. a) Pathogens b) Nutritious and biodegradable substances c) Organic agentsand d) Toxic substances. Md. Anwarul Islam also worked on it. On the other hand Prof. Jasim Uddin Ahmed worked on arsenic pollution.

2.1.4 Exposure of heavy metal due to river pollution

The river Buriganga is increasingly being polluted with the city’s thousands of industrial units and sewerage lines dumping huge volumes of toxic wastes which contain lots of heavy metal into it day and night (Islam *et al.*, 2006). Heavy metals contamination in aquatic environment is of critical concern, due to toxicity of metals and their accumulation in aquatic habitats. Trace metals in contrast to most pollutants, not biodegradable, and they undergo a global ecological cycle in which natural water are the main pathways. Of the chemical pollutants, heavy metal being non-biodegradable, they can be concentrated along the food chain, producing their toxic effect at points after far removed from the source of pollution (Tilzer and Khondker, 1993). Exposure to heavy metals has linked to several human diseases such as development retardation or malformation, kidney damage, cancer, abortion, effect on intelligence and behavior, and even death in some cases of exposure to very high concentrations.

In Bangladesh the concentration of heavy metals in fish, water and sediment are studied by some authors but Chowdhury (1994), Hossain (1996), Khan *et al.* (1998), Sharif *et al.* (1991, 1993a, b, c), Bhowmik (2002), Ahmed (2000), Ahmed *et al*. (2002, 2003, 2009a,b,c) and Haque *et al*. (2003, 2004, 2005, 2006, 2007) are prominent. Some previous studies investigated the concentration of heavy metal in water, sediment and some fishes (Ahmad *et al*., 2010), Shah and Hossain, (2011) observed the heavy metal concentration in the Buriganga river.

Most of the previous studies have been focused mainly on the Buriganga river water chemistry (Ali *et al.,* 2008; Moniruzzaman*et al.,* 2009; Alam*et al*, 2003; Ahmad *et al.,* 2010). Mohiuddin *et al.,* (2011) collected water samples from the Burigangariver to observe the seasonal and spatial distribution of heavy metals and reported extreme heavy metal pollution load in the water samples. Bhuiyan *et al.* (2010) conducted an experiment to evaluate the heavy metal pollution level of tannery effluent-affected lagoon and canal water in the south western Dhaka, Bangladesh. The measured physicochemical parameters electrical conductivity, chemical oxygen demand, pH, SO_4^{2-}, PO_4^{3-},Cl^-, NO_3-and metals (As, Ca, Cd, Co, Cr, Cu, Fe, K, Mn, Ni, Pb, and Zn) were subjected to principal component (PCA) and hierarchical cluster analyses, and examining correlation matrix as well in order to explain the behavior and sources of the metals. The study had provided the evidence that effluents discharged from the tannery and auxiliary industries and urban sewage system were the main sources of heavy metal pollution in the lagoon and canal water systems in the Hazaribagh area of southwestern Dhaka.

Mahfuza *et al.* (2012) performed a study on "Toxic Metal Contamination on the River near Industrial Area of Dhaka" and pointed out that the content of the most toxic metals in wastewater and sediments of the industrial canals are much higher than that of river water and sediments. Moreover, most of the toxic metal contents are found to exceed the background concentration in all sediment samples. Higher geo-accumulation values are observed for Zn, Ni and Cu probably due to the anthropogenic metal supply with uncontrolled discharge of industrial effluents into the river. This research work entails the evolution of environmental deterioration of the study area by analyzing toxic metal contamination in the surface water of Turagriver and river sediment in terms of their concentration level. Among the nine toxic metals analyzed in the river water, iron and manganese had much higher concentration than that of standards for drinking water. Significant correlation was also observed between Ni and Fe (0.93), Ni and Cu (0.95), Ni and Zn (0.71), suggesting the same source of occurrence.

Mohuya *et al.* (2010) conducted an experiment "heavy metal contamination in Gulshanbaridhara Lake, Dhaka." And found the concentrations of Cd, Cr, Cu, Ni and Pb in the lake water varied from 0.068 - 0.091, 0.048 - 0.225, 0 - 6.135, 0 - 0.062 and 0.023 - 0.067 mg/l during the summer season, respectively. Mean values of the samples collected from mid points for Cd, Cr, Cu, Ni and Pb of ten stations in summer were 0.083, 0.100, 2.336, 0.074, and 0.046 mg/l, respectively. In monsoon the concentration of above mentioned heavy metals varied from 0.016 - 0.019 mg Cd/l, 0.005 - 0.035 mg Cr/l, 0.002 - 0.018 mg Cu/l, 0.007 - 0.159 mg Ni/l, and 0.052 -0.151 mg Pb/l. Mean values of these heavy metals in monsoon were 0.018, 0.018, 0.011, 0.037 and 0.093 mg/l, respectively. Finally the study revealed that among the heavy metals only Pb concentration exceeded the standard level during the monsoon, otherwise concentrations of all other four heavy metals (viz. Cd, Cr,Cu and Ni) exceeded the standard level of drinking-, fishing- and surface water as set up by WHO, GOB, USEPA, DOE and FWPCA, for the summer period.

A study was conducted by Zakir *et al.* (2006) to assess the metal pollution levels in water and sediments of lower Turag River in Bangladesh. Industrial wastewaters and urban sewage from the Tongi municipal and industrial area directly discharge to this part of the river without any sorts of treatment. The results showed that the heavy metal concentrations in the water samples greatly exceeded the standard values for the surface water quality.

Islam *et al.,* (2012) reported that Iron concentration is much higher than other toxic elements and Fe and Mn concentration is much higher than the acceptable limit throughout the year. He also shows that Heavy metal concentration varies with the intensity of industrial and agricultural run-off and differs site to site.

In the Sitalakhya River, the DO values have frequently been found below 4 mg/l since 1997 (DoE/BEMP, 2003). Data on heavy metal concentration in the river water during 1997-98 showed that Aluminum(Al), Cadmium(Cd), Lead (Pb), and Mercury (Hg) concentrations of water samples collected from the intake point of the Saidabad water treatment plant exceeded the Bangladesh drinking water standard (GoB, 1997). In the Sitalakhya river, DO value recorded at the intake point on 28-04-03 was 2.9 mg/l, and ammonia concentration in the Sitalakhya river was 1.6-2.0 mg/l (DoE/BEMP, 2003).

Vallini *et al.* (1998) reported that the sludge from various treatment procedures in tannery caused environmental pollution. Azom *et al.* (2012), reported that in Bangladesh the tannery industries afflict the soil and river water environment and thus lessen ecological balance. This study had revealed that the tanning activities involve serious environmental hazards. Scientist stated that About 200 tons of solid waste is generated per day during peak season and 75 tons during off-peak season from the tanneries of Hazaribag .The solid waste largely contains pieces of raw hides, and small portion of lime flashings. While some quantity of solid waste like shaving dusts are used for making leather board, a significant portion is left every day on the roadside and in the nearby dustbins causing bad odor to the surrounding area (Huq 1998).Valliniet al. (1998) also reported that Wastes and effluents from the tanneries also cause - great harm to the environment. The highly toxic nature of the waste water coming from hide processing causes soil and fresh water pollution.

2.2 Heavy metal toxicity and the environment

2.2.1 Potential effect of toxic heavy metal on the environment

Heavy metals are naturally occurring metallic elements that have a relatively high atomic weight and a density compared to water (Tchounwou, P.B *etl* (2012). There is inter-relationship between heaviness and toxicity. In recent years, there has been an increasing ecological and global public health concern associated with environmental contamination by these metals. Also, human exposure has risen dramatically as a result of an exponential increase of their use in several industrial, agricultural, domestic and technological applications (Bradl, 2002). Their multiple industrial, domestic, agricultural, medical and technological applications have led to their wide distribution in the environment and raising concerns over their potential effects on human health and the environment. Their toxicity depends on several factors including the dose, route of exposure, and chemical species, as well as the age, gender, genetics, and nutritional status of exposed individuals. Because of their high degree of toxicity, cadmium, chromium, lead, nickel, arsenic, mercury, cupper, zink and iron rank among the priority metals that are of public health significance. These metallic elements are considered systemic toxicants that are known to induce multiple organ damage, even at lower levels of exposure.

2.2.2 Harmful effect of heavy metal

Metal pollution has harmful effect on biological systems and does not undergo biodegradation. Toxic heavy metals such as Pb, Co, Cd can be differentiated from other pollutants, since they cannot be biodegraded but can be accumulated in living organisms, thus causing various diseases and disorders even in relatively lower concentrations (Pehlivan, 2009). Heavy metals, with soil residence times of thousands of years, pose numerous health dangers to higher organisms. They are also known to have effect on plant growth, ground cover and have a negative impact on soil microflora (Roy, 2005). It is well known that heavy metals cannot be chemically degraded and need to be physically removed or be transformed into nontoxic compounds (Gaur, 2004).

Water contamination by heavy metals in some areas is practically inevitable due to natural process (weathering of rocks) and anthropogenic activities (industrial, agricultural and domestic effluents). Waste water from the industries of tannery, mining, electroplating, paint, garments, or chemical laboratories often contains high concentrations of heavy metals, including chromium (Cr), Cadmium (Cd), Copper (Cu) and lead (Pb). Heavy metals are non-biodegradable and persistent environmental contaminants which may be deposited on the surfaces and then adsorbed into the tissues of the vegetables. Plants take up heavy metals by absorbing them from deposits on the parts of the plants exposed to the air from polluted environment as well as from contaminated soils (Singh, 2010). These elements, at concentrations exceeding the physiological demand of crop/vegetables, not only could administer toxic effect in them but also could enter food chains, get biomagnified and pose a potential threat to human health (Sharma, 2008).

Fish are commonly situated at the top of the food chain, and therefore, they can accumulate large amounts of some HMs. HMs pollution in fish has become an important worldwide concern, not only due to the threat to fish population but also due to the health risks associated with fish consumption. In our country HMs accumulation and distribution in soil, water and environment are increasing at an alarming rate causing deposition and sedimentation in water reservoirs and affecting fish growth and breeding. Rivers are a dominant pathway for metals transport and HMs become significant pollutants of many riverine systems. The behavior of HMs in natural waters is a function of the substrate sediment composition, the suspended sediment composition, and the water chemistry. During their transport, the HMs undergoes numerous changes in their speciation due to dissolution, precipitation, sorption and complexation phenomena which affect their behavior and bioavailability. Hence, HMs are sensitive indicators for monitoring changes in the water environment where fish grow and breed. However, to assess the environmental impact of contaminated sediments, information on total concentrations of HMs is not sufficient. The overall behavior of HMs in fish growth and fish breeding is strongly influenced by the associations of metals with various geochemical phases in sediments.

2.2.3 Toxic effect of common heavy metal

Heavy metal-induced toxicity and carcinogenicity involves many mechanistic aspects, some of which are not clearly elucidated or understood. However, each metal is known to have unique features and physio-chemical properties that confer to its specific toxicological mechanisms of action.

2.2.3.1 Cadmium

Cadmium is a chemical element with symbol Cd and atomic number 48. This soft, bluish-white metal is chemically similar to the two other stable metals in group 12, zinc and mercury. Cadmium is a heavy metal of considerable environmental and occupational concern. It is widely distributed in the earth's crust at an average concentration of about 0.1 mg/kg. The highest level of cadmium compounds in the environment is accumulated in sedimentary rocks, and marine phosphates contain about 15 mg cadmium/kg (IMO/FAO/UNESCO, 1987).

Cadmium is frequently used in various industrial activities. The major industrial applications of cadmium include the production of alloys, pigments, and batteries Wilson, 1988). Although the use of cadmium in batteries has shown considerable growth in recent years, its commercial use has declined in developed countries in response to environmental concerns.

Potential for Human Exposure

The main routes of exposure to cadmium are via inhalation or cigarette smoke, and ingestion of food. Skin absorption is rare. Human exposure to cadmium is possible through a number of several sources including employment in primary metal industries, eating contaminated food, smoking cigarettes, and working in cadmium-contaminated work places, with smoking being a major contributor. Other sources of cadmium include emissions from industrial activities, including mining, smelting, and manufacturing of batteries, pigments, stabilizers, and alloys (ATSDR, 2008).
Cadmium is a severe pulmonary and gastrointestinal irritant, which can be fatal if inhaled or ingested. After acute ingestion, symptoms such as abdominal pain, burning sensation, nausea, vomiting, salivation, muscle cramps, vertigo, shock, loss of consciousness and convulsions usually appear within 15 to 30 min. Acute cadmium ingestion can also cause gastrointestinal tract erosion, pulmonary, hepatic or renal injury and coma, depending on the route of poisoning (Baselt, 2000). Chronic exposure to cadmium has a depressive effect on levels of norepinephrine, serotonin, and acetylcholine. Cadmium causes damage to cells primarily through the generation of ROS (Stohs, 1995) which causes single-strand DNA damage and disrupts the synthesis of nucleic acids and proteins (Mitra, 1984).

The lung is the most definitively established site of human carcinogenesis from cadmium exposure. Other target tissues of cadmium carcinogenesis in animals include injection sites, adrenals, testes, and the hemopoietic system (Waalkes, 1995). In some studies, occupational or environmental cadmium exposure has also been associated with development of cancers of the prostate, kidney, liver, hematopoietic system and stomach (Waalkes, 1996). Carcinogenic metals including arsenic, cadmium, chromium, and nickel have all been associated with DNA damage through base pair mutation, deletion, or oxygen radical attack on DNA.

2.2.3.2 Chromium

Chromium is a chemical element with symbol Cr and atomic number 24. It is the first element in Group 6. It is a steely-grey, lustrous, hard and brittle metal which takes a high polish, resists tarnishing, and has a high melting point. It is a naturally occurring element present in the earth’s crust, with oxidation states (or valence states) ranging from chromium (II) to chromium (VI) (Jacobs, 2005). Chromium compounds are stable in the trivalent [Cr(III)] form and occur in nature in this state in ores, such as ferrochromite. The hexavalent [Cr(VI)] form is the second-most stable state. Major factors governing the toxicity of chromium compounds are oxidation state and solubility. Cr(VI) compounds, which are powerful oxidizing agents and thus tend to be irritating and corrosive, appear to be much more toxic systemically than Cr(III) compounds, given similar amount and solubility (De Flora, 1990). Elemental chromium [Cr(0)] does not occur naturally. Chromium enters into various environmental matrices (air, water, and soil) from a wide variety of natural and anthropogenic sources with the largest release coming from industrial establishments.

Industries with the largest contribution to chromium release include metal processing, tannery facilities, chromate production, stainless steel welding, and ferrochrome and chrome pigment production. The increase in the environmental concentrations of chromium has been linked to air and wastewater release of chromium, mainly from metallurgical, refractory, and chemical industries. Chromium released into the environment from anthropogenic activity occurs mainly in the hexavalent form [Cr(VI)]. Hexavalent chromium [Cr(VI)] is a toxic industrial pollutant that is classified as human carcinogen by several regulatory and non-regulatory agencies (U.S. EPA, 1992). The health hazard associated with exposure to chromium depends on its oxidation state, ranging from the low toxicity of the metal form to the high toxicity of the hexavalent form. All Cr(VI)-containing compounds were once thought to be man-made, with only Cr(III) naturally ubiquitous in air, water, soil and biological materials. Recently, however, naturally occurring Cr(VI) has been found in ground and surface waters at values exceeding the World Health Organization limit for drinking water of 50 µg of Cr(VI) per liter (Velma, 2009). Chromium is widely used in numerous industrial processes and as a result, is a contaminant of many environmental systems (Cohen, 1993).

Potential for Human Exposure

It is estimated that more than 300,000 workers are exposed annually to chromium and chromium-containing compounds in the workplace. In humans and animals, [Cr (III)] is an essential nutrient that plays a role in glucose, fat and protein metabolism by potentiating the action of insulin (Goyer, 2001). However, occupational exposure has been a major concern because of the high risk of Cr-induced diseases in industrial workers occupationally exposed to Cr (VI). Also, the general human population and some wildlife may also be at risk. It is estimated that 33 tons of total Cr are released annually into the environment.

Non-occupational exposure occurs via ingestion of chromium containing food and water whereas occupational exposure occurs via inhalation (Langård, 1983). Chromium content in foods varies greatly and depends on the processing and preparation. In general, most fresh foods typically contain chromium levels ranging from <10 to 1,300 µg/kg. Present day workers in chromium-related industries can be exposed to chromium concentrations two orders of magnitude higher than the general population. Even though the principal route of human exposure to chromium is through inhalation, and the lung is the primary target organ, significant human exposure to chromium has also been reported to take place through the skin(Costa, 1997). For example, the widespread incidence of dermatitis noticed among construction workers is attributed to their exposure to chromium present in cement (Shelnutt, 2007). Occupational and environmental exposure to Cr(VI)-containing compounds is known to cause multiorgan toxicity such as renal damage, allergy and asthma, and cancer of the respiratory tract in humans (WHO/IPCS, 1988). Breathing high levels of chromium (VI) can cause irritation to the lining of the nose, and nose ulcers. Some individuals are extremely sensitive to chromium(VI) or chromium(III), allergic reactions consisting of severe redness and swelling of the skin have been noted. An increase in stomach tumors was observed in humans and animals exposed to chromium(VI) in drinking water. Accidental or intentional ingestion of extremely high doses of chromium (VI) compounds by humans has resulted in severe respiratory, cardiovascular, gastrointestinal, hematological, hepatic, renal, and neurological effects as part of the sequelae leading to death or in patients who survived because of medical treatment (ATSDR, 2008).

Adverse health effects induced by Cr (VI) have been reported in humans. Epidemiological investigations have reported respiratory cancers in workers occupationally exposed to Cr (VI)-containing compounds. DNA strand breaks in peripheral lymphocytes and lipid peroxidation products in urine observed in chromium-exposed workers also support the evidence of Cr (VI)-induced toxicity to humans (Goulart, 2005). Oxidative damage is considered to be the underlying cause of these genotoxic effects including chromosomal abnormalities and DNA strand breaks (Wise, 2002). Nevertheless, recent studies indicate a biological relevance of non-oxidative mechanisms in Cr(VI) carcinogenesis. Carcinogenicity appears to be associated with the inhalation

of the less soluble/insoluble Cr(VI) compounds. The toxicology of Cr(VI) does not reside with the elemental form. It varies greatly among a wide variety of very different Cr(VI) compounds(Patlolla, 2008). Epidemiological evidence strongly points to Cr(VI) as the agent in carcinogenesis. Solubility and other characteristics of chromium, such as size, crystal modification, surface charge, and the ability to be phagocytized might be important in determining cancer risk(Norseth, 1981).
Various hypotheses have been proposed to explain the carcinogenicity of chromium and its salts; however some inherent difficulties exist when discussing metal carcinogenesis. A metal cannot be classified as carcinogenic per se since its different compounds may have different potencies. Because of the multiple chemical exposures in industrial establishments, it is difficult from an epidemiological standpoint to relate the carcinogenic effect to a single compound. Thus, the carcinogenic risk must often be related to a process or to a group of metal compounds rather than to a single substance. Differences in carcinogenic potential are related not only to different chemical forms of the same metal but also to the particle size of the inhaled aerosol and to physical characteristics of the particle such as surface charge and crystal modification .

2.2.3.3 Lead (Pb)

Lead is a naturally occurring bluish-gray metal with atomic number 82, atomic weight 207.19, and a specific gravity of 11.34 present in small amounts in the earth's crust. Lead has four electrons on its valence shell; its typical oxidation state is +2 rather than +4, since only two of the four electrons ionize easily. Apart from nitrate, chlorate, and chloride, most of the inorganic salts of lead^{2+}have poor solubility in water.

Although lead occurs naturally in the environment, anthropogenic activities such as fossil fuels burning, mining, and manufacturing contribute to the release of high concentrations. Lead has many different industrial, agricultural and domestic applications. It is currently used in the production of lead-acid batteries, ammunitions, metal products (solder and pipes), and devices to shield X-rays. Lead (Pb) exists in many forms in the natural sources throughout the world and is now one of the most widely and evenly distributed trace metals.

Ionic lead, Pb(II), lead oxides and hydroxides, and lead metal oxyanion complexes are the general forms of Pb that are released into the soil, groundwater, and surface waters. The most stable forms of lead are Pb(II) and lead-hydroxy complexes. Lead(II) is the most common and reactive form of Pb, forming mononuclear and polynuclear oxides and hydroxides . The predominant insoluble Pb compounds are lead phosphates, lead carbonates (form when the pH is above 6), and lead (hydr) oxides. Lead sulfide (PbS) is the most stable solid form within the soil matrix and forms under reducing conditions, when increased concentrations of sulfide are present. Under anaerobic conditions a volatile organolead (tetramethyl lead) can be formed due to microbial alkylation.

Lead(II) compounds are predominantly ionic (e.g., Pb_2^+ SO_4^{2-}), whereas Pb(IV) compounds tend to be covalent (e.g., tetraethyl lead, $Pb(C_2H_5)_4$). Some Pb (IV) compounds, such as PbO_2, are strong oxidants. Lead forms several basic salts, such as $Pb(OH)_2{\cdot}2PbCO_3$, which was once the most widely used white paint pigment and the source of considerable chronic lead poisoning to children who ate peeling white paint. Many compounds of Pb(II) and a few Pb(IV) compounds are useful. The two most common of these are lead dioxide and lead sulphate, which are participants in the reversible reaction that occurs during the charge and discharge of lead storage battery.

Soil can be contaminated with Pb from several other sources such as industrial sites, from leaded fuels, old lead plumbing pipes, or even old orchard sites in production where lead arsenate is used. Lead accumulates in the upper 8 inches of the soil and is highly immobile. Contamination is long-term. Without remedial action, high soil lead levels will never return to normal. In the environment, lead is known to be toxic to plants, animals, and microorganisms. Effects are generally limited to especially contaminated areas. Pb contamination in the environment exists as an insoluble form, and the toxic metals pose serious human health problem, namely, brain damage and retardation. Pb_2^+ was found to be acute toxic to human beings when present in high amounts. Since Pb_2^+ is not biodegradable, once soil has become contaminated, it remains a long-term source of Pb_2^+ exposure. Metal pollution has a harmful effect on biological systems and does not undergo biodegradation.

Potential for Human Exposure

Inhalation and ingestion are the two routes of exposure, and the effects from both are the same. Pb accumulates in the body organs (i.e., brain), which may lead to poisoning (plumbism) or even death. The gastrointestinal tract, kidneys, and central nervous system are also affected by the presence of lead. Children exposed to lead are at risk for impaired development, lower IQ, shortened attention span, hyperactivity, and mental deterioration, with children under the age of six being at a more substantial risk. Adults usually experience decreased reaction time, loss of memory, nausea, insomnia, anorexia, and weakness of the joints when exposed to lead (NSC, 2009). Lead is not an essential element. It is well known to be toxic and its effects have been more extensively reviewed than the effects of other trace metals. Lead can cause serious injury to the brain, nervous system, red blood cells, and kidneys (Baldwin and Marshall, 1999). Exposure to lead can result in a wide range of biological effects depending on the level and duration of exposure. Various effects occur over a broad range of doses, with the developing young and infants being more sensitive than adults. Lead poisoning, which is so severe as to cause evident illness, is now very rare. Lead performs no known essential function in the human body, it can merely do harm after uptake from food, air, or water. Lead is a particularly dangerous chemical, as it can accumulate in individual organisms, but also in entire food chains.

Exposure to lead occurs mainly via inhalation of lead-contaminated dust particles or aerosols, and ingestion of lead-contaminated food, water, and paints (ATSDR, 1999). Adults absorb 35 to 50% of lead through drinking water and the absorption rate for children may be greater than 50%. Lead absorption is influenced by factors such as age and physiological status. In the human body, the greatest percentage of lead is taken into the kidney, followed by the liver and the other soft tissues such as heart and brain, however, the lead in the skeleton represents the major body fraction (Flora, 2006). The nervous system is the most vulnerable target of lead poisoning. Headache, poor attention spam, irritability, loss of memory and dullness are the early symptoms of the effects of lead exposure on the central nervous system (ATSDR, 1992).

2.2.3.4 Nickel (Ni)

Nickel (Ni) is a hard but brittle metal which possesses high thermal and electrical conductivities. It is a silvery-white lustrous metal with a slight golden tinge. Nickel belongs to the transition metals and is hard and ductile.Powdered nickel is reactive and may spontaneously ignite in air (ATSDR 2005). Nickel is a transition element of Group VIIIa of the Periodic Table, with an atomic number of 28 and an atomic weight of 58.693, a melting point of 1455^{0}C, a boiling point of 2913^{0}C and a specific density of 8.9 g/cm3 at 25^{0}C (Haynes 2011).
In the environment, nickel can be found in a variety of inorganic and organic compounds, depending on such factors as the medium considered and ambient environmental conditions. In water, Ni^{2+} forms a number of compounds of varying solubility's with sulphate, nitrate, chloride, hydroxide and carbonate. Elemental nickel is insoluble in water (Cotton and Wilkinson 1988; WHO 1991).

Potential for Human Exposure

Food intake, gastric emptying and peristalsis of theintestine are of substantial significance for the bioavailability of nickel, because absorption of ingested nickelis lower when it is administrated in food or in water together with a meal. The presence of food in the stomachsignificantly alters the bioavailability of nickel salts (Haber, 2000). Absorption is influenced by the amount of food, theacidity of the gut and the presence of dietary constituents, possibly phosphate, phytate, fibres and similar metal ionbinding components, which may bind nickel and make itmuch less available for absorption than nickel dissolvedin water and ingested on an empty stomach. In particular, the levels of other minerals, such as iron, magnesium, zinc and calcium, may alter nickel absorption from thegut. Nickel binding to food components may also be pH dependent and there by depend on the time interval between food ingestion and ingestion of nickel.

Nickel is a ubiquitous metal frequently responsible forallergic skin reaction and has been reported to be oneof the most common causes of allergic contact dermatitis, as reflected by positive dermal patch tests. High levels of exposure to nickel have been associated with a wide variety of effects that mayinclude adverse gastrointestinal and neurological effects in various studies in both laboratoryanimals and people (mostly industrial workers) (ATSDR 2005). Nevertheless, the key concerns ofhealth agencies are the potential effects of nickel on the developing fetus and respiratory cancer (EU2004; HC 1996; US EPA 1996; WHO 2000; 2007; EC 2001).

Human exposure to highly nickel-polluted environments has the potential to produce a variety of pathological effects. Among them are skin allergies, lung fibrosis, cancer of the respiratory tract and iatrogenic nickel poisoning. A number of studies demonstrated the hepatic toxicity associated with nickel exposure anddose-related changes in serum enzyme activity were observed following animal treatment with nickel. Nephrotoxicity has been noted and aminoaciduria and proteinuriawere the indices of nickel toxicity. Nickel exposure hasbeen reported to produce haematological effects in bothanimals and humans.

2.2.3.5 Zinc (Zn)

Zinc is a chemical element with symbol Zn and is the first element in group 12 of the periodic table. The atomic number of Zinc is 30 with its atomic weight is 65.38; melting and boiling point are 419.5°C and 907°C, respectively.

Potential for Human Exposure

Zinc is extraordinarily needed in biological systems. It is exigent for the survival of many biochemical processes that support life and required for a host of physiological functions including normal immune function, sexual function, neurosensory function such as cognition and vision. Numerous proteins, enzymes and transcription factors depend on zinc for their function. It is generally reasoned that in order for a metal to exert its toxicity it must be in soluble form as opposed to suspended or insoluble. In an investigation on the toxicity of zinc sulfate to bluegill, Cairns et al. (1971) found soluble zinc as toxic and insoluble zinc as nontoxic. To alienate between soluble and insoluble zinc for analytical purposes, the portion that will pass through a 0.45 µm pore size membrane filter is the soluble zinc. The combination of soluble and insoluble zinc is termed total zinc.

2.2.3.6 Copper (Cu)

Cupper (Cu) is a soft, malleable and ductile metal with very high thermal and electrical conductivity. It is a transition metal which belongs toperiod 4 and group IB of the periodic table withatomicnumber 29, atomic weight 63.5, density 8.96 g cm^{-3}, meltingpoint 1083 °C and boiling point 2595◦C. Copper is the third most used metal in the world.

Potential for Human Exposure

Copper is an essential micronutrient required in the growthof both plants and animals. In humans, it helps in theproduction of blood haemoglobin. In plants, Cu is especially important in seed production, disease resistance, and regulation of water. Copper is indeed essential, but in highdoses it can cause anaemia, liver and kidney damage, andstomach and intestinal irritation. Copper normally occursin drinking water from Cu pipes, as well as from additives designed to control algal growth. While Cu's interaction withthe environment is complex, research shows that most Cuintroduced into the environment is, or rapidly becomes,stable and results in a form which does not pose a risk tothe environment. In fact, unlike some man-made materials,Cu is not magnified in the body or bioaccumulated in thefood chain. In the soil, Cu strongly complexes to the organicimplying that only a small fraction of copper will be found in solution as ionic copper, Cu(II). The solubility of Cu isdrastically increased at pH 5.5, which is rather close to the ideal farmland pH of 6.0–6.5 (Mart´ınezand Motto, 2000).

2.2.3.7 Iron (Fe)

Iron is a chemical element with symbol Fe and atomic number 26and is the second most abundant metal and fourth most abundant element in the Earth's crust. It is a metal in the first transition series. It is by mass the most common element on Earth, forming much of Earth's outer and inner core.

Concentration of iron in water is quite low because of low solubility. Generally, iron concentrations in natural freshwaters do not exceed 1 mg L^{-1}. Iron exists in two forms, soluble ferrous iron and insoluble ferric particulate iron. In most aquaculture systems there will be a high oxygen concentration, and all iron present in the water will be in the form of insoluble ferric Fe^{3+}. Ferric iron as a chemical is non-toxic; however this doesn't mean that it does not exert a pathological response. Population explosion, fast urbanization and development of industries give rise to various ecological problems in the ecosystems of most water-bodies.

Potential for Human Exposure

Iron toxicity occurs when the cell contains free iron, which generally occurs when iron levels exceed the availability of transferrin to bind the iron. Damage to the cells of the gastrointestinal tract can also prevent them from regulating iron absorption, leading to further increases in blood levels. Iron typically damages cells in the heart, liver and elsewhere, causing adverse effects that include coma, metabolic acidosis, shock, liver failure, coagulopathy, adult respiratory distress syndrome, long-term organ damage, and even death (Cheney, K.; Gumbiner,1995).

3. Approaches and Methods

3.1 Study area

Over the last couple of decades major industrialization and urbanization has been observed in Dhaka. The dyeing factories and tanneries are the main polluters of the rivers. Waste from these industries is usually connected to the sewerage system that directly follows to the rivers around the Dhaka city. Moreover, the rivers have become a dumping ground of all kinds of solid, liquid and other chemical waste. Encroachment on rivers is a common practice in Dhaka andmost of the natural drainages disappeared or are in way to due to illegal encroachment. Due to river encroachment and dumping of solid waste into the rivers are losing their natural flow. As a result, Dhaka is the worst city in terms of environmental degradation. In this situation, Dhaka and its surrounding rivers were selected for this research work.

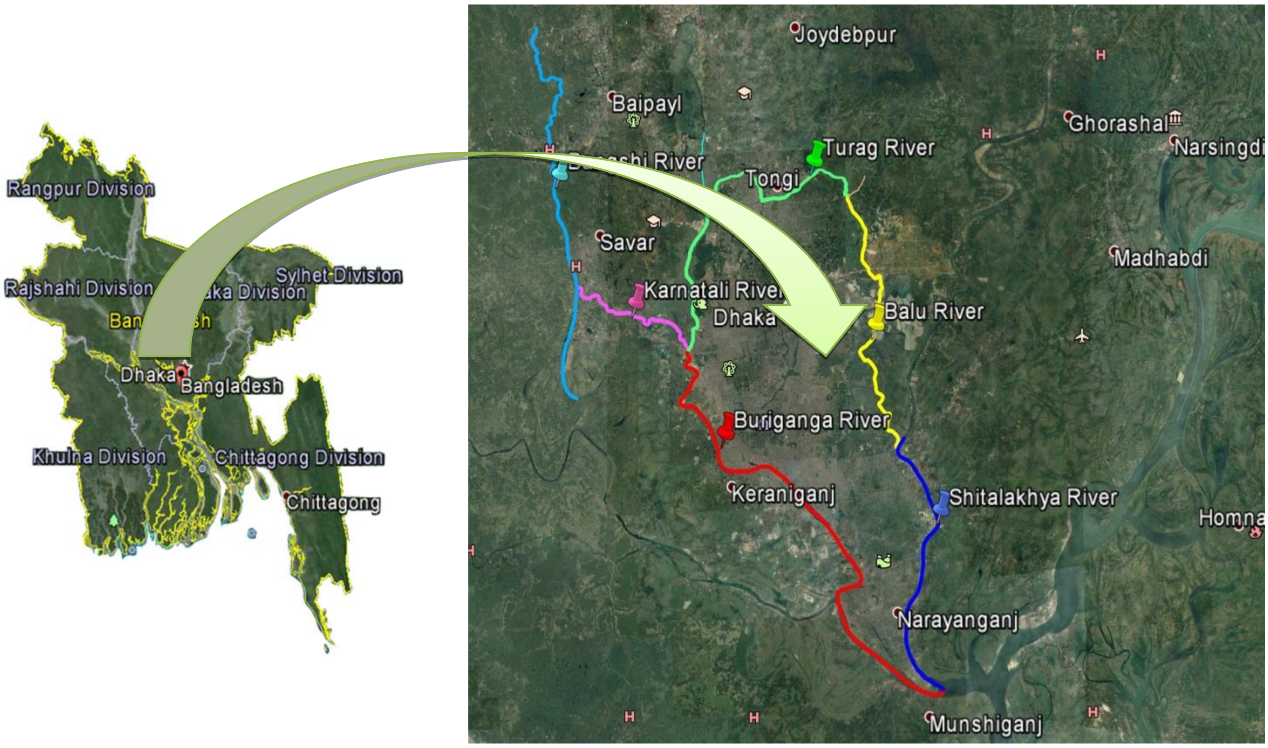


Figure 3.1: Dhaka and its surrounding rivers

3.2 Selection of rivers and origins

Bongshi, Buriganga, Karnatoli,Turag,Balu and Shitalakharivers are very important for the survival of eco-system of Dhaka.These rivers are the top priority rivers by Government to save Dhaka from pollution.Dhaka is bounded by the river Bongshi, Karnatoli, Turag, Balu, Shitalakhya and Buriganga showing in Figure 3.2.

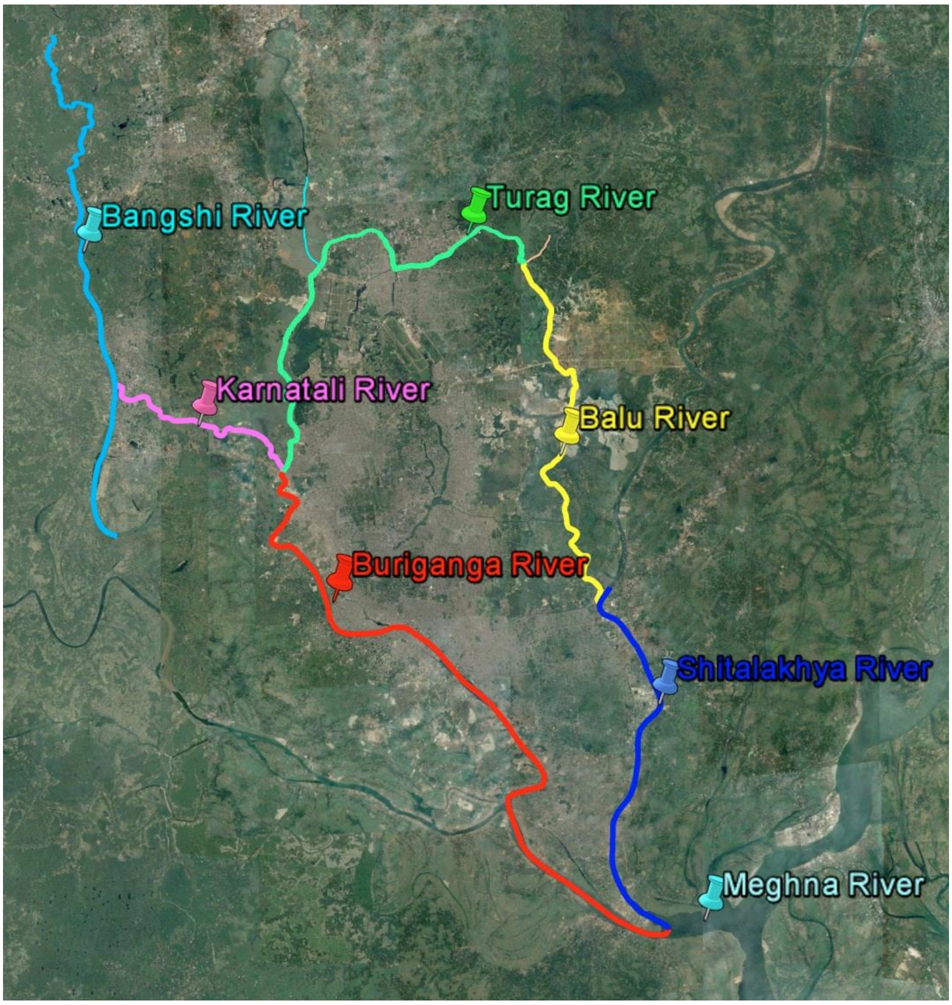


Figure 3.2: Study loop of the Bongshi, Karnatoli, Turag, Balu, Shitalakha and Buriganga rivers around Dhaka.

The Bongshi is originated from the right bank of the old Brahmaputra River. It flows through JamalpurSadar of Jamalpur District, Madhupur, Ghatail, Kalihati, Basail of Tangail District, Kaliakair of Gazipur District and Savar of Dhaka District. The course from Sharifpur to Madhupur is only navigable in rainy season. The length of the river is about 184 km, while from Madhupur to Savar is about 160 km. The width of the river is about 70 m while the maximum depth is about 8 m at Mirzapur. Bangshi River has no tidal effect in dry season and the navigability become very low and almost dry in many places (Biswas, 2011; Haque, 2008). The course from Sharifpur to Madhupur is only navigable in rainy season. Gohailbari is a place of Shimuliya union of SavarUpazilla where Bongshi enters into Dhaka district. At this point it get very narrow canal becomimg a canal in dry season and carries only the waste water of various industries situated near Nabinagar-Chandra highway, to down. Violating the environment law, tons and tons of untreated industrial effluents are being dumped into these rivers. These include carpet mills, spinning mills, textile mills, pharmaceuticals, electrical and electronic goods, footwear and leather goods, garments, dyeing, metal, paper goods, plastic goods and hardware. As a result serious river pollution occur causing severe environmental degradation surrounding areas of this river. Moreover, the new leather industry is being moved from Hazarybagh to Hemayetpur adjacent to Bongshi river. Six locations including Gohailbari were selected along the Bongshi River. These were Gohailbari, Dhamsona (Beximco Canal), Nolam (DEPZ Canal), Saver Namabazar, RafiqSetu and Hemayetpur (New tannery).

Figure 3.3: Up stream of Bongshi which carries only industrial waste in dry season (left) and Solid wastes dumping at Namabazar on the bank of Bongshi (right)

The Buriganga is afflicted by the noisome problem of pollution. It flows past the southwest peripheries of Dhaka city. In the distant past, a course of the Ganges River used to reach the Bay of Bengal through the Dhaleshwari river. When this course gradually shifted and ultimately lost its link with the main channel of the Ganges it was renamed the Buriganga.Its average depth is 7.6 meters and its maximum depth is 18 meters. According to the Department of the Environment, 22,000 litres of toxic waste are released into the river by the tanneries every day. The chemical waste of mills and factories, household waste, medical waste, sewage, dead animals, plastics, and oil are some of the Buriganga's pollutants. The city of Dhaka discharges about 4,500 tons of solid waste every day and most of it is released into the Buriganga. In this situation, along the Buriganga 15 locations were selected in this study. These were Amin Bazar Bridge, Bosila, Hazaribagh Canal, GazirGhat, Kholamora boat ghat, Swary Ghat, Babu Bazar Bridge, Sadarghat, Mirer Bag, Postagola, MonsiKhola, Pagla, Fatullah.

Figure 3.4. Tannery wastes enter to Buriganga without any treatment at Kamrangirchar (left) and Municipal wastes enter to Buriganga at Babubazar Bridge without any treatment (right).

Figure 3.5: RRI Scientists selecting location at Babubazar point of Buriganga River (left) and New Tannery point of Bangshi River (right).

Karnatoli river originates from Bongshi and fall to the Turag. Karnatoli has also severe pollution threat as its upstream and downstream both are severe polluted rivers. Solid wastes from Dhaka city dumped to bank of this river. Along the Karnatoli river three sampling points Begunbari, Alfala char khet, Karnapara Bridge were selected.

The Turag river is the upper tributary of the Buriganga. It originates from the Bongshi River, the latter an important tributary of the Dhaleshwari River, flows through Gazipur and joins the Buriganga at Mirpur. TheTurag suffers from acute water pollution. The most pollution sources of Turag river water are various consumer goods industries (soap and detergent), garments industries, pharmaceuticals industries, lots of tanneries, dyeing industries, aluminum industries, battery manufacturing industries, match industries, ink manufacturing industries, textile, paint, iron industries, pulp and paper factories, chemical factories, frozen food factories and Steel workshop etc. Most of the industries discharge their effluents directly or indirectly into the Turag river without any treatment causing pollution of the surface water. Moreover, many sewerage and municipal sewage drainage system have become a dumping ground of all kinds of solid, liquid and chemical waste that polluted the river bank. Pal para, Sluice gate, Birulia, Asulia lake, TongiBridge,Teromukh were selected along the Turag for this study.

Figure 3.6: Industrial waste enter into Turag without any treatment (left) and solid waste dumped on the bank of Turag at Tongibazar

The Balu River is a tributary of the Shitalakshya River. It passes through the wetlands of BeelBelai and Dhaka before its confluence with the Shitalakshya at Demra. It has a narrow connection through the Suti nadi near Kapasia with the Shitalakhya, and also by way of the Tongi Khal with the

Turag, there is also a link with the Shitalakshya near kaliganj (Banglapedia, 2006). Balu River is one of the importent water resource in Dhaka district especially for Tongi. This river water is used for domestic, agricultural and residential purposes. But Balu river are being polluted through a number of pointed and non-pointed sources including untreated sewerage inputs from the town of Dhaka and Tongi, waste water and other numerous other contamination sources, such as small-manufacturing facilities (e.g., tannery and battery factory) and significant non-point agricultural activities. Moreover, other important pollution sources such as industrial inputs from a paint factory, power station, building materials factory and municipal solid wastes that drain directly into the river and receive sewage effluents from the sewer system of the town. Ichapura, Beraid, Dakhin para and Char Chanpara were selected along the Balu river.

Figure 3.7: Launch terminal on Shitalakhya (left) and industrial wastes enter to the Shitalakhya (right)

Shitalakhya River is a distributary of the Brahmaputra. In its initial stages it flows in a southwest direction and then east of the city of Narayanganj in central Bangladesh until it merges with the Dhaleswari near Kalagachhiya. Shitalakhya is a very busy river as the steamers, launches, boats etc. plyingon the rivers which pollutes the water by their fuel andwastematerials. Many industries like e jute mills andcotton mills discharged solids wastes of cotton and jute into the river.The industrial wastes, unhygienic sewageand domestic wastes are also responsible for the pollution.Along the Shitalakhya 6 locations namely Nowapara, Demra Bridge, Tarabo(Kachpur Bridge), EPZ Adamzi, Narayangonj Launch Terminal and Shah Cement Factory (Muktergonj) were selected.

Under above these circumstances Bongshi, Buriganga, Karnatoli, Turag, Balu and Shitalakha rivers were selected in this study.

3.3 Locations

The following Table 3.1 summarizes selected locations with Latitude & Longitude and reason for choosing location.

Table 3.1: River name and testing/sampling location

River name	Selected length (km)	Location	Reason for choosing location	Latitude and Longitude
Bongshi	27.5	Gohailbari	Gohailbari is a place where Bongshi enters in Dhaka. In dry season,at this point it gets completely dry and become very narrow, and it carries only the waste water of various industries located at Jirani area.	23°59'14.11"N 90°12'56.96"E
		Dhamsona (Beximco Canal)	Dhamsona is a union of SavarUpazila. There are many garments, textile miles, pharmaceutical industries in Dhamsona union. A canal carrying the untreated water of these industries meets the Bongshi River at this sampling point.	23°57'30.14"N 90°14'5.92"E
		Nolam (DEPZ Canal)	This sampling point connects the canal carrying waste water from DEPZ and other industries to the Bongshi river.	23°56'39.81"N 90°13'54.41"E
		Savar Namabazar	In the Savar Namabazar sampling point there are some canals fall into the Bongshi river carrying municipal & industrial waste and solid wastes are also dumped at this location.	23°50'39.11"N 90°14'30.81"E
		RafiqSetu	A distributary of Bonshi river named Karnatoli starts three kilometres up of Rafiq setu reducing the intensity contamination at this point and also the Bongshi river get wider at this point. At this point water quality seemed to be good.	23°47'54.57"N 90°14'42.28"E
		Hemayetpur (New tannery)	Hemayetpur (New tannery) is a sampling point where leather industries of Hazaribagh is being shifted. Now the water quality of this sampling point is the best than that of all other sampling points. This sampling point was chosen to compare future contamination of the point if it will be caused by leather industry waste water.	23°46'47.49"N 90°14'20.55"E
Buriganga	26	Amin Bazar Bridge	Turag and Karnatoli river get joint at this point. Itis the commencing point of the Buriganga river.	23°47'1.69"N 90°20'8.28"E
		Bosila	At this sampling point many storm water drains and surface drains are connected to the Buriganga river	23°44'38.61"N 90°20'46.27"E

River name	Selected length (km)	Location	Reason for choosing location	Latitude and Longitude
			carrying municipal waste.	
		Hazaribagh Canal	At this sampling point a canal carrying waste water of tanneries of Hazaribagh area meets the Buriganga river.	23°44'24.52"N 90°21'5.00"E
		Gazir Ghat	Some Canals carrying municipal waste and untreated water of tanneries meets the Buriganga river at this point.	23°43'41.24"N 90°21'28.03"E
		Kholamora boat ghat	A rivulet fall into the Buriganga river at this point. This point was chosen to compare whether contamination was less or not to other points.	23°42'51.54"N 90°21'31.39"E
		SwaryGhat	A big canal carrying municipal and industrial waste of Kamrangirchar and Shahidnagar area get joint to Buriganga river at this point.	23°42'38.27"N 90°23'30.26"E
		Babu Bazar Bridge	A storm water drain carrying municipal waste from Babu Bazar area was connected to the Buriganga river at this point.	23°42'33.11"N 90°24'7.70"E
		Sadarghat	Sadarghat Launch terminal is one of the largest river ports in Bangladesh. The river port of Dhaka, however, do not have facilities to receive and treat bilge and ballast water. Oil and lube spillage also happens during refuelling of vessels and cargo handling. These vessels dump waste, including burnt oil, into the water. Also some city drains and sewers carrying municipal waste and industrial sewage meets with the Buriganga river.	23°42'21.59"N 90°24'26.24"E
		Mirer Bag	There is a launch terminal at Mirer Bag point for this reason this point was chosen.	23°41'40.06"N 90°25'2.82"E
		Postagola	Some canals carrying municipal and industrial waste of Potagola area meet at this point with the Buriganga river.	23°41'15.67"N 90°25'41.72"E
		MonsiKhola	It is the point where local brick traders run their business through loading and unloading bricks.	23°40'47.95"N 90°26'18.59"E
		Pagla	There are salt, leather, food industries in Pagla. These industries dump untreated waste water into the Buriaganga river at this point.	23°40'8.39"N9 0°26'54.82"E
		Fatullah	There is a launch terminal at Fatullah. Spillage of oil and lubricants occur during anchoring of launches and motorized boat. There are leather, food, knitwear,	23°38'29.40"N 90°28'18.55"E

River name	Selected length (km)	Location	Reason for choosing location	Latitude and Longitude
			Garment, textile factories in Fatullah. These industries dump untreated waste water into the Buriaganga river at this point alongwith municipality waste.	
Karnatoli	12	Begunbari	A Canal carrying municipal waste meets the Karnatoli river at this point.	23°47'28.95"N 90°19'48.72"E
		Alfala char khet	A Canal carrying municipal and agricultural waste of Bongaon and Genda area meets the Karnatoli river at this point.	23°48'3.71"N 90°18'13.24"E
		Karnapara Bridge	A Canal carrying municipal waste of Bank town area of Savar meets the Karnatoli river at this point.	23°49'5.21"N 90°15'25.81"E
Turag	28.45	Pal para	There is small boat ghat at Pal para sampling point. Some motorized boat carrying passenger are seen to go different destination point.	23°47'36.02"N 90°20'23.65"E
		Sluice gate	A Canal passing through sluice gate carrying municipal waste of Dhaka Zoo area falls into the Turag river at this point.	23°49'38.42"N 90°20'34.06"E
		Birulia	There are some agricultural lands at Birulia point near the river bank of Turag river. Agricultural waste of this area fall into the Turag river.	23°50'58.20"N 90°20'21.28"E
		Ashulia lake	Ashulia lake is as like as a big reservoir. Water quality seemed good at this point.	23°52'37.58"N 90°21'1.94"E
		Tongi Bridge	Tongi is an industrial area. There are many industries and factories in Tongi area including textile mills, garments, dyeing factories, pharmaceutical industries, and so on. These industries and factories of this area dump untreated waste water to Turag river.	23°52'55.11"N 90°24'1.81"E
		Teromukh	Teromukh is the last sampling point of Turag river. There are some brick kilns in this area.	23°52'55.47"N 90°27'38.01"E
Balu	21.76	Ichapura	Some small canals carrying municipal waste of Khilkhet area meets the Balu river at this point.	23°49'40.62"N 90°29'14.79"E
		Beraid	A Canal carrying municipal waste of Bashundhar residential area and Beraid area fall into the Balu river at this point.	23°48'3.66"N9 0°28'55.20"E
		Dakhin para	A big canal carrying municipal waste of Badda, Rampura and Khilgaon area meets the Balu river at this point.	23°45'40.29"N 90°28'57.52"E

River name	Selected length (km)	Location	Reason for choosing location	Latitude and Longitude
		Char Chanpara	Two or three earthen canals carrying municipal waste fall into the Balu river at this point.	23°43'51.24"N 90°29'56.65"E
Shitalakhaya	20 km	Nowapara	Factories like spinning mills, pharmaceuticals, edible oil factories are situated at Nowapara.	23°43'57.22"N 90°30'31.56"E
		Demra Bridge	Some storm water drains meet the Shitalakhya carrying municipal and industrial waste of Demra area at this point.	23°43'17.00"N 90°29'56.67"E
		Tarabo (Kanchpur Bridge)	Some storm water drains meet the Shitalakhya carrying municipal and industrial waste of Tarabo area at this point.	23°42'7.10"N 90°31'3.20"E
		EPZ Adamzi	Untreated waste water from Adamzi EPZ and municipal waste of Adamzi area directly dump into the Shitalakya river.	23°40'59.07"N 90°31'36.51"E
		Narayangonj Launch Terminal	It is a launch terminal. Here spewing of oil and lubricants occur.	23°36'58.63"N 90°30'21.65"E
		Shah Cement Factory (Muktergonj)	There are some cement factories at this sampling point. Untreated waste from cement factories directly dump into the Shitalakya river.	23°34'16.24"N 90°31'32.47"E

3.4 Research methods

The research was carried out based on following methods

- In-situ Investigation
- Samples collection
- Laboratory investigation
- Questionnaire survey from the river bank communities

3.4.1 In-Situ Investigation

In-situ test has been done to avoid biodegradation between sampling and analysis.In-situ tests were conducted in dry season and post rainy season. In the first year, in-situ tests were done in March 2015 as dry season in Bongshi and Buriganga rivers. Thereafter for extensive research, more rivers were included gradually parallel to Bongshi and Buriganga adjacent to Dhaka. In post rainy season Bongshi, BurigangaandTurag were investigated in October 2015. In February 2016, six rivers surrounding Dhaka Bongshi, Buriganga, Karnatoli, Turag,Balu and Shitalakha were investigated as dry season. Three replications were carried out at each location. In-situ water quality parameters which were measured instantly on the boat are following:

- Dissolve oxygen (DO)
- Temperature
- pH
- Total Dissolve Solid (TDS)
- Electrical conductivity (EC)
- Ammonia (NH_3)
- Carbon di-oxide (CO_2)

- Chloride
- Hardness
- Alkalinity

3.4.1.1 In-Situ Testing Instruments

HACH portable Single Input Digital Multi-parameter Meter (HQ30d) and HACH Portable Freshwater Aquaculture (FF-2) Test apparatus with digital titrator were used as instruments for the in-situ test.Temperature, DO, pH and TDS and EC were quantified using Single Input Digital Multi-parameter Meter (30QD) with probes and Freshwater Aquaculture Test apparatus with digital titrator (**Figure: 3.7**) were used for measuring Ammonia (NH_3) Carbon di-oxide (CO_2) Chloride, Hardness and Alkalinity.

Figure 3.8: HQ30d Digital Single input Multi-parameter Meter (left) and Freshwater Aquaculture (FF-2) Test apparatus (right)

Figure 3.9. Detecting water quality parameters in-situ condition on the boat

3.4.2 Sample collections

Samples were collected in both dry season and post rainy season. In the first year, samples were collected in March 2015 as dry season in Bongshi and Buriganga rivers. Thereafter for extensive research, more rivers were included gradually parallel to Bongshi and Buriganga adjacent to Dhaka for sample collection. The month of October as treated as post rainy season assuming the river water become stable after rainy season and fish may get sufficient time for their growth. In post rainy season Bongshi, BurigangaandTurag were investigated in October 2015. In February 2016, six rivers surrounding Dhaka Bongshi, Buriganga, Karnatoli, Turag,Balu and Shitalakha were investigated as dry season.

3.4.2.1 Sample collection categories

Samples were collected in the following categories:

- **Water samples:** Water samples were collected from all the locations of five rivers.
- **Sediment/river bank soil:** Sediment/river bank soils were collected from selected most hazardous areas.
- **Crops/vegetables:** Crop/vegetables were collected from the worst polluted areas
- **Fish:** Fishes were also collected from selected most hazardous areas.

3.4.2.2 Water sample collection procedure

One Liter HDP plastic bottles were used for water sample collection. All bottles washed with dilute HNO_3 followed by distilled water washing and dried. The bottles were labeled with date and sampling source. Prior to sample collection, the bottles were rinsed with the water to be collected. The collected water samples were immediately acidified with HNO_3 and the bottles were carefully stoppered to avoid contact with air. At each sampling location, a composite sample was collected by taking 3 numbers of samples at 1 m interval.

3.4.2.3. Preservation of collected water sample

The water samples were transferred to the laboratory as early as possible. The samples were stored at 4°C in a refrigerator to minimize the potential for volatilization or biodegradation between sampling and analysis.

3.4.2.4 Collection of sediment/river bank soil

Sediment/river bank soil samples were collected from different places along the Bongshi, Buriganga, Turag and Shitalakhaya for heavy metal analysis. These samples were collected by vertical corer and Ekman dredge grab sampler.

Figure 3.10: Collection of sediment samples from the river

3.4.2.5 Collection and sample preparation of crops/vegetables

Usually farmers are used contaminated river water for irrigation purposes in dry season to grow crops/ vegetables in agricultural land along the Bongshi and Buriganga rivers. Plenty of crops and vegetables are grown both sides of the Bongshi and TuragRiver. Buriganga, Balu and Shitalakhya rivers are mostly industrial areas and usually no crop production has taken place. Crops/ Vegetables samples were collected from Gohail Bari location of the Bongshi for heavy metal analysis. Vegetable/crops samples were collected from three different locations to provide replicate samples of each plant. Vegetable samples include Tomato, Pumpkin and red spinach were collected in March, 2015. Rice plants were collected during harvesting of BRRI Dhan 28 rice plants and separated into three parts namely matured grain (paddy), shoot and root.

Figure 3.11: Rice cultivation along the Bongshi irrigating with contaminated river water

3.4.2.6 Collection of fish

Fish samples were collected from different places of the Bongshi, Buriganga, Turag and Shitalakhaya. Usually no fish are available during the month of March and April in dry season due to severe pollution of river water. Therefore, fish were collected in the month of October, 2015 as post rainy season and in the month of February, 2016 as dry season. In post rainy season Taki, Puti, Tangra, Chapila, Tatkiny, Bacha, Foli, Chingri, Kakila were collected and in dry season Taki, Shing, Tangra were collected for heavy metal analysis.

Figure 3.12: RRI personnel collecting fish from Turag river.

3.4.3 Laboratory investigations

Heavy/toxic metals of collected samples were investigated in the laboratory. Three replications were taken for laboratory analysis. Moreover, COD were determined from collected water samples in the laboratory.

3.4.3.1 Water sample preparation at laboratory for analysis of heavy metals

For heavy metal analysis, water samples were prepared and analyze according to Sharma and Tyagi, 2013. The samples preparation techniques are following:

- Transferred 100 ml of well mixed acid preserved sample into a beaker
- Added 2 ml of concentrated HNO_3 + 5 ml of concentrated HCl
- Placed the beaker on a hot plate at 90 to 95 °C
- Reduced the volume up to 10-20 ml
- Removed the beaker and allowed to cool
- Wash down the beaker with deionized water (3 times)
- Filtered through a Whatman filter paper no. 42
- Poured the sample into 100 ml volumetric flask and made it up 100 ml
- Mix thoroughly & poured to HDP plastic bottle and keep in refrigerator
- Heavy metals concentration were quantified by atomic absorption spectrometer (AAS) in the laboratory

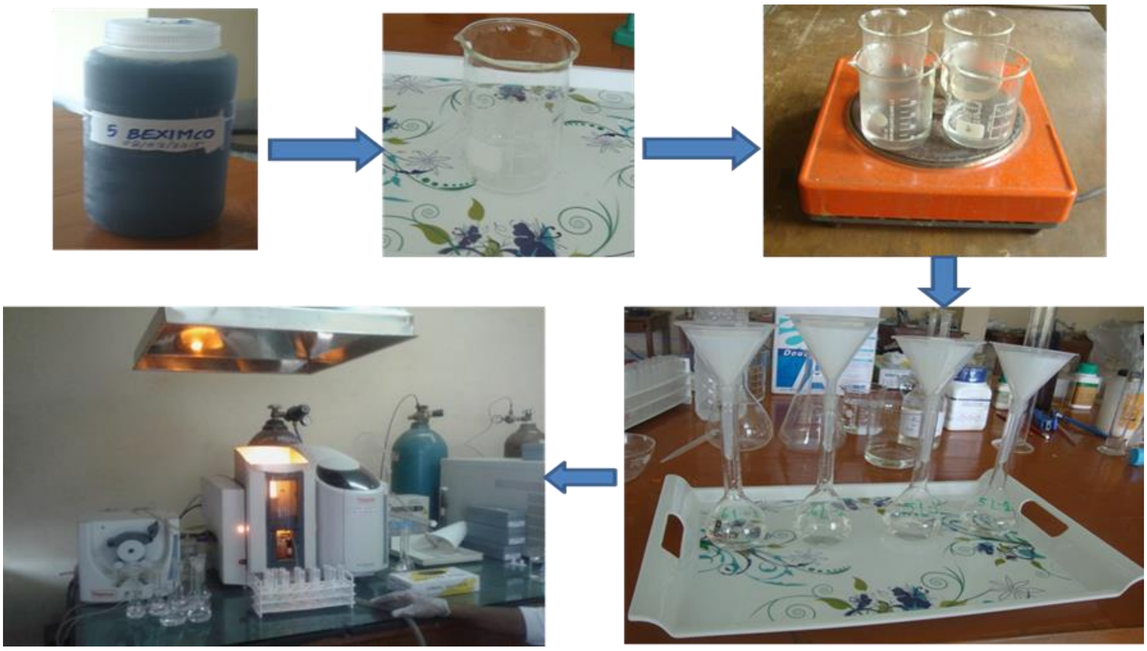


Figure 3.13: Schematic diagram for water sample preparation

Heavy metals concentrations were quantified by atomic absorption spectrometer (AAS) in the laboratory. The steps were followed for quantifying metals by AAS below:

- Prepared at least three concentrations of standard solution of a particular metal
- Aspirated blank solution and adjust zero
- Aspirated each standard solution into flame
- Prepared a calibration curve for absorbance versus concentration of standard solution
- Took the reading of the prepared sample solution directly from the instrument
- Use the appropriate dilution factor for the samples having higher concentration of metal ions (When necessary)

3.4.3.2 Sample preparation for river bank soils/sediments

The soil/sediments samples were weighed to determine the fresh weight and dried in an oven at 65 °C for 24 hours to determine their dry weight. 0.5g of oven dried soil/sediments samples were cold digested overnight with 15 ml of $HClO_4$ and HNO_3 (1:4). Then the samples were heated on a hot plate until a transparent Solution appeared. The solution were then filtered through Whatman 42 Filter paper and diluted to 100ml on a volumetric flask. Mix thoroughly & pour to HDP plastic bottle and keep in refrigerator to quantify heavy metals concentration by AAS.

Figure 3.14: Sample preparing for metals analysis (left) and detectingmetals using AAS at the lab (right).

3.4.3.3 Sample preparation for crops and vegetables

The crops/vegetables samples were weighed to determine the fresh weight and dried in an oven at 65 °C for 72 hours to determine their dry weight. The oven-dried samples were crushed in a mortar, sieved (<1mm) and weigh 2.0 g of powder. 2g of dried crop/vegetables samples were cold digested overnight with 15 ml of HClO4 and HNO3 (1:4). Then the samples were heated on a hot plate until a transparent Solution appeared. The solution were then filtered through Whatman 42 Filter paper and diluted to 100ml on a volumetric flask. Mix thoroughly & pour to HDP plastic bottle and keep in refrigerator to quantify heavy metals concentration by AAS.

3.4.3.4 Fish sample preparation techniques

Fish sample preparationtechniques are following:

- Fish samples were dried on an oven at 65°C for 3 days.
- The dried samples were ground in a morter pastle to make a paste.
- 10g of paste samples were taken on a crucible and dried in oven at 100°C for overnight.
- The dried samples were then heated on a muffle furnace at 450°C for overnight to make a grey white ash.
- 15 ml of water was added to the crucible and dried on a hot plate until all the samples become grey white ash.
- 10 ml of M HCl were added to the crucible and dried on the hot plate.
- 30ml of 0.1M HNO_3 was added to the crucible and stayed overnight under a watch glass.
- The samples were then transferred in to a 100ml volumetric flask through a Whatman 42 filter paper and diluted with DDW to volume.
- Heavy metals concentration were quantified by atomic absorption spectrometer (AAS)

3.5 Questionnaire survey from the river bank communities

Questionnaire surveys have been done from 400 respondents to each river of Buriganga and Bongshi. In this study simple random sampling method was used. The study was done on the basis of data collection through questionnaire survey, observation and discussion with limited participation of the people of the study area. Sample of respondents were selected from the river bank community randomly both male and female and they were interviewed through structured questionnaire. Structured Questionnaire has prepared including causes of pollution, availability of fish, health hazards, use of river water and crop production etc.

Figure 3.15: Questionnaire surveys at Kholamora Boat Ghat and Sadarghat from the Buriganga river bank communities

3.6 Statistical analysis

Statistical analysis has been done using GENSTAT 12th Edition (VSN International, Hemel Hemel Hempstead, England) for water quality parameters including heavy metals.

3.7 Quality control

All chemicals and standards were AR or LR grade throughout the study period. If unexpected results were found during measurement repetition was conducted to confirm the results.

4. Data analysis and Interpretation of Results

Dissolve oxygen (DO), pH, Temperature (T), Total Dissolve Solid (TDS), Electrical conductivity (EC), Chloride, Hardness, Alkalinity, Ammonia (NH_3) and Carbon di-oxide (CO_2) were measured instantly at the field sites/locations. Heavy/toxic metals and Chemical oxygen demand (COD) were measured in the laboratory.

4.1 In situ test

Wide variations of water quality parameters were observed among the locations and the rivers. In-situ water quality parameters were compared with several standard levels set by different organizations like Worl Health Organization (WHO), Department of Environment (DoE), Food and Agricultural Organization (FAO) and Canadian Council of Ministers of the Environment (CCME). These standard values were fixed up for drinking, irrigation and aquatic life purposes. The following table represents the value of standard water quality parameters set by different organizations:

Table-4.1: The standard water quality value set by different organizations for different purposes

Parameter	For Drinking water		For Irrigation water	For Aquatic Life
	WHO (2011)	DoE (ECR, 1997)	FAO (1994)	CCME (2007)
Dissolve Oxygen (DO)	-	6 mg/l, *5mg/l or above	-	6.0–9.5 mg/l
pH	6.5–8.5	6.5–8.5	8.5	6.5–9.0
Temperature	-	20-30 ^{0}C	-	-
Total Dissolve Solid (TDS)	-	1000 mg/l	2000 mg/l	-
Electrical Conductivity (EC)	-	-	3000 μs/cm	-
Carbon-di-Oxide (CO_2)	-	-	-	-
Chloride	200 mg/l	150-600 mg/l	1063 mg/l	120 mg/l
Hardness	500 mg/l	200-500 mg/l	-	-
Alkalinity	-	-	-	-
Un-ionized Ammonia (NH_3)	0.2 mg/l	0.05 mg/l		0.019 mg/l

*5mg/l or above = For Aquaculture and Irrigation
* EC=2250 μS/cm for Irrigation DoE (ECR, 1997)

4.1.1 Dissolve oxygen (DO)

4.1.1.1 Spatial distribution of DO

The DO is the measurement of oxygen dissolved in water and available for fish and other aquatic life. It is an important water quality parameter for most chemical and biological processes in the water column and is essential for aquatic life. Aquatic organisms need dissolved oxygen to respire. It is necessary for the survival of fish, invertebrates, bacteria, and underwater plants. The DO is also needed for the decomposition of organic matter. The DO levels below 2 mg/l will not support fish and levels of 5 to 6 mg/l are usually required for most of the fish population. The average value of DO levels (6.5 mg/l) indicates the average quality of river water (APHA, 2005).

In natural and waste water, DO levels depend on the physical, chemical and biological activities in the water body (Huq and Alam, 2005). The effect of waste water released into a water body largely determined by discharge of oxygen demanding waste and oxygen balance of the system. The exchange of oxygen across the air, water interface depends upon temperature, partial pressure of gases, solubility, photosynthetic activity of plant and respiration by bacteria, plants and animals in the water (Krishnaram *et al.,* 2007). Temperature and salinity affect the dissolution of oxygen (Vijaya Kumar *et al.,* 2000). The rate of oxidation of organic matter increases as oxygen gets consumed and at higher temperature oxygen holding capacity of water decreases (Welch, 1952).

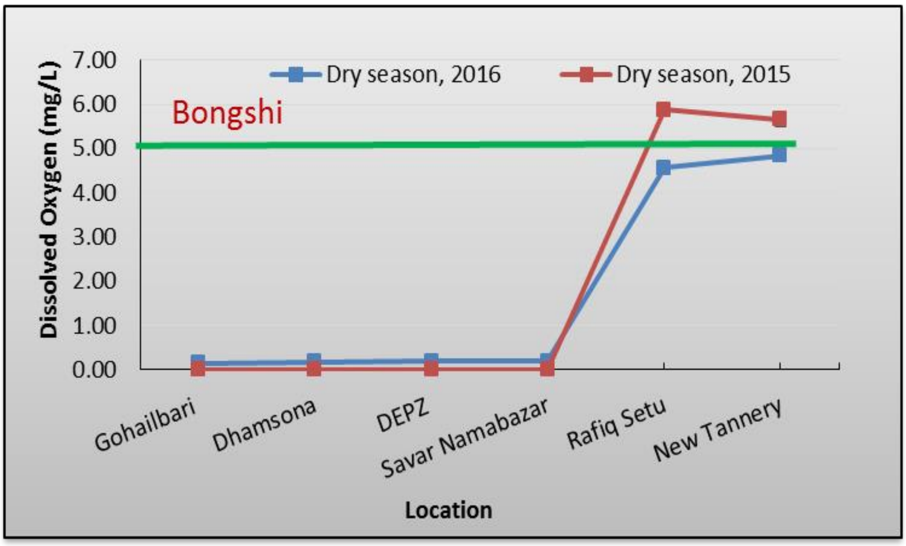


Figure 4.1.1: Dissolve Oxygen level in mg/L along the Bongshi at different locations in 2015 and 2016 in dry season. Bars represent standard error of the mean. Green line indicates DoE standard value (ECR, 1997) for Fisheries.

In Bongshi, DO levels for Gohailbari, Dhamsona, DEPZ and Saver Namabazar locations were found 0.14 mg/l, 0.17 mg/l, 0.20 mg/l and 0.19 mg/l respectively in dry season in 2016 (**Figure 4.1.1**) indicating extreme below than the DoE standard for fisheries (ECR, 1997) which is 5 mg/l and for sustaining aquatic life is 6.5–9.0 mg/l (CCME, 2007). Moreover, DO levels were similar in 2015 and there was no significant difference ($P\leq 0.05$) between 2015 and 2016 **(Figure 4.1.1)** except Rafiq setu and New Tannery locations. In dry season, Gohailbari location gets totally dried because of lack of water flow. Moreover, many waste disposal canals directly connected to this upstream of this river and these connections continuing at the left bank of this river which release easily oxidized industrial and municipal organic wastes. Therefore, the depletion of DO is likely to occur in these locations in dry season. It is obvious that in such low DO state, aquatic life such as fish can not survive (**Figure 4.1.2**) and thus the four reaches of this river to a dying stage. In this situation, without stopping further discharge of the oxygen demanding wastes, it will be impossible to recover the river water from its dying stage.

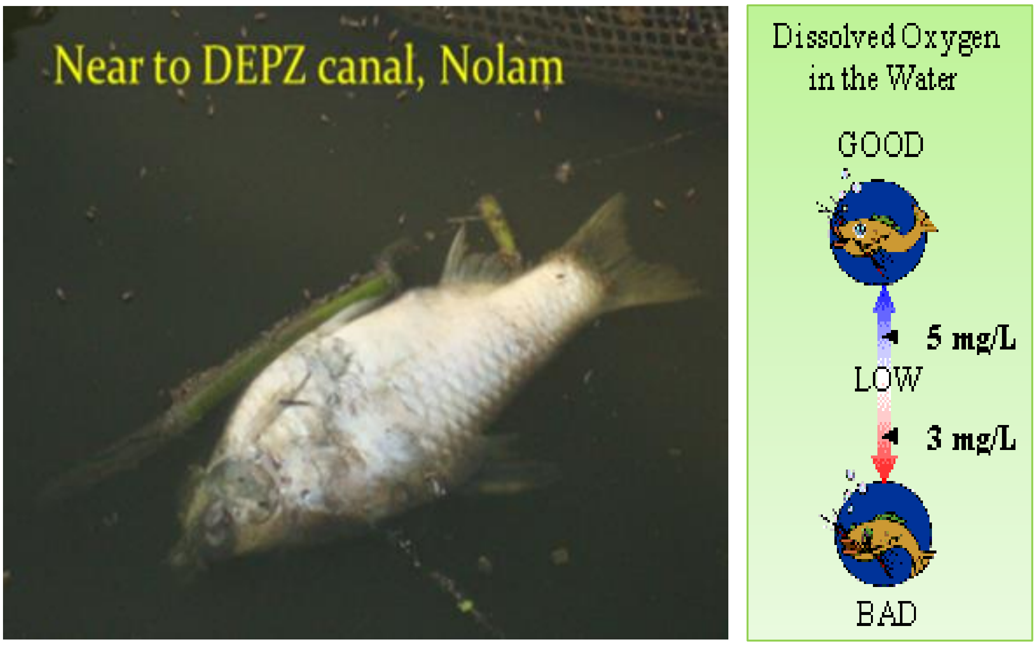


Figure 4.1.2: Fish has died adjacent to DEPZ canal in Bongshi. This photo has taken in March 2015 (left) and required DO for the survival of fish (right)

On the other hand, DO value were 4.57 and 4.87 mg/l in Rafiq Bridge and New tannery (Hemayetpur) areas in Bongshi which were above the DoE standard for fisheries (ECR, 1997) but not sufficient for aquatic life (CCME, 2007). The acceptable DO in this location possibly due to limited waste disposed from industry to the riverbank with high depth of water.

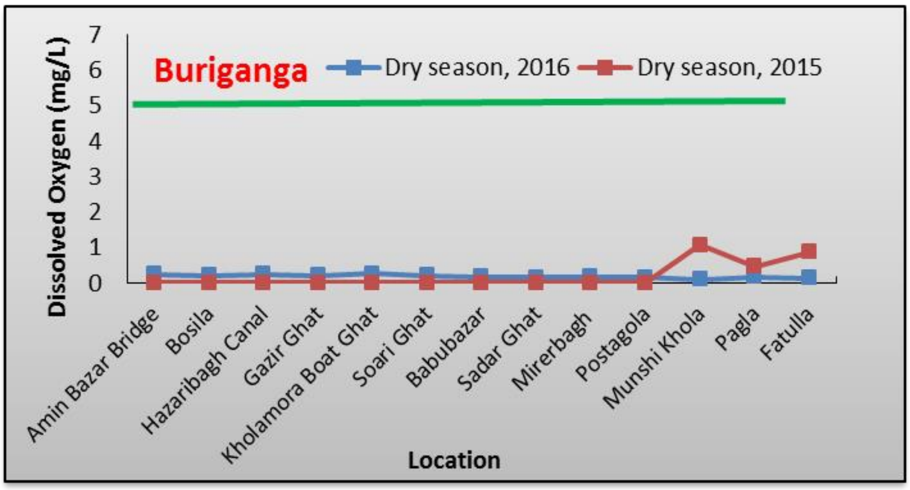


Figure 4.1.3: Dissolve Oxygen level in mg/L at different locations along the Buriganga in 2015 and 2016 in dry season. Bars represent standard error of the mean. Green line indicates DoE standard value (ECR, 1997) for for Fisheries.

Along the Buriganga DO levels were found approximately zero in dry season (**Figure 4.1.3**) indicating extremely adverse condition for aquatic environment. DO levels at Amin Bazar Bridge, Bosila, Hazaribagh Canal, Gazir Ghat, Kholamora Boat Ghat, Soari Ghat, Babubazar, Sadar Ghat, Mirerbagh, Postagola, Munshi Khola, Pagla and Fatulla locations were observed 0.24, 0.20, 0.24, 0.20, 0.27, 0.21, 0.16, 0.16, 0.18, 0.15, 0.10, 0.17and 0.14 mg/l respectively in dry season in 2016 (**Figure 4.1.3**). The DO levels were also approximately zero in 2015 except Munshikhola, Pagla and Fatulla

(**Figure 4.1.3**) though DO concentrations were far below of (WHO, 2001), DoE (ECR, 1997) and CCME (2007) standard level in these three locations.

DO concentration at different locations along the Karnatoli, Turag, Balu and Shitalakhaya rivers were below 0.5 mg/l (**Figure 4.1.4**) indicating severe oxygen shortages in these river environments. The DO concentrations at Begun Bari, Alfalah Char khet and Karnapara bridge in Karnoatoli river were 0.36, 0.49, 0.21 mg/l and at Pal para, Sluice gate, Birulia, Ashulia lake, Tongi Bridge and Termukh in Turag were 0.18, 0.21, 0.18, 0.22, 0.17, 0.13 mg/l, respectively (**Figure 4.1.4**). The DO concentrations in Balu at Ichapur, Beraid, Dakinpara and Chanpara were 0.15, 0.25, 0.45 and 0.20 mg/L and in Shitalakhaya at Nowapara, Demra Bridge, Kanchpur Bridge, Adamzi EPZ, Narayangonj Boat ghat, Shah cement factory (Muktergonj) were 0.19, 0.17, 0.18, 0.16, 0.14 and 0.19 mg/L, respectively **(Figure 4.1.4)**.

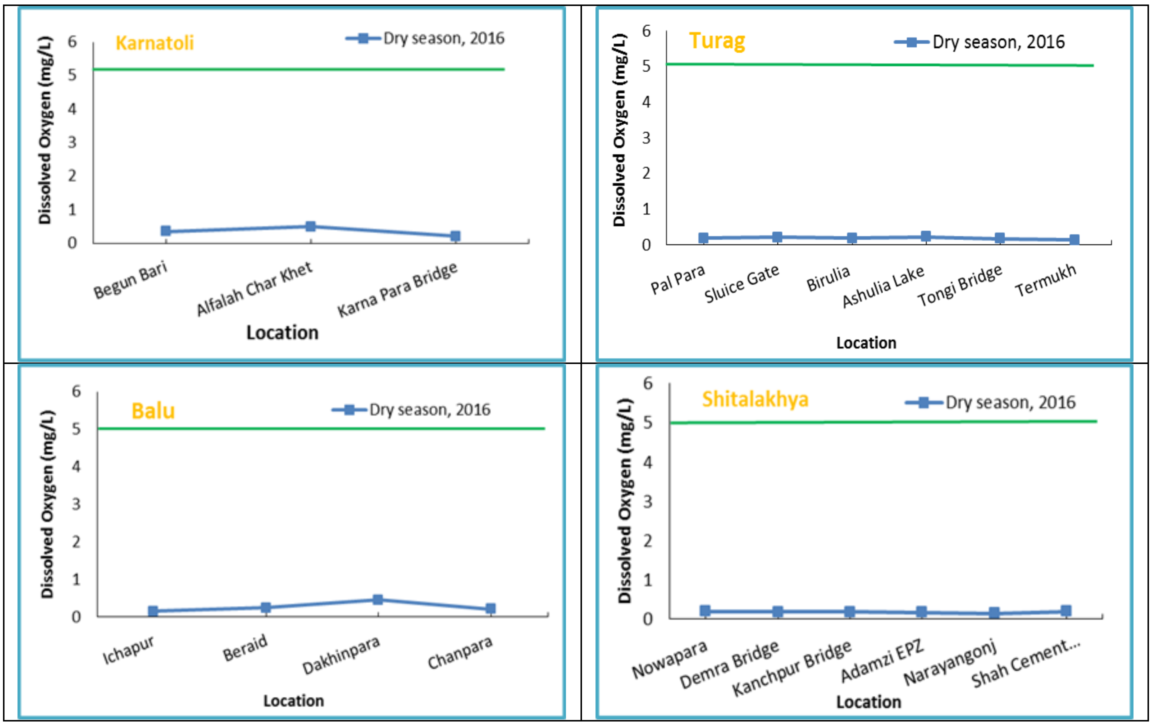


Figure 4.1.4: Dissolve Oxygen level in mg/l at different locations along the Karnatoli, Turag, Balu and Shitalakhaya in 2016 in dry season. Bars represent standard error of the mean. Green line indicates DoE standard value (ECR, 1997) for Fisheries.

4.1.1.2 Variation of DO between dry season and post rainy season

To observe the seasonal variation of water quality, in-situ test were done in post rainy season (October 2015) in four locations of Bongshi and four locations of Buriganga and five locations of Turag rivers. As expected, DO concentrations were much greater in post rainy season compared to dry season at Gohailbari, Dhamsona, Nolam (DEPZ) and New tannery locations (**Figure 4.1.5**). In post rainy season, the concentration of DO was increased due to cumulative effects of increasing water flow from upstream with higher wind velocity, runoff, rainfall, and the resultant of river water mixing. DO values in four particular reaches were 5.5 mg/l to 4.1 mg/l in (**Figure 4.1.5**) in post rainy season indicating acceptable level for fisheries (ECR, 1997) but not for aquatic life (CCME, 2007).

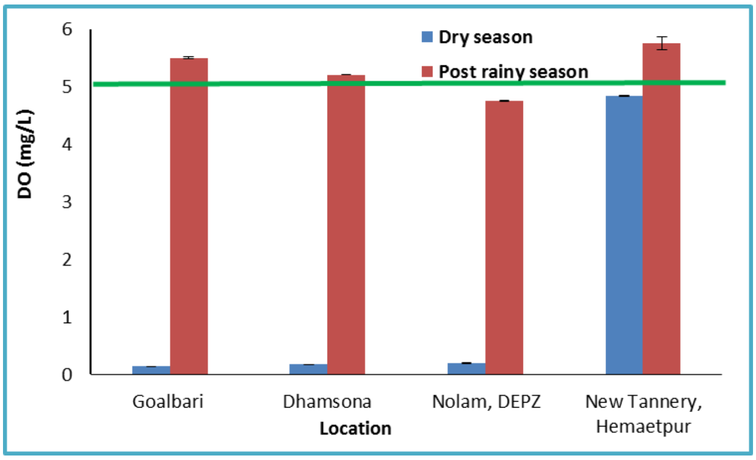


Figure 4.1.5: Variation in Dissolve Oxygen level in mg/l between dry season and post rainy season at different locations along the Bongshi. Bars represent standard error of the mean. Green line indicates DoE standard value (ECR, 1997) for Fisheries.

Even though DO concentration was greater in post rainy season compared to dry season in Buriganga, DO level only varied from 0.2 to 2.82 mg/l at Amin bazar, Hazaribagh, Soari ghat and Fatulla (**Figure 4.1.6**). These DO concentrations were far below the standard level provided by DoE (ECR, 1997) indicating shortage of oxygen for fish and other aquatic life even in post rainy season too. However, the DO values were gradually decreased from upstream to downstream of the river possibly due to the greater water flow along with carrying waste material from tanneries and municipality which consumed oxygen.

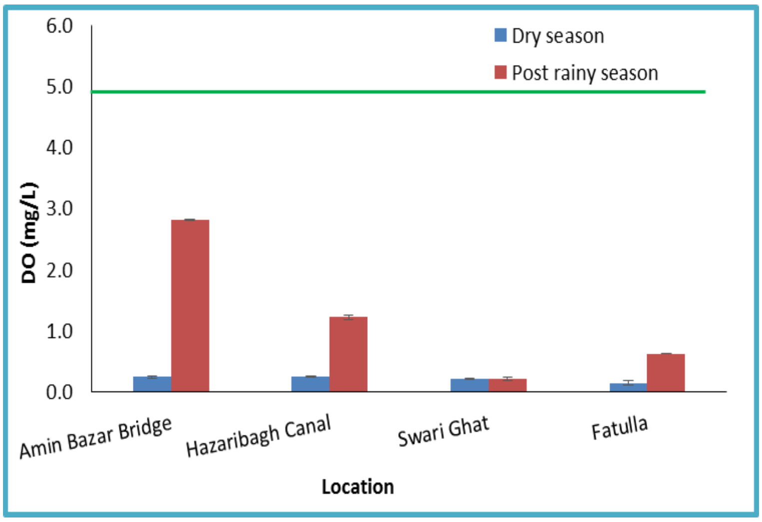


Figure 4.1.6: Variation in Dissolve Oxygen level in mg/l between dry season and post rainy season at four locations along the Buriganga. Bars represent standard error of the mean. Green line indicates DoE standard value (ECR, 1997) for for Fisheries.

Similar to Bongshi and Buriganga, DO level was greater in Post rainy season compared to dry season at five locations in the Turag. DO concentration in post rainy season were 2.6, 4.0, 4.1, 3.9 and 1.5 mg/l at Pal para, Sluice gate, Birulia, Ashulia lake and Tongi bridge, respectively (**Figure 4.1.7**). These DO levels were lower than the standard limit set by DoE (ECR, 1997) and CCME (2007).

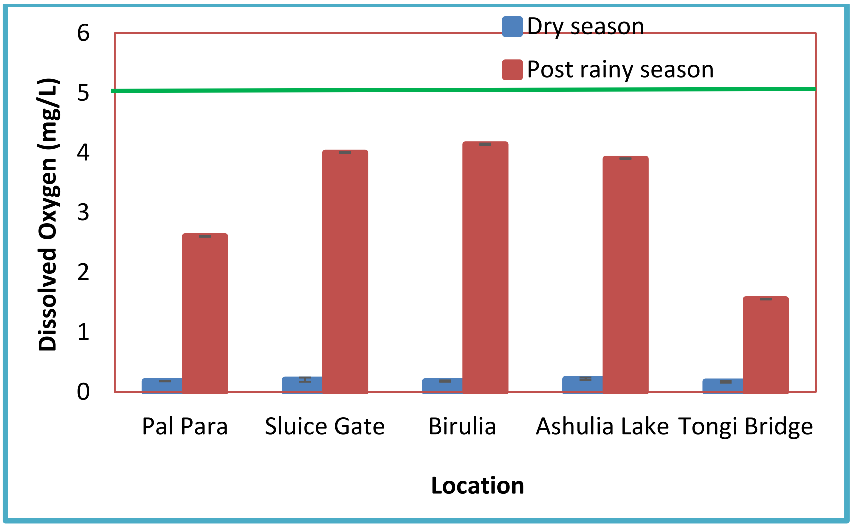


Figure 4.1.7: Variation in Dissolve Oxygen level in mg/l between dry season and post rainy season at five locations along the Turag. Bars represent standard error of the mean. Green line indicates DoE standard value (ECR, 1997) for fisheries.

4.1.1.3 Variation of DO concentration among the rivers

The comparison of average DO concentration among the Bongshi, Buriganga, Karnatoli, Balu, Turag, and Shitalakhaya rivers in dry season is shown in **Figure 4.1.8**. Among the six rivers, the average concentration of DO in Bongshi is greater than that of the other rivers even though DO concentrations among all the rivers were far below the DoE standard (ECR, 1997) and CCME (2007). DO levels at six (6) locations varied from 0.14 to 4.84 mg/l in dry season in Bongshi and the average value of DO was 1.67 (SD±1.17) mg/l. The higher SD value is due to difference in DO concentrations among the locations in Bongshi. DO values of Buriganga river at 15 locations of water samples were varied from 0.14 to 0.27 mg/l and the average value of DO was 0.18 (SD±0.05) in mg/l. DO values at six (6) locations of Turag river water samples varied from 0.14 to 0.22 in mg/l and the average value of DO was 0.18 (SD±0.03) in mg/l. DO values of 4 locations of Balu river water samples were varied from 0.13 to 0.45 mg/l and the average value of DO is 0.26 (SD±0.13) in mg/l. DO values of 6 locations of Shitolakhaya river water samples were varied from 0.15 to 0.21 mg/l and the average value of DO is 0.18 (SD±0.02) mg/l. DO values of 3 locations of Karnotoli river water samples were varied between 0.20 to 0.49 mg/l and the average value of DO is 0.35(SD±0.14) in mg/l.

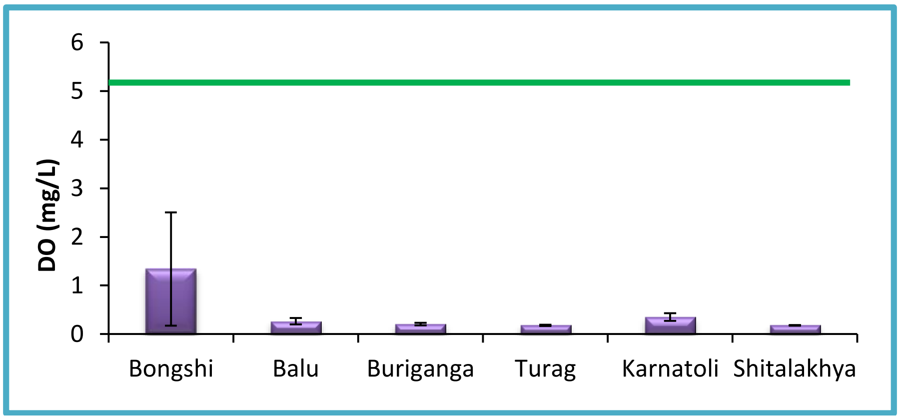


Figure 4.1.8: Variation in average Dissolve Oxgen level in mg/L among the six rivers around Dhaka in dry season. Green line indicates DoE standard value (ECR, 1997) for fisheries. Bar indicates variation in DO among the location of each river.

In Post rainy season, the average DO concentrations of three rivers were greater than the dry season (**Figure 4.1.9)**. The DO concentration of Bongshi river water was varied from 4.56 to 5. 76 mg/l and the average DO concentration was 5.31 (SD±0.43). DO values of Buriganga river water samples varied from 0.20 to 2.82 mg/l in post rainy season and the average value of DO is 1.21 (SD±1.15) in mg/l in post rainy season. DO values of Turag river water samples varied from 1.55 to 4.14 mg/l in post rainy season and the average value of DO is 2.72 (SD±1.62) mg/L in post rainy season. It is observed that in the Post rainy season, the DO concentration was the lowest in Buriganga followed by Turag and Bongshi (**Figure 4.1.9**) indicating industrial organic effluents and sewage load enters to in order of Buriganga> Turag> Bongshi. DO concentration was far below the recommended value set by different organizations for different purposes in Buriganga and Turag too (**Table 4.1).**

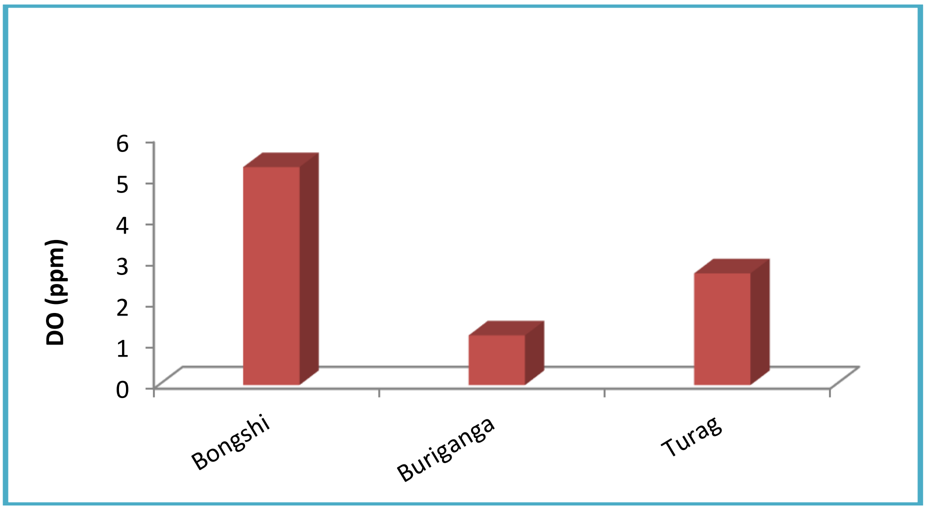


Figure 4.1.9: Variation in Dissolve Oxygen level in mg/L among the three rivers around Dhaka in post rainy season.

The Severe shotage of DO was observed in six rivers sorrounded by Daka in both dry season and post rainy season because of industrial organic effluents as well as sewage load. The results ensured that the amount of dissolved oxygen in six rivers was extremely low for aquatic environment and the rivers surrounding Dhaka lost the normal quality in both dry season and post rainy season.

4.1.2 pH

4.1.2.1 Spatial distribution of pH

The acidic or alkaline condition of the water is expressed by pH. It is an important indication of water quality and provides information about various geochemical equilibrium. Higher value of pH is normally associated with high photosynthetic activity in water (Hujare, 2008) and natural waters are alkaline due to presence of sufficient quantities of carbonates (Trivedy and Goel, 1984). The higher values of pH represent that there is high chloride, bicarbonate, carbonate etc. that means the water is alkaline. The DoE (ECR, 1997) standard of this parameter is 6.5 to 8.5.

The pH values varied from 7.69 to 8.77 in 2016 and 7.46 to 8.76 in 2015 in dry season at different location's of Bongshi (**Figure 4.1.10**). The highest value was observed at Dhamsona and lowest was Saver Namabazar in both 2015 and 2016. The highest value in Dhamsona possibly due to CO_3 containing wastes discharges through Dhamsona canal which produce hydroxyl ion (OH^-). Saver Namabazar is the dumping ground of solid waste (rotten vegetables and others) which may contains N compounds. The lower pH value at Saver Namabazar is likely that these wastes decomposed and may nitrification take place. However, the pH levels are within the permissible limit set by DoE (ECR, 1997) for fisheries. Hoque et al., (2012) observed slightly greater pH value (8.0 to 8.8) than this study at eight locations in Bongshi in winter.

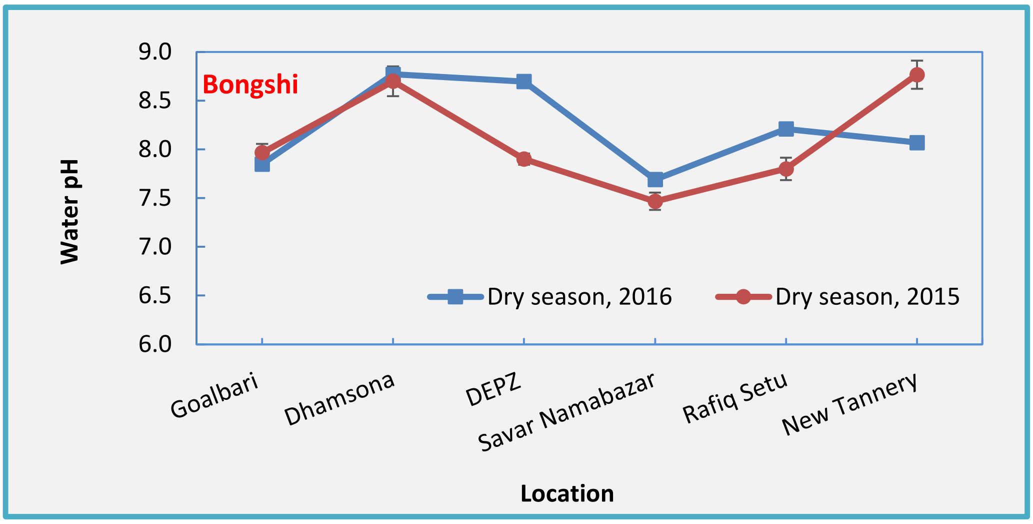


Figure 4.1.10 Level of pH along the Bongshi at different locations in 2015 and 2016 in dry season. Bars represent standard error of the mean.

The pH values varied from 6.77 to 7.85 in 2016 and 7.30 to 8.10 in 2015 in dry season at different location's of Buriganga (**Figure 4.1.11**). The highest value of pH was observed at Potagola and lowest was Amin Bazar Bridge in 2015 and for the year 2016 the highest value was observed at Fatullah and lowest was Bosila.

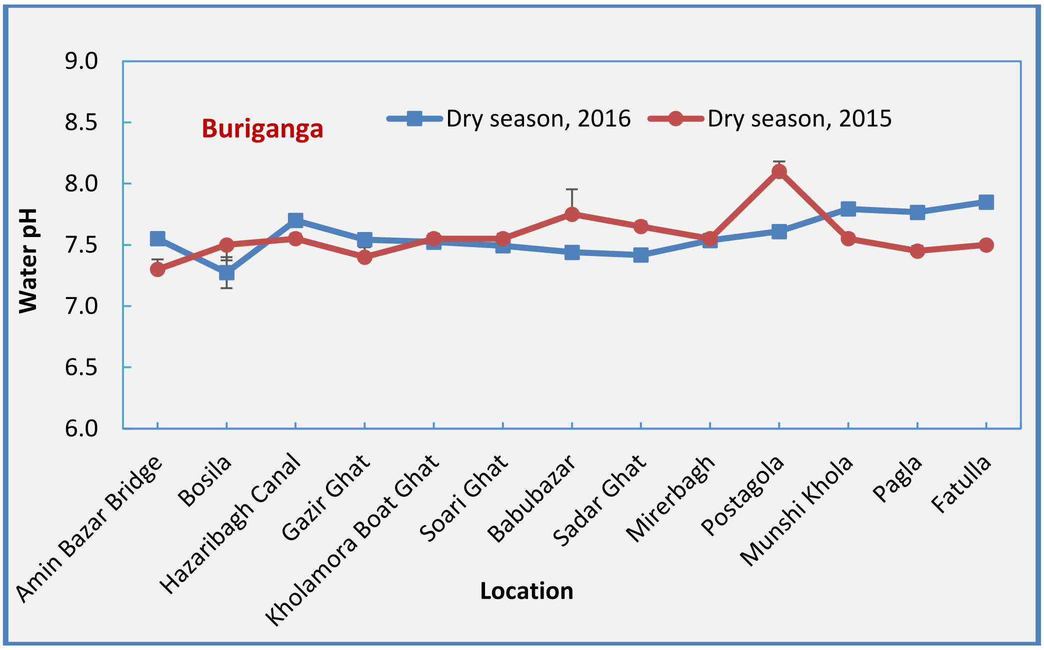


Figure 4.1.11 Level of pH along the Buriganga different locations in 2015 and 2016 in dry season. Bars represent standard error of the mean.

The pH level at different places in Karnatoli, Turag, Balu and Shitalakhaya in dry season has shown in **Figure 4.1.12**. The pH varied from 7.52 to 8.12 in Karnatali, 7.28 to 8.20 in Turag, 7.24 to 7.64 in

Balu and 7.54 to 8.23 in Shitalakhya indicating the pH of these rivers water is moderately alkaline. The pH levels are within the permissible limit set by DoE (ECR, 1997) for fisheries, irrigation and driniking water.

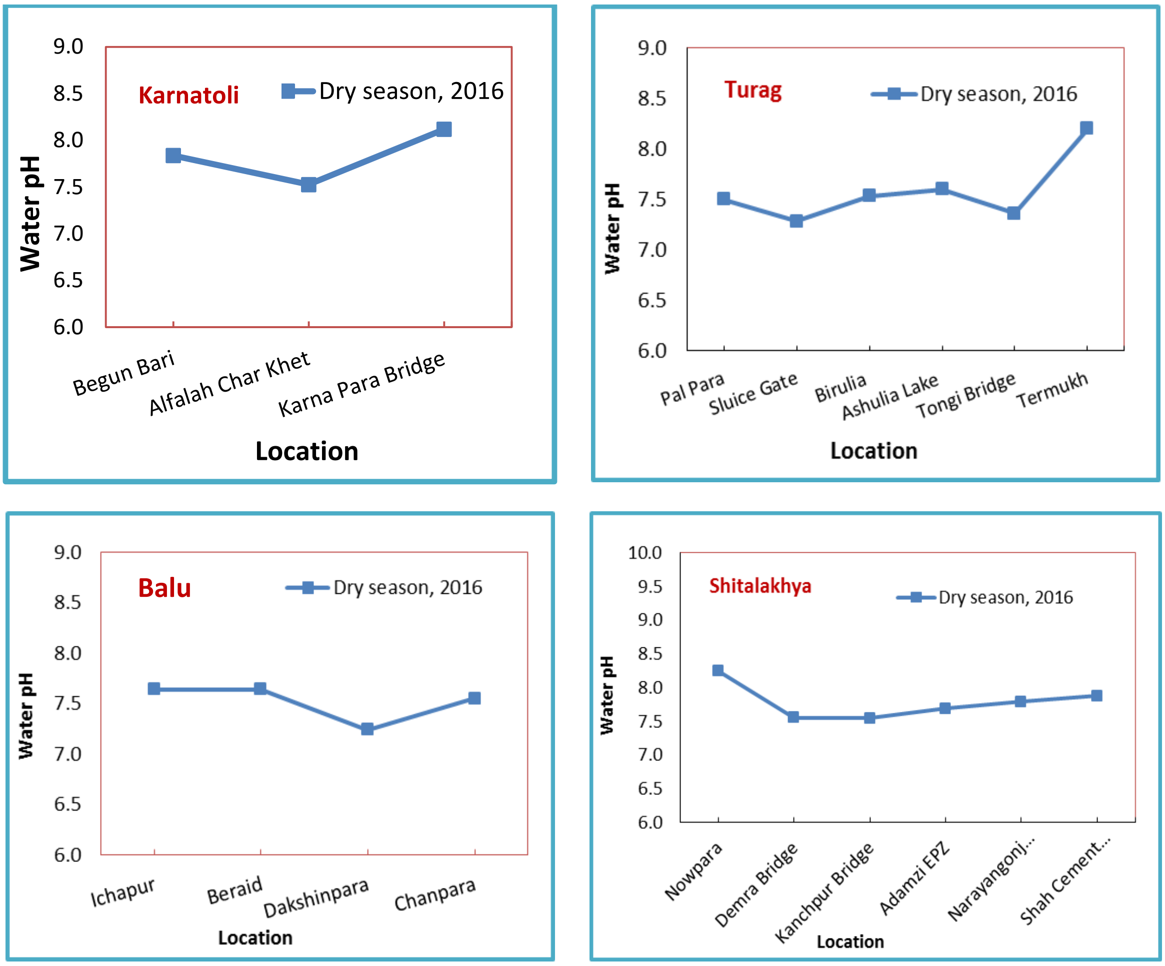


Figure 4.1.12: pH level at different locations along the Karnatoli, Turag, Balu and Shitalakhya in 2016 in dry season. Bars represent standard error of the mean.

4.1.2.2 Variation of pH between dry season and post rainy season

The pH level was higher in dry season than that of the post rainy season in both Bongshi and Buriganga rivers at four locations of each river. The pH level fluctuated from 7.85 to 8.77 among the locations in dry season in Bongshi. The maximum pH variation was observed at Dhamsona and the lowest was Gohailbari. At Dhamsona pH was found 8.77 in dry season and 7.33 in post rainy season whereas at Gohail Bari pH was found 7.85 in dry season and 7.42 in post rainy season. However, there was no significant difference (*P*< 0.05) in pH among the locations in post rainy season. Higher depth of water along with greater water flow may be responsible for lower and stable pH in the post rainy season.

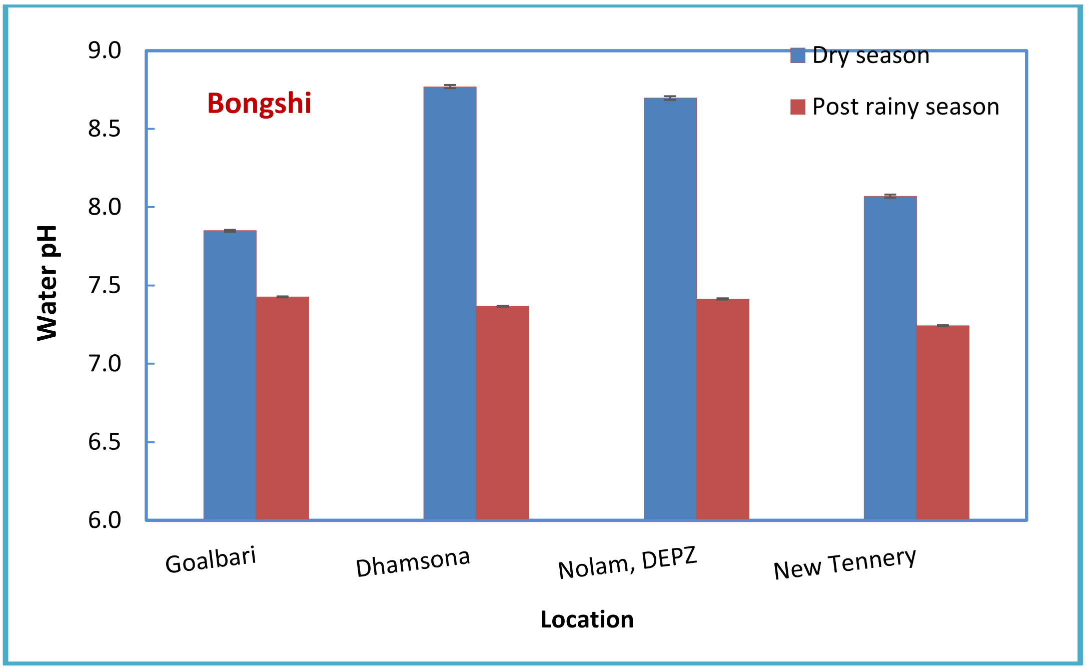


Figure 4.1.13: Variation in pH level between dry season and post rainy season at four locations along the Bongshi. Bars represent standard error of the mean.

As of Bongshi the pH was observed lower in post rainy season compared to dry season in Buriganga too. The pH varied from 7.15 to 7.3 at Amin Bazar Bridge, Hazaribagh, Soari Ghat and Fatulla in post rainy season whereas varied from 7.49 to 7.85 in dry season for the same locations. The difference in pH variation between dry season and post rainy season in Buriganga was lower than that of the Bongshi. Similar to Bongshi, pH was relatively stable from upstream to downstream.

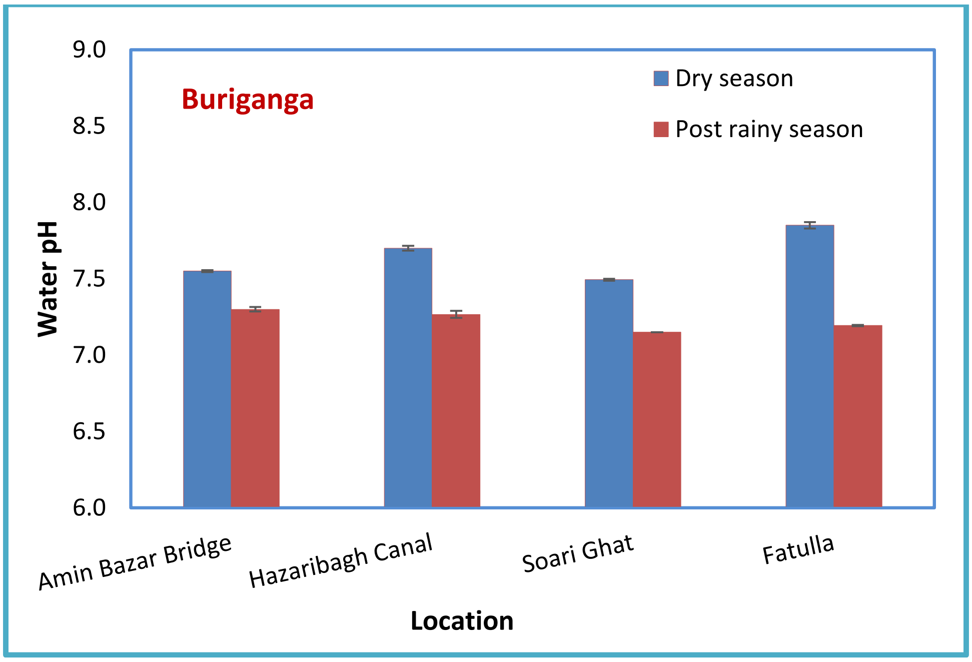


Figure 4.1.14: Variation in pH level between dry season and post rainy season at four locations along the Buriganga. Bars represent standard error of the mean.

4.1.2.3 Variation of pH among the rivers

The average water pH among the Buriganga, Bongshi, Karnatoli, Turag, Balu, and Shitalakhaya in dry season is shown in **Figure 4.1.15**. The average pH was lowest in the Balu and the highest in Bongshi. The average pH were 8.35 (SD±0.44), 7.54 (SD±0.27), 7.58 (SD±0.33), 7.52 (SD±0.19), 7.83 (SD±0.30) and 7.78(SD±0.26) in Bongshi, Buriganga, Turag, Balu, Karnatoli and Shitalakhya, respectively.

In post rainy season, the average water pH among the Buriganga, Bongshi, and Turag is shown in **Figure 4.1.16**. The average pH was lower in post rainy season compared to dry season among these three rivers. The average pH were 7.76(SD±0.09), 7.23(SD±0.07) and 7.39(SD±0.12) in the Bongshi, Buriganga and Turag, respectively.

The acceptable range of pH for irrigation water is 6.5 to 8.5 according to DoE (ECR, 1997), FAO, WHO (2011). The acceptable range of pH for fish culture is 6.5 to 8.0 (Meade, 1998; ADB, 1994; ECR, 1997). The acceptable range of pH for drinking water is 6.5 to 8.5, recreational water is 6.0 to 9.5, industrial water is 6.0 to 9.5 and livestock water is 5.5 to 9.0 (ADB, 1994). The pH standard limits for inland surface water is 6.5 to 8.5 (EQS, 1997). The study found that the pH values of all sampling sites were within the standard limit.

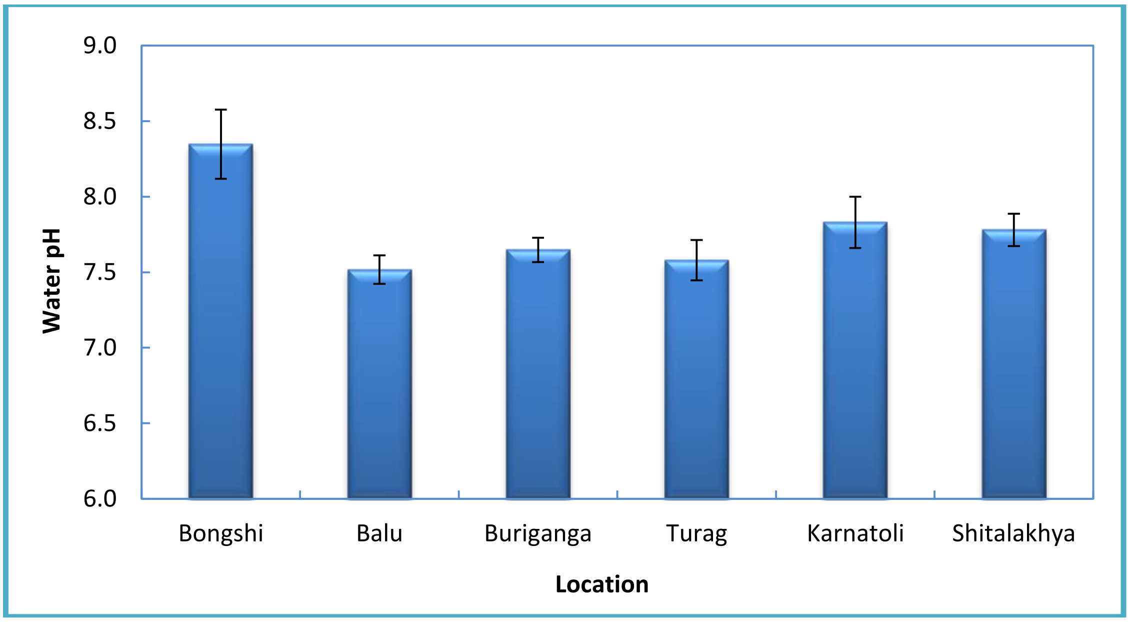


Figure 4.1.15: Variation in average pH among the six rivers around Dhaka in dry season. DoE standard value (ECR, 1997) of pH is 6.5 to 8.5 for fisheries. Bar indicates variation in pH among the locations of each river.

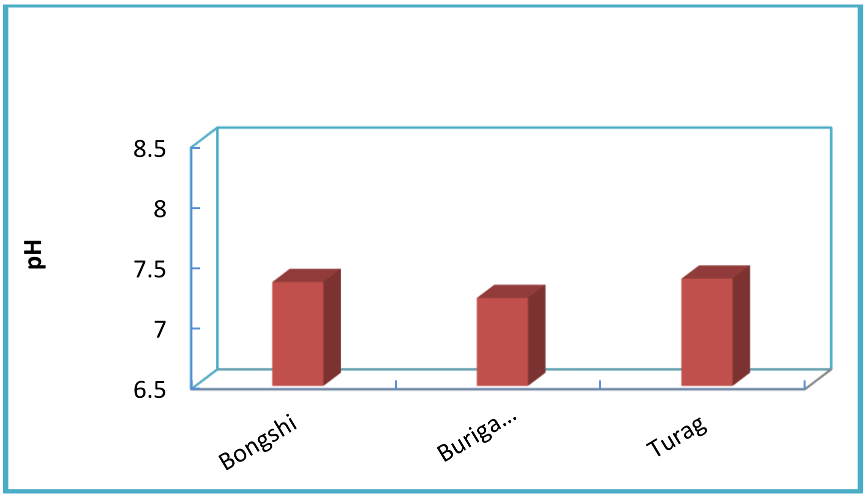


Figure 4.1.16: Variation in average pH among the three rivers around Dhaka in post rainy season.

4.1.3 Temperature

Temperature of water may not be as important in pure water because of the wide range of temperature tolerance in aquatic life, but in polluted water, temperature can have profound effects on dissolved oxygen (DO) and biological oxygen demand (BOD). The fluctuation in river water temperature usually depends on the season, geographic location, sampling time, circulation of air, temperature of effluents entering the stream and depth of water and its flow rate.

The temperature was found 30 ^{0}C, 31.8 ^{0}C, 28.60 ^{0}C, 25.5 ^{0}C, 26.30 ^{0}C, and 24.0 ^{0}C at Gohailbari, Dhamsona, Nolam (DEPZ canal), Saver Namabazar, Rafiq Bridge and New Tannery in dry season in Bongshi (**Figure 4.1.17)**. The temperature was gradually decreased from upstream to downstream. This could be reason that hot industrial waste directly disposed from factory to the rivers or there may be possibility of heat producing compounds exists in the disposed wastes as industrial waste disposed relatively lower from upstream to downstream. The temperature of Bongshi River in dry season complies with the standard valu set by DoE except at Dhamsona (**Table 4.1**). At Dhamsona temperature was 31.8 ^{0}C which is slightly greater than the standard temperature as the range of standard temperature is 20-30 ^{0}C.

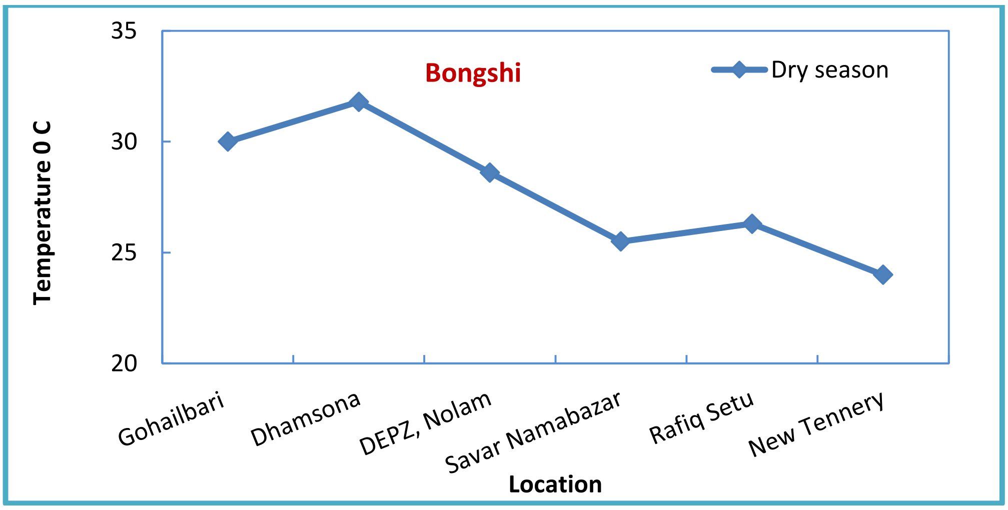


Figure 4.1.17: Variation in water temperature in ^{0}C at different locations in Bongshi River in dry season.

Water temperature at 14 locations in dry season in Buriganga is shown in **Figure 4.1.18**. The highest temperature was found 23.7⁰C at Hazaribagh and the lowest was 22.20 ⁰C at Dharmoganj. The water temperature was relatively stable from upstream to downstream in dry season. The suitable temperature range of water is 20 - 30 ⁰C (**Table 4.1**).

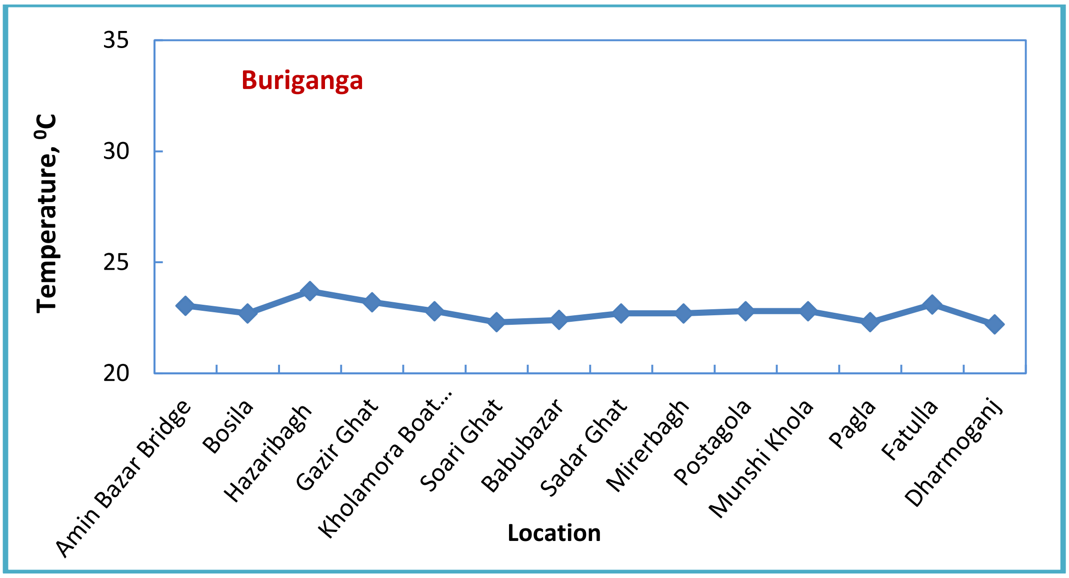
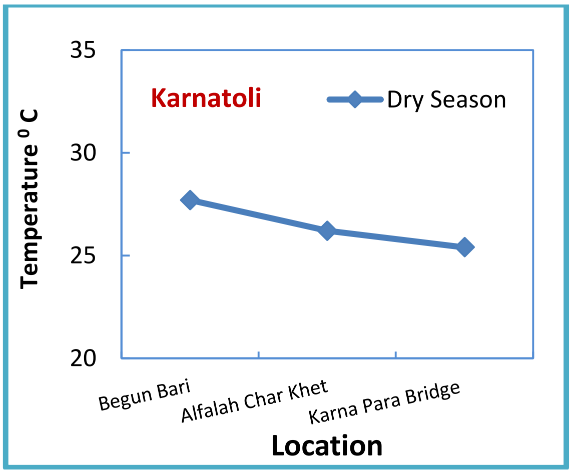
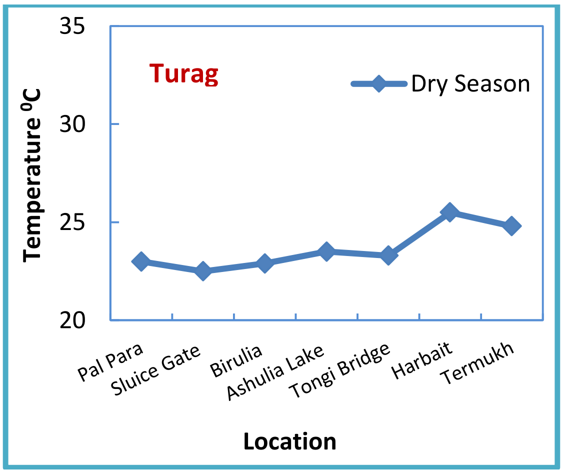
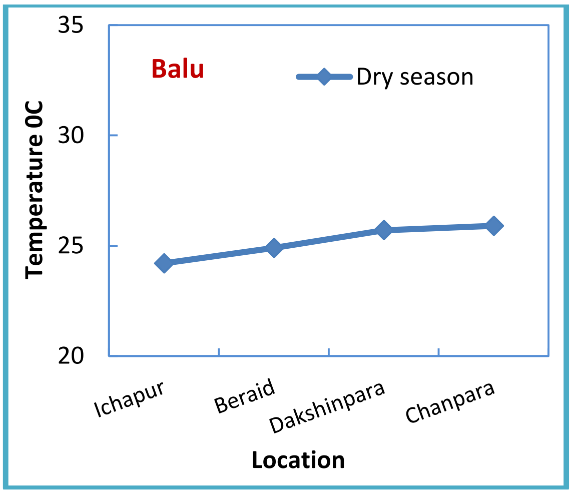


Figure 4.1.18: Variation in water temperature in ⁰C at different locations in Buriganga River in dry season.

The water temperature at Begunbari, Alfalaf char khet and Karnapara Bridge was 27.70, 26.20, 25.40 ⁰C, respectively in Karnatoli in dry season. In Turag, the water temperature at Pal para, Sluice gate, Birulia, Ahulia lake, Tonghi Bridge, Harbait and Termukh was 23.0, 22.50, 22.90, 23.5, 23.30, 24.80, 24.20, 24.90, 25.70, 25.90, 27.70, 26.20, and 25. 40 ⁰C, respectively in dry season. In Balu, the water temperature at Ichapur, Beraid, Dakhinpara and Chanpara was 24.20, 24.90 and 25.70, ⁰C, respectively in dry season. The temperature in Shitalakhya was 25.30, 24.60, 24.60, 25.90, 25.70 and 24.20 ⁰C at Nowpara, Demra Bridge, Kanchpur Bridge, Adamzi EPZ, Narayangonj Launch Terminal and Shah cement factory, Mukhterpur, respectively.







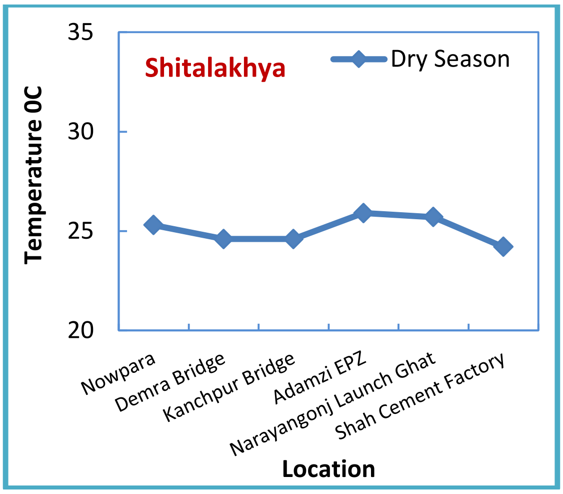


Figure 4.1.19: Variation in water temperature in ^{0}C at different locations in Karnatoli, Turag, Balu and Shitalakhya River in dry season.

4.1.3.1 Variation of Temperature among the rivers

The average water temperature among the Buriganga, Bongshi, Karnatoli, Turag, Balu, and Shitalakhaya in dry season is shown in **Figure 4.1.20**. The average temperature was lowest in the Buriganga and the highest in Bongshi. The average temperature was 23.74 °C (SD±2.94), 22.77 °C (SD±0.41), 23.33 °C (SD±0.80), 25.18 °C (SD±0.78) 26.43 °C (SD±1.17) and 25.05 °C (SD±0.68) in Bongshi, Buriganga, Turag, Balu, Karnatoli and Shitalakhya, respectively.

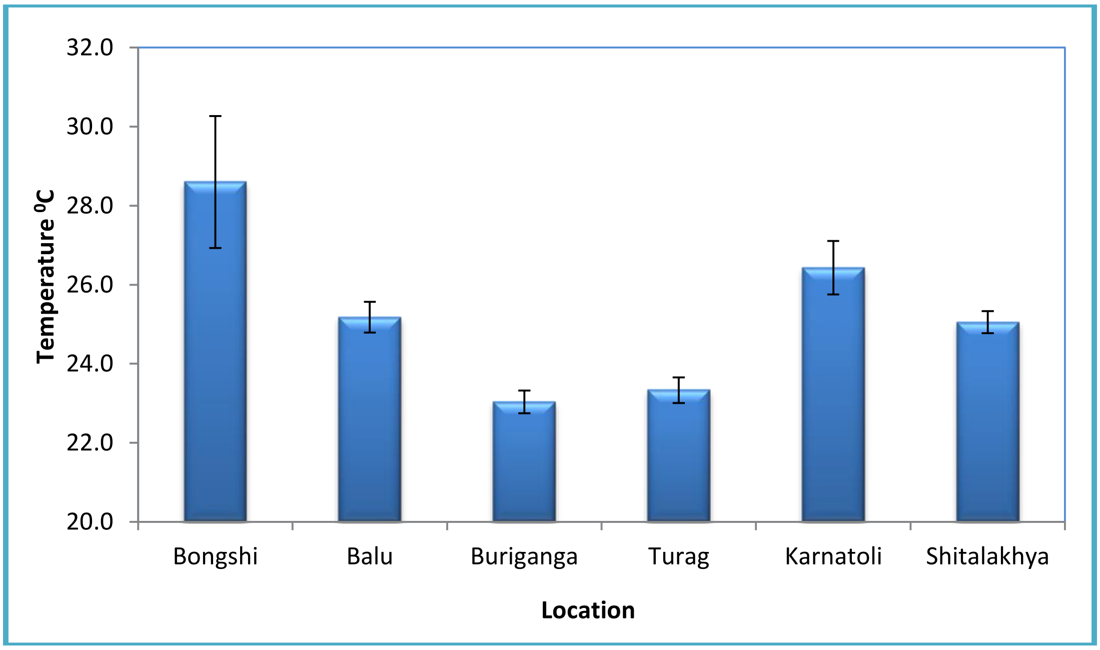


Figure 4.1.20: Variation in average water temperature in ^{0}C among the six rivers in dry season.

In post rainy season, the average water pH among the Buriganga, Bongshi, and Turag is shown in **Figure 4.1.21**. The average temperature was greater in post rainy season compared to dry season among these three rivers. The average temperature were 29.68 °C (SD±0.35), 30.10 °C (SD±0.64) and 29.62 °C (SD±0.41) in the Bongshi, Buriganga and Turag, respectively.

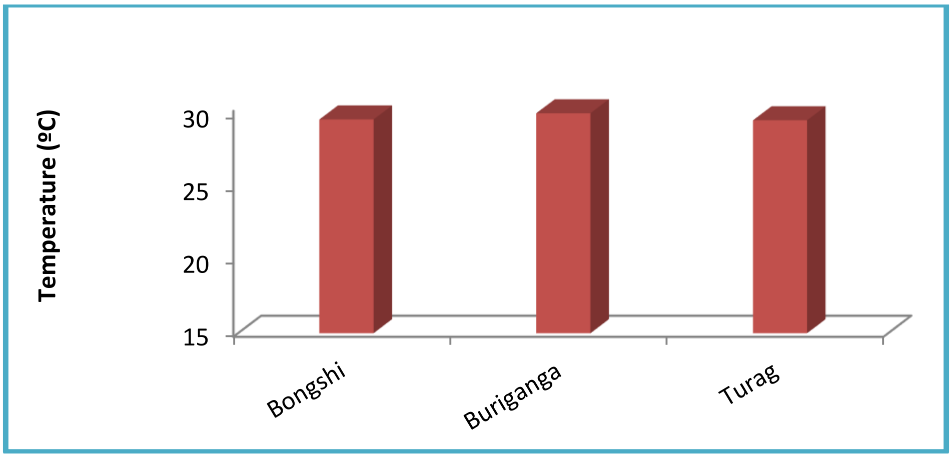


Figure 4.1.21: Variation in average water temperature in ^{0}C among Bongshi, Buriganga and Turag in Post rainy season.

4.1.4 Electrical conductivity (EC)

The electrical conductivity (EC) is usually used for indicating the total concentration of charged ionic species in water. Its value depends on the concentration and degree of dissociation of the ions as well as the temperature and migration velocity of the ion in the electric filed. The electrical conductivity measures the concentration of ions in water. The concentration of ions depends on the environment, movement and sources of water. The soluble ions in the surface water originate primarily from solution of rock materials. While freshwater sources have a low conductivity and seawater has a high conductivity, there is no set standard for the conductivity of water. Instead, some organizations and regions have set limits on total dissolved solids for bodies of water. This is because conductivity and salinity can differ not only between oceans and freshwater, but even between neighboring streams. If the surrounding geology is different enough, or if one source has a separate inflow, conductivity values of neighboring water bodies will not be the same.

In dry season the highest EC value was found at Nolam, DEPZ (2120 µS/cm) and the lowest at New Tannery (656 µS/cm) of Bongshi river **(Figure 4.1.22)**. The extreme EC value at Nolam, Dhamsona and Goalbari locations indicate that the river receive industrial and sewage effluents that contains high ionic concentrations which is eventually detrimental for the aquatic life of the river. The EC value was much lower at Rafiq setu and New tannery area because the flow and depth of water which may cause the dilution of the ionic concentration of water.

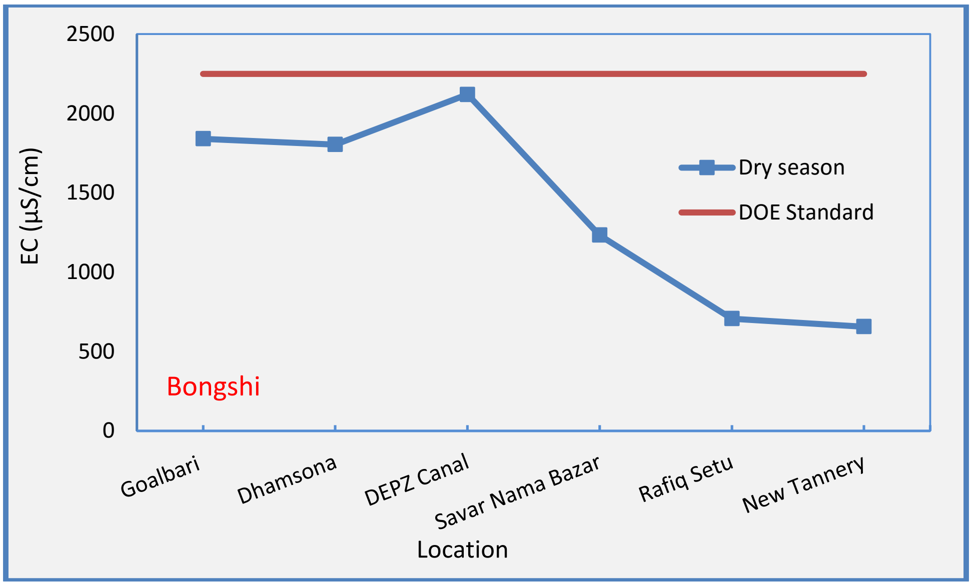


Figure 4.1.22: Electrical conductivity in µS/cm along the Bongshi at different locations in dry season. Bars represent standard error of the mean. Red line indicates DoE standard value (ECR, 1997) for irrigation.

Electrical conductivity was relatively stable from upstream to downstram of 13 locations in the Buriganga in dry season **(Figure 4.1.23)**. The EC value was highest in Bosila (1094 µS/cm) and lowest in Fatulla (877.33 µS/cm) location in the Buriganga river. The EC values were 990.67, 1094.00, 1082.00, 1059.67, 1079.00, 1043.67, 1052.00, 1044.67, 1041.00, 1091.00, 1022.33, 941.67, 877.33 µS/cm at Amin Bazar Bridge, Bosila, Hazaribagh, Gazir Ghat, Kholamora Boat Ghat, Soari Ghat, Babubazar, Sadar Ghat, Mirerbagh, Postogola, Munshi Khola, Pagla and Fatulla, respectively.

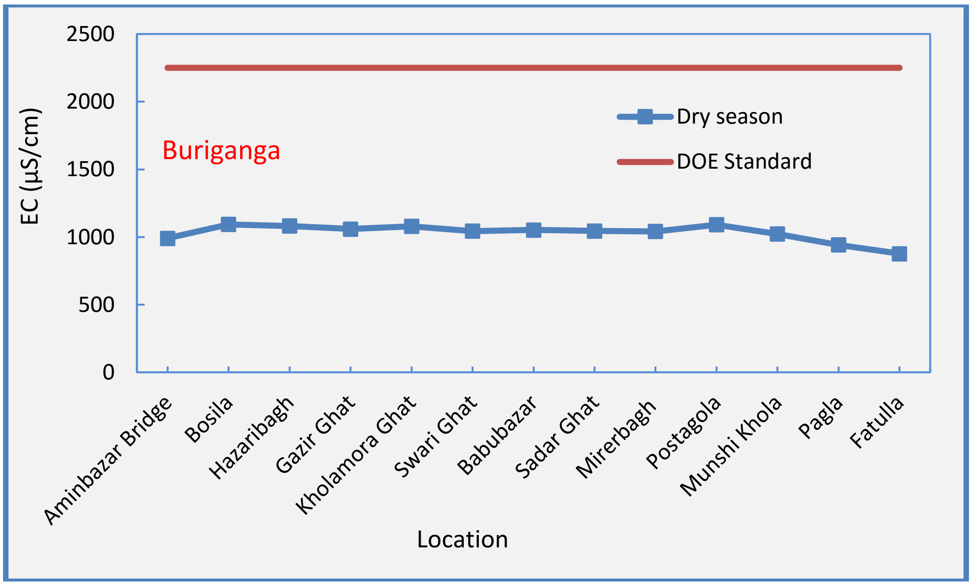


Figure 4.1.23: Electrical conductivity in µS/cm along the Buriganga at different locations in dry season. Bars represent standard error of the mean. Red line indicates DoE standard value (ECR, 1997) for irrigation.

The EC values of different locations of Karnatali, Turag, Balu and Shytalakhya in dry season were shown in **Figure 4.1.24**. The highest EC value was 1634.33 µS/cm at Termukh point and the lowest value of EC at Beri Bhad 872.67 µS/cm in Turag river. Ichapur had highest EC value (1042 µS/cm) and Chanpara showed lowest EC value (905.67µS/cm) for the Balu River. The EC value did not differ significantly among the locations of Karnatali River. However, Adamzi EPZ location has highest EC value (983.33µS/cm) and Shah Cement Factory location showed lowest EC value (595.67) for the Shitalakhya River in dry season.

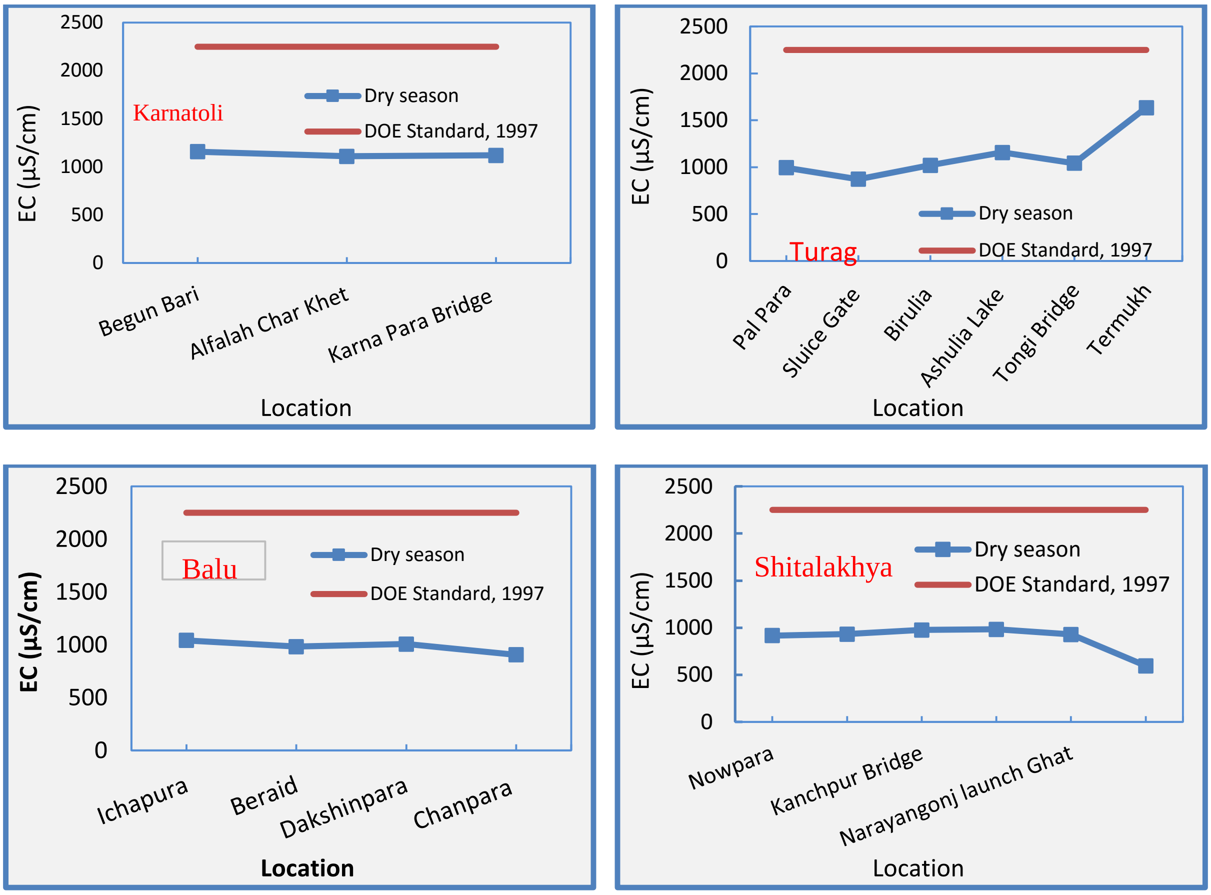


Figure 4.1.24: EC level at different locations along the Karnatoli, Turag, Balu and Shitalakhya in 2016 in dry season. Bars represent standard error of the mean. Red line indicates DoE standard value (ECR, 1997) for irrigation.

4.1.4.1 Variation of EC between dry season and post rainy season

Dry season has more EC value than post rainy season is likely to occur as at post rainy season water becomes diluted. The EC values were found 1840.0 µS/cm, 1804.3 µS/cm, 2119.7 µS/cm, 656.3 µS/cm at Goalbari, Dhamsona, DEPZ and New tannery locations, respectively. The extreme EC value at DEPZ, Dhamsona and Goalbari locations indicate that the river receive industrial and sewage effluents that contains high ionic concentrations which is eventually detrimental for the aquatic life of the river. However, the EC value was much lower in post rainy season than the dry season as the flow of the river increases which may cause the dilution of the salinity of the water. Less sampling were done in post rainy season due to low salinity exist in post rainy season. The EC value did not differ significantly among several locations of Bongshi River in post rainy season. The EC value was found 230.0 µS/cm to 282.67 µS/cm in post rainy season at all locations (**Figure 4.1.25)**. In this study, a positive relation was found between EC and TDS, the EC concentration increased with increasing the TDS. However, lowest EC value (277.33µS/cm) was found in Ashuli Lake and highest EC value was found at Termukh point (453µS/cm) in the Turag River. No sampling was done in Balu, Karnatali and Shitalakhya river in post rainy season.

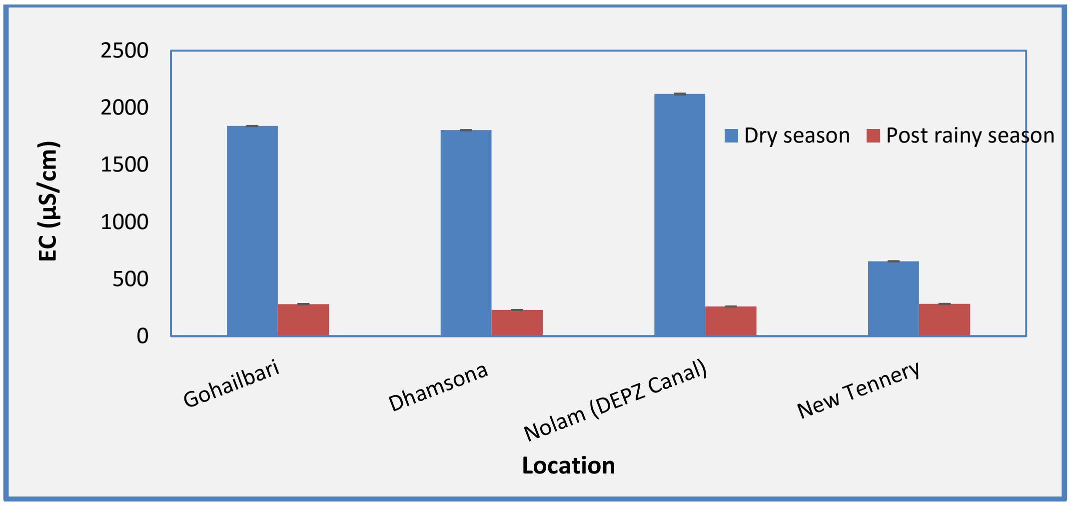


Figure 4.1.25: Variation in EC level in µS/cm between dry season and post rainy season at four locations along the Bongshi. Bars represent standard error of the mean.

Simila to Bongshi, EC concentration was much lower in post rainy season in the Buiriganga compared to dry season (**Figure 4.1.26)** because of high water flow in Buriganga in post rainy season. With increasing water flow, water was diluted and reduced salinity. EC concentration was only varied from 272 to 306 µS/cm and there was no significant difference among the locations in post rainy season. The EC value was varied from 877.33 µS/cm to 1094 µS/cm at four locations in the Buriganga river which was approximately 4 times greater than post rainy season.

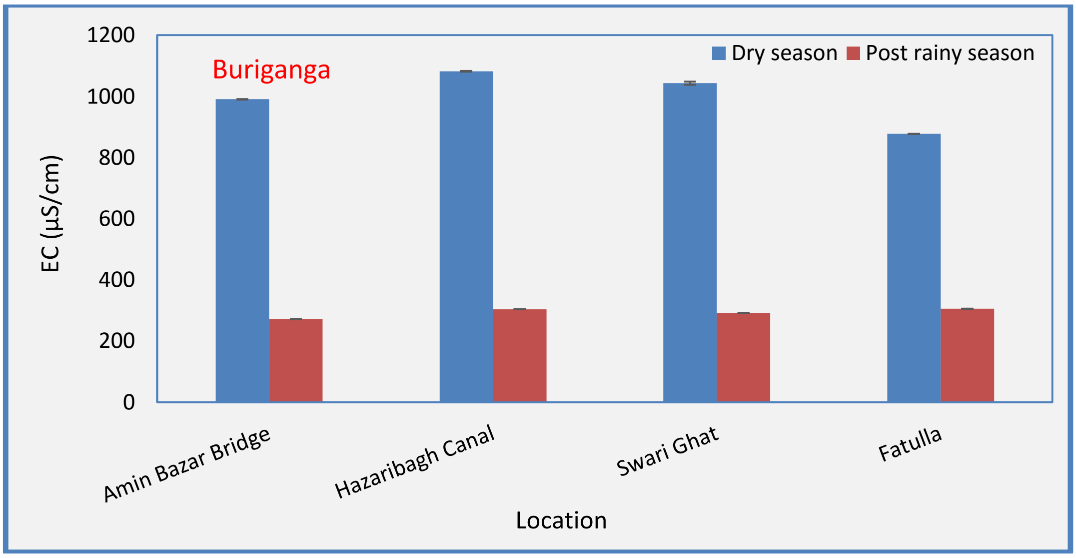


Figure 4.1.26: Variation in EC level µS/cm between dry season and post rainy season at four locations along the Buriganga. Bars represent standard error of the mean.

4.1.2.2 Variation of EC among the rivers

The average Electric Conductivity of six rivers in dry season is shown in **Figure 4.1.27**. The EC in the Bongshi river water samples ranged from 656.33 to 2119.67 µS/cm in dry season and average value of pH was found as 1605.08 µS/cm (SD±648.03). The Electric Conductivity in the Buriganga river water samples varied from 877.33 to 1082.0 µS/cm and average value was found as 998.42 µS/cm (SD±88.90) in dry season. In dry season the EC concentration in the Turag river water samples varied from 872.997 µS/cm to 1634.33 µS/cm and average value was 1120.33 µS/cm (SD±267.85).

The Electrical Conductivity in the Balu river water samples varied from 905.67 µS/cm and average value was 984.84(SD±57.90) in dry season. The Electric Conductivity in the Shitolakhya river water samples varied from 595.67 to 983.33 µS/cm and average value was 888.78(SD±146.08) in dry season. The Electric Conductivity in the Karnotoli river water samples varies from 1109.0 to 1159.0 µS/cm and average value was 1129.0(SD±26.46) in dry season. The EC concentration was found following the order as Bongshi > Karnatoli > Turag > Buriganga > Balu > Shitalakhaya in dry season.

The EC in the Bangshi river water samples were varied from 230.0 to 282.67 µS/cm in post rainy season and average value was 263.75 µS/cm (SD±24.5) shown in **Figure 4.1.28**. The Electric Conductivity in the Buriganga river water samples varied from 272.00 µS/cm to 306.0 µS/cm in post rainy season and average value was 293.5 µS/cm (SD±15.61). The Electric Conductivity in the Turag river water samples varied from 277.33 µS/cm to 497.00 µS/cm in post rainy season and average value was 349.22 µS/cm (SD±98.74).

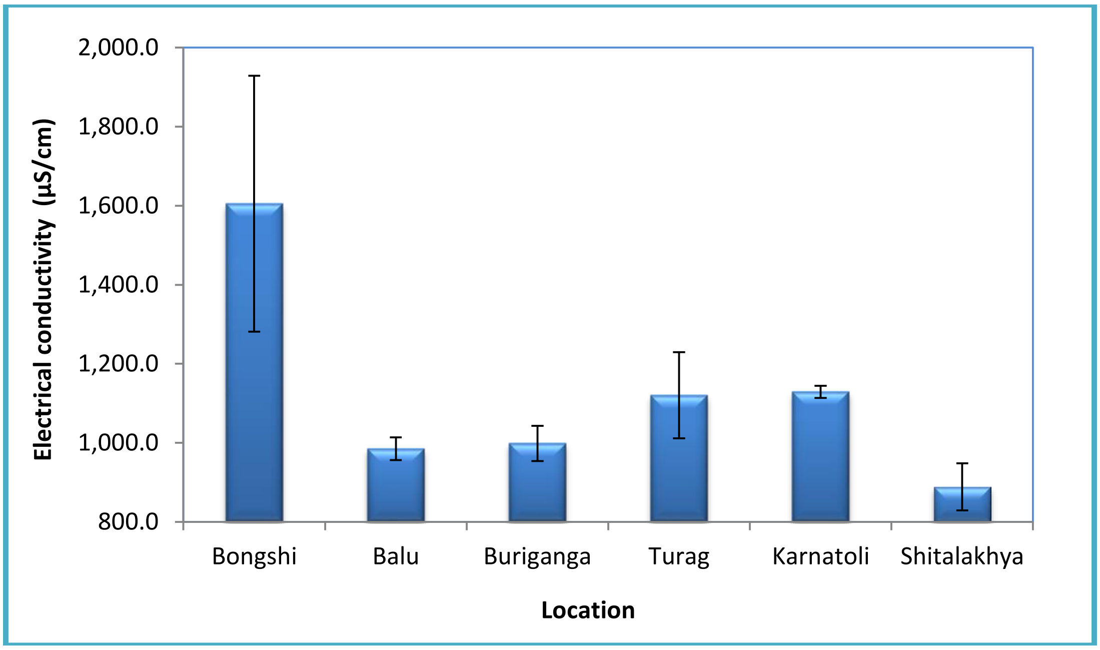


Figure 4.1.27: Variation in average Electrical conductivity in µS/cm among the rivers in dry season. Bar indicates variation in EC among the locations of each river.

The standard of electrical conductivity of water for irrigation purposes set by DoE is 2250 µS/cm at 25 °C (ECR, 1997). The acceptable range of EC for recreational water is 500 µS/cm, irrigation is 750 µS/cm and aquaculture is 800 µS/cm to 1000 µS/cm (ADB, 1994). From the study, the measured EC of all water samples in post rainy season was lower than acceptable range. In the post rainy season, the flow of the river increases which may cause the dilution of the TDS and salinity of the water, while in dry season, the flow of the river decreases which results in increase of EC. From the result it was observed that the EC value increased with increasing TDS.

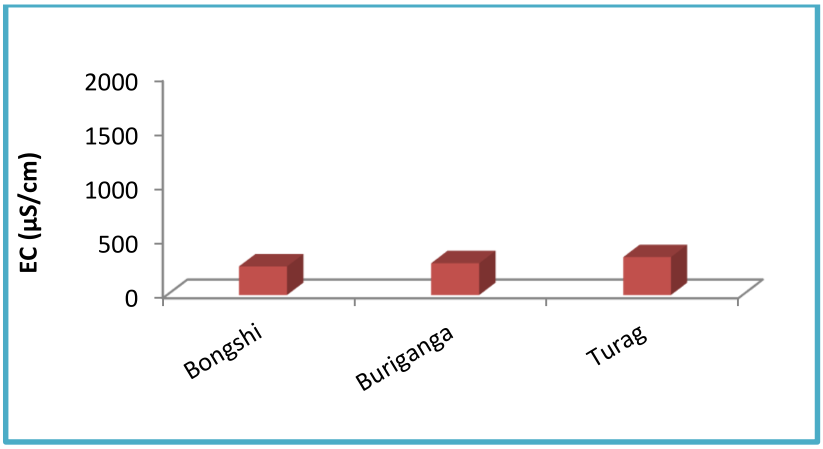


Figure 4.1.28: Variation in average Electrical conductivity in µS/cm among the three rivers in post rainy season.

4.1.5 Total Dissolved Solids (TDS)

The total dissolved solid (TDS) mainly indicates the presence of various kinds of minerals like ammonia, nitrite, nitrate, phosphate, alkalis, sulphates and metallic ions etc. which are comprised both colloidal and dissolved solids in water. Water that contains too much dissolve matter is not suitable for common uses.

TDS in the six locations of Bongshi varied from 321.7 mg/l to 1082.0 mg/l in dry season (**Figure 4.1.29)**. The highest TDS concentration was observed at Nolam and the lowest was at New Tannery. The TDS values were much higher than the standard limit set by 500 mg/l set by DoE (ECR, 1997) at Goalbari, Dhamsona & Nolam DEPZ locations but at Rafiq setu and New tannery locations TDS was found within the standard limit.

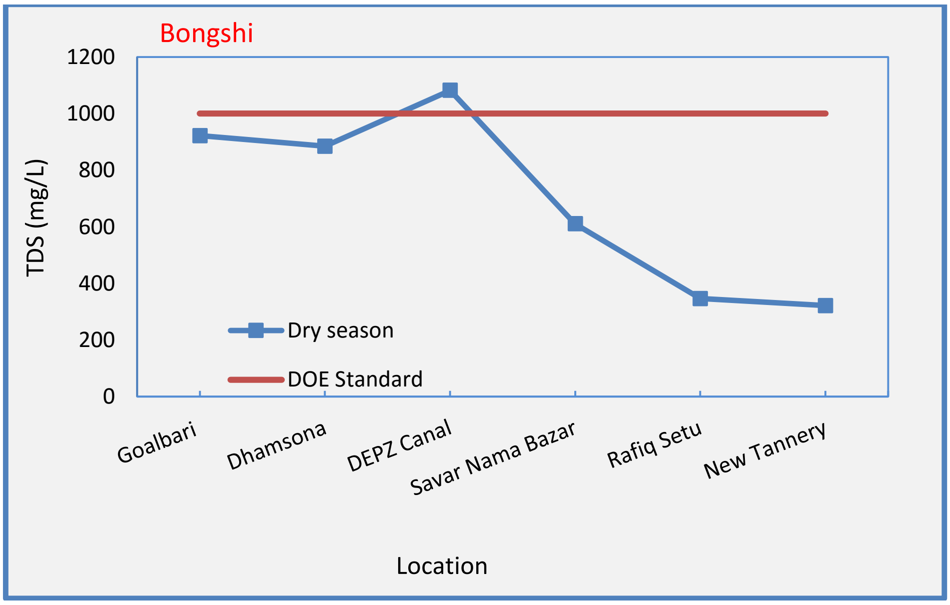


Figure 4.1.29: Total dissolve solid in mg/l along the Bongshi at different locations in dry season. Bars represent standard error of the mean. Red line indicates DoE standard value (ECR, 1997) for driniking water.

TDS varied from 430.0 to 543.67 mg/l at 13 locations along the Buraganga river in dry season (**Figure 4.1.30)**. The TDS was relatively stable from Basila to Postogola is likely to occur as surrounding of this locations receives continuously waste from tanneries, solid and municipal wastes. TDS was gradualy decreased from Postogola to Fatulla due lower wastes inter to these locations and higher flow of water. At Postogola TDS was 538.67 mg/l in this study whereas Saifullah, *et al.* (2012) was observed 641 mg/l TDS at Postagola which is slightly greater than this study.

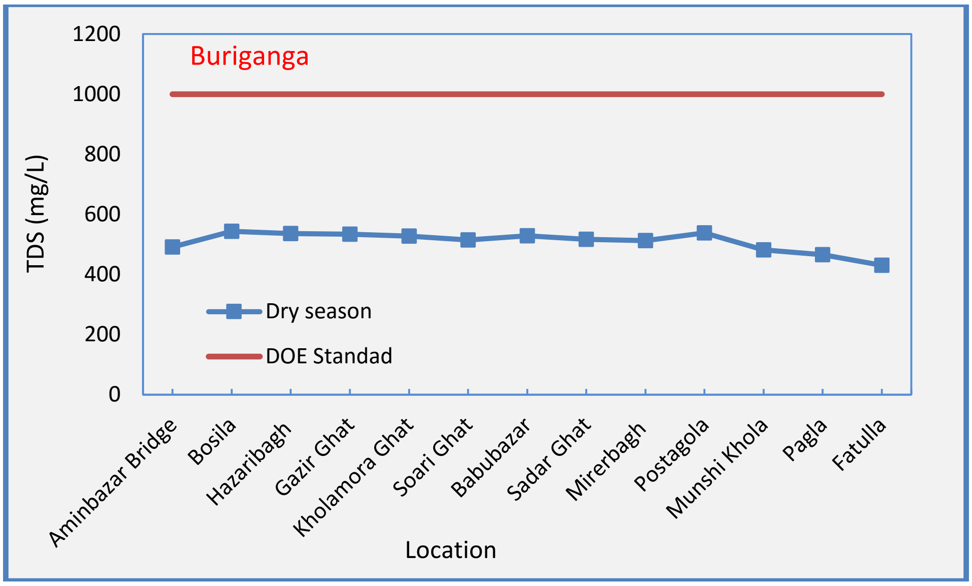
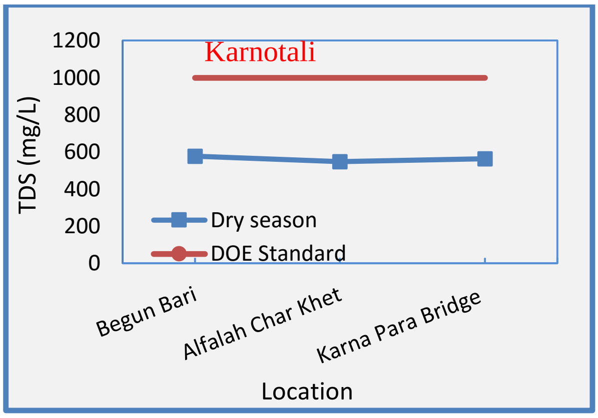
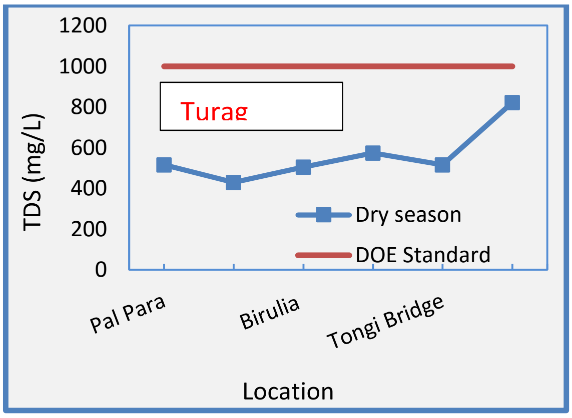
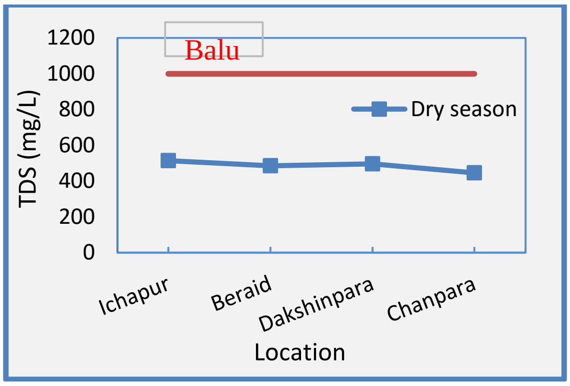


Figure 4.1.30: Total dissolve solid in mg/l along the Bongshi at different locations in dry season. Bars represent standard error of the mean. Green line indicates DoE standard value (ECR, 1997) for dirniking water.

TDS at different location along the Karnatoli, Turag, Balu and Shitalakhya rivers in dry season is shown in **Figure 4.1.31.** TDS was observed 516.33, 429.0, 504.0, 574.0, 516.0, 822.0 mg/l at Pal Para, Sluice gate, Birulia, Ashulia Lake, Tonghi Bridge and Termukh, respectively in dry season in Turag. Along the Balu river, TDS varied from 446 to 513 mg/l at Ichapur, Beraid, Dakshinpara and Chanpara. TDS was 577, 548, 563 mg/l at Begun Bari, Alfalah and Karna Para Bridge in Balu. TDS was relatively stable from Nowpara to Narayangonj Launch Terminal and after that it was significantly decreased at adjacent to Shah Cement Factory at Muktergonj in Shitalakhaya. This location (adjacent to Shah Cement Factory) is the confluence of Meghna river and the data has taken during tidal flow that diluted the water. As a result, the TDS at at this location has reduced significant*ly*.







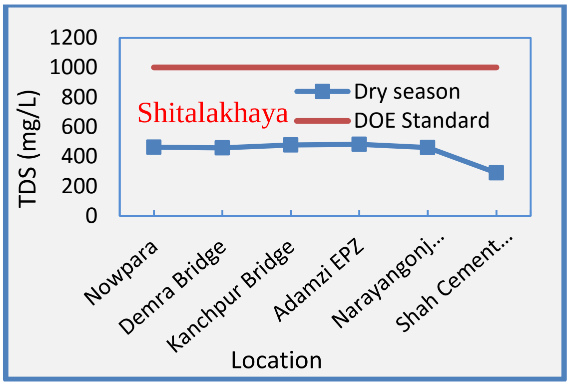


Figure 4.1.31: Total dissolve solid in mg/L along the Karnatoli, Turag, Balu and Shitalakhya rivers at different locations in dry season.

AS expected, TDS was much lower in post rainy season compared to dry season and it was significantly differed between dry season and post rainy season. TDS was only varied from 109.23 to 134.90 mg/l at four locations in post rainy season which are within standard limit. TDS were also not significantly differed (*P* < 0.05) among the locations in post rainy season in Bongshi. However, TDS were significantly differed among the locations in dry season.

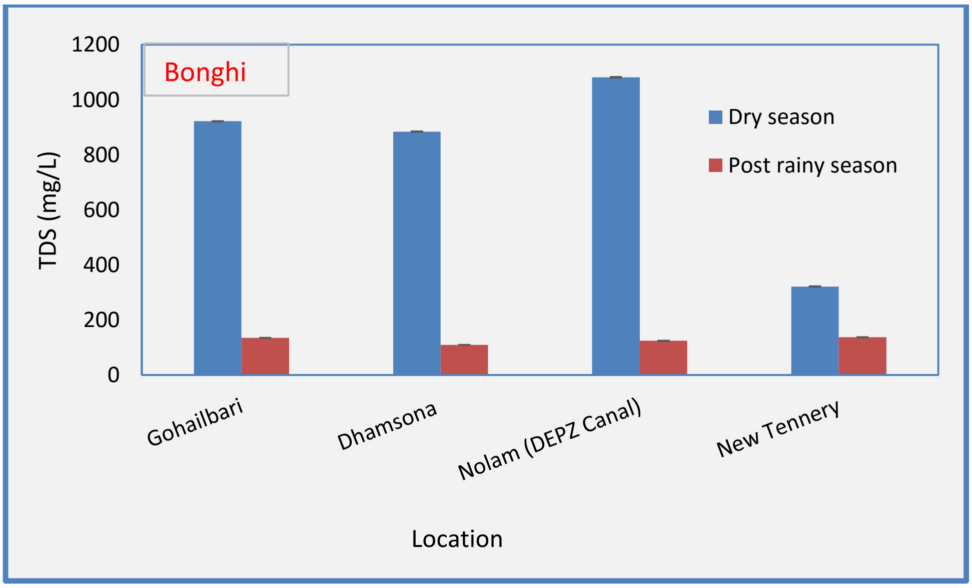


Figure 4.1.32: Variation in TDS level in mg/l between dry season and post rainy season at four locations along the Bongshi. Bars represent standard error of the mean.

The average TDS all of the rivers is shown in (**Figure 4.1.33**). The TDS of all collected water samples of Bongshi river were within the range of 321.67 to 1082.0 mg/l in dry season with average values of 802.59 (SD±331.84). In dry season the TDS of all water samples of Buriganga river were within the range of 430.0 to 536.0 mg/l with keeping average value of 493.0 mg/l (SD±45.8). The TDS of all collected water samples of Turag river were within the range of 429.0 to 822.0 mg/l in dry season with average value of 560.22 mg/l (SD±136.37). The TDS of all collected water samples of Balu river were within the range of 446.0 to 513.0 mg/l in dry season with an average values of 485.0 mg/l (SD±28.44). The TDS of all water samples of Shitolakhaya river were within the range of 289.67 to 482.33 mg/l in dry season with an average value of 438.83 mg/l. The TDS of all collected water samples of Karnotoli river were within the range of 548.0 to 577 mg/l in dry season with an average values of 562.67 mg/l (SD±14.5).

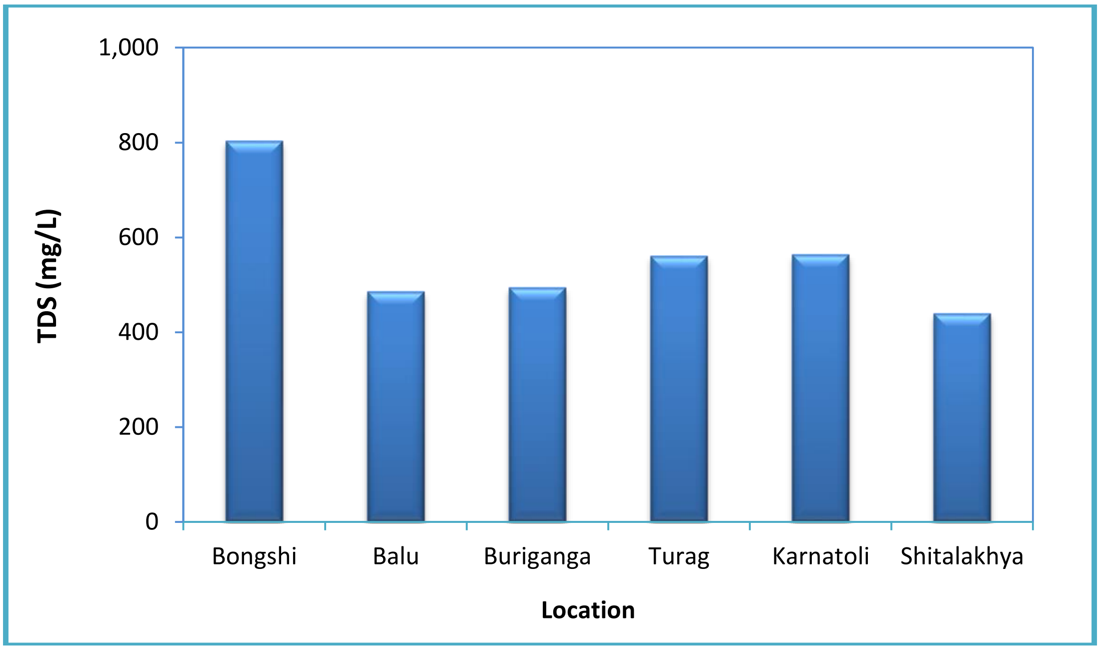


Figure 4.1.33: Variation in TDS level in mg/L among the six rivers in dry season.

The acceptable standard of TDS for drinking water set by DoE is 1000 mg/l and for industrial water is 2100 mg/l (ECR, 1997). Standard value set by FAO for livestock is 5000 mg/l, and irrigation is 2000 mg/l (FAO, 1994). From the study it has been observed that the concentration of TDS was within the limit of standard in the both season.

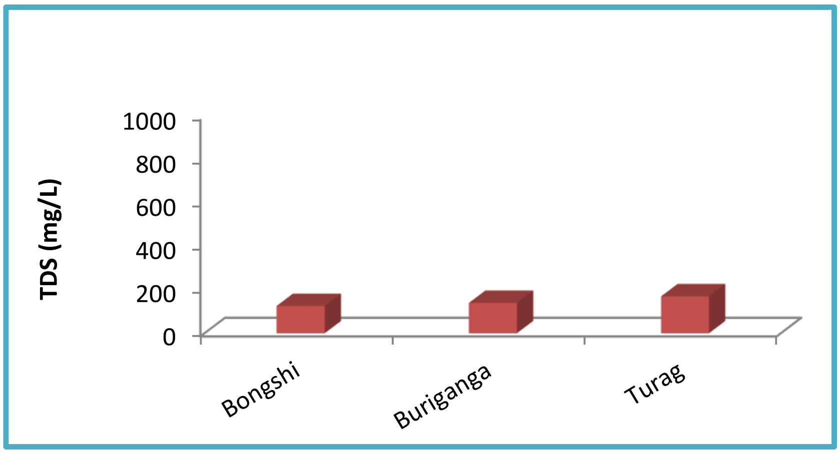


Figure 4.1.34: The average value of TDS of Bongshi, Buriganga and Turag rivers in post rainy season

The TDS was not significantly ($P< 0.05$) differed among the Bongshi, Buriganga and the Turag in post rainy season. The TDS values were lower than the DoE standard (ECR, 1997) in the Bongshi, Buriganga and the Turag. The TDS of all water samples of Bongshi river were within the range of 109.23 to 136.97 mg/l with average value of 126.35 (SD±12.69). The TDS of all water samples of Buriganga river were within the range of 130.50 to 146.3 mg/l in post rainy season with average values of 140.63 (SD±7.35). The TDS of all water samples of Turag river were within the range of 132.267 to 260.33 mg/l in post rainy season with average values of 171.11 (SD±54.67).

4.1.6 Hardness

4.1.6.1 Spatial variation of Hardness in dry season

Hardness is the property of water which prevents the lather formation with soap and increses the boiling point of water. The major cations imparting hardness are calcium and magnisium. The responsible anions are bicarbonate, carbonate, sulphate, and clorides. Hardness in water is derived from CO_2 released in bacterial action and also by metabolic ions dissolved in wastewater. Meshram (2005) has noticed that hardness is essential for normal growth of aquatic ecosystem. Krishnaram *et al.,* 2008 noted that calcium as cation causes water hardness in natural water and favors to zooplankton production, alkalinity and phosphate content of water body. According to DoE (ECR, 1997), the standard level of hardness for drinking water is 200-500 mg/l and according to WHO (2011) is 500 mg/L.

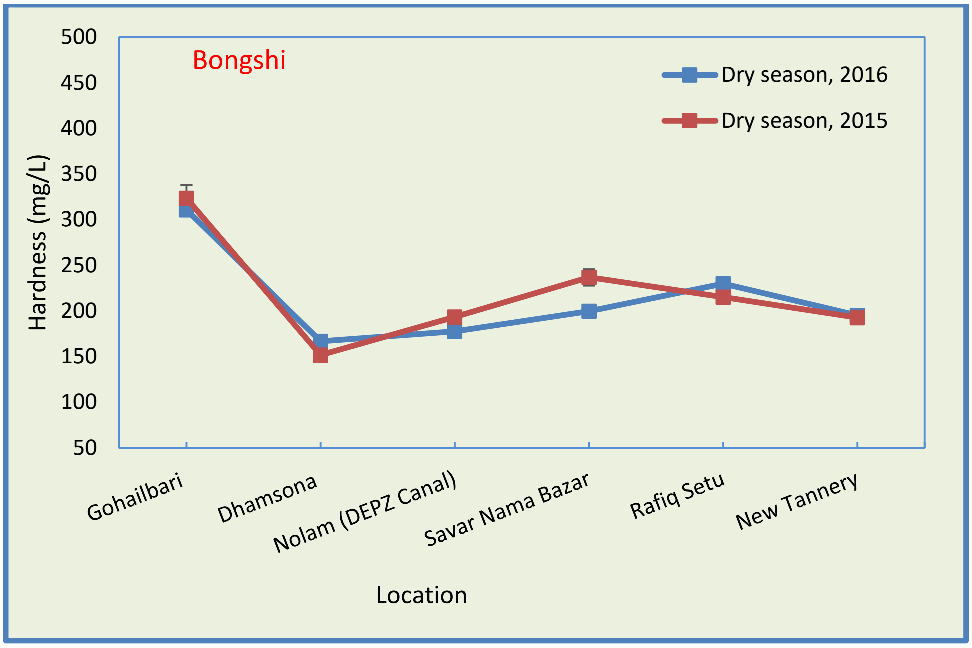


Figure 4.1.35 Hardness in mg/l along the Bongshi at different locations in dry season. Bars represent standard error of the mean.

The total hardness was fluctuated at different locations in Bongshi in Dry season (**Figure 4.1.35**). The hardness was found 310.67, 166.67, 177.67, 199.67, 229.67 and 195.0 mg/l at Gahailbari, Dhamsona, Nolam, Saver namabazar, Rafiq setu and New Tannery, respectively in dry season in 2016. The highest hardness at Gohailbari attribute by the presense of high content of calsium and magnesium containing industrial waste coming from Zirani area. Similar trend was found in 2015.

The total hardness was relatively stable at different locations in Buriganga during dry season (**Figure 4.1.36**). The hardness varied from 126.0 to 205.33 mg/l in 2016 and 113.0 to 178.0 mg/l in 2015 at 13 locations in the Buriganga in dry season due to alkaline nature of industrial/sewerage wastewater dispose to the river.

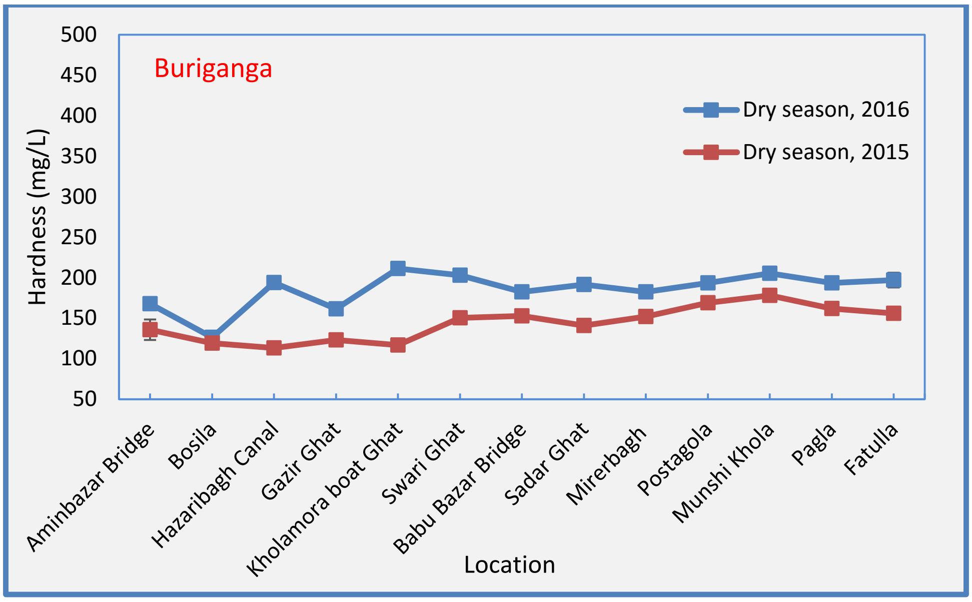


Figure 4.1.36 Hardness in mg/l along the Buriganga at different locations in dry season. Bars represent standard error of the mean. Bar represents standard error of the mean.

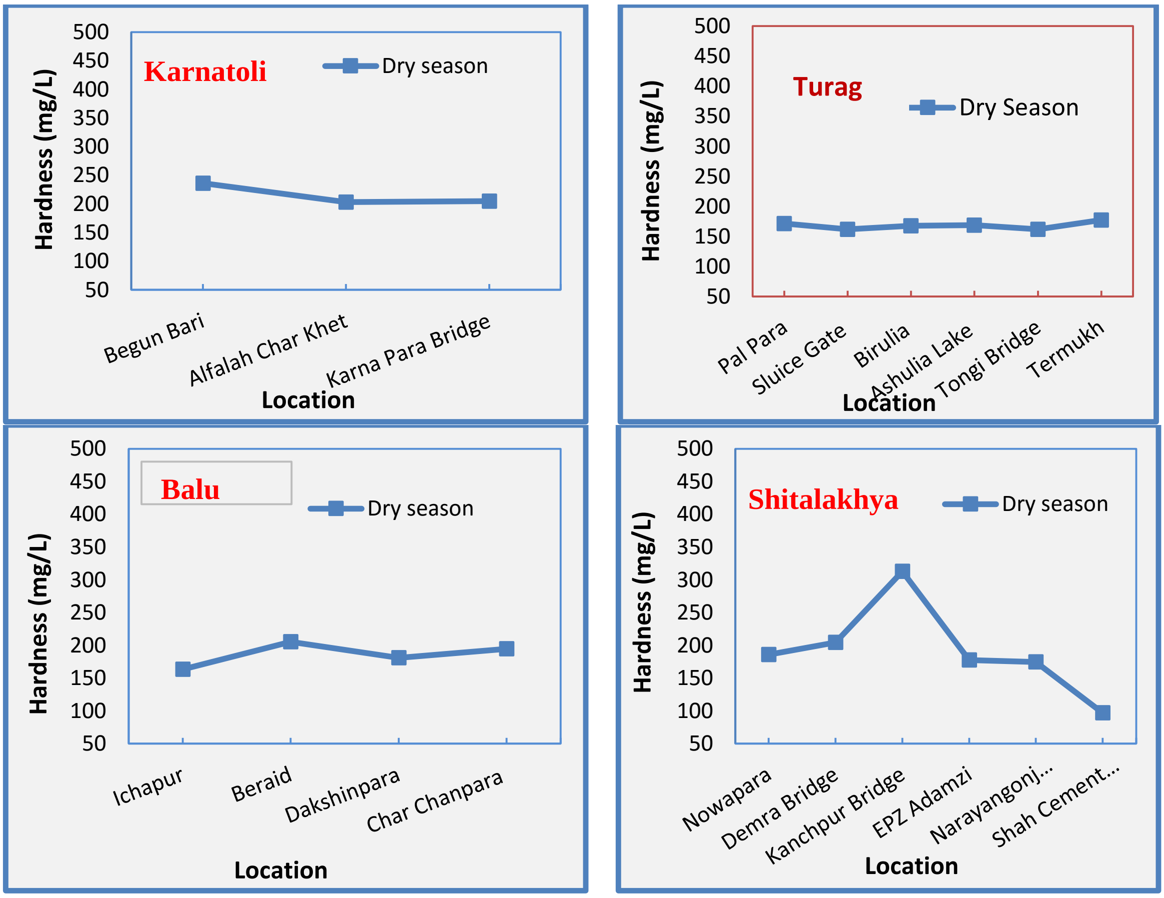


Figure 4.1.37: Hardness in mg/l along the Karnatoli, Turag, Balu and Shitalakhya rivers at different locations in dry season. Bars represent standard error of the mean.

The total hardness was relatively stable at different locations of the Karnatoli, Turag, Balu and fluctuated in Shitalakhya in dry season (**Figure 4.1.37**). Hardness varied from 203.0 to 236.0 mg/l at

3 locations in Karnatoli, from 161.67 to 177.33 mg/l at 6 locations in Turag, from 163.33 to 205.33 to 4 locations in Balu and varied from 97.0 to 204.3 mg/l at 6 locations in Shitalakhya in dry season 2016. In Shitalakhya, the maximum level reached at Kachpur Bridge and minimum was at near to Shah Cement Factory, Mukterpur. The TDS, EC and chloride levels of this study support to get these levels of hardness at Kachpur and Near to Shahcement factory in Shitalakhya.

4.1.6.2 Variation of Hardness between dry season and post rainy season

Hardness value ranged from 166.67 to 310.67 mg/l in dry season and 82.0 to 92.67 mg/l in post rainy season (**Figure 4.1.38**). The greater level of hardness in dry season can be attributed to the decrease in water volume and increase in the rate of evaporation, high loading organic industrial wastes and other pollution. This may be due to the presence of high content of calcium and magnesium in addition to sulphate. Similar to this study Kaur and Sharma (2001) was reported maximum hardness in dry season. In the post rainy season, hardness was the same (not significantly differed, at *P*< 0.05 among the locations) throughout the river because of high volume of water along with flow which diluted the pollion.

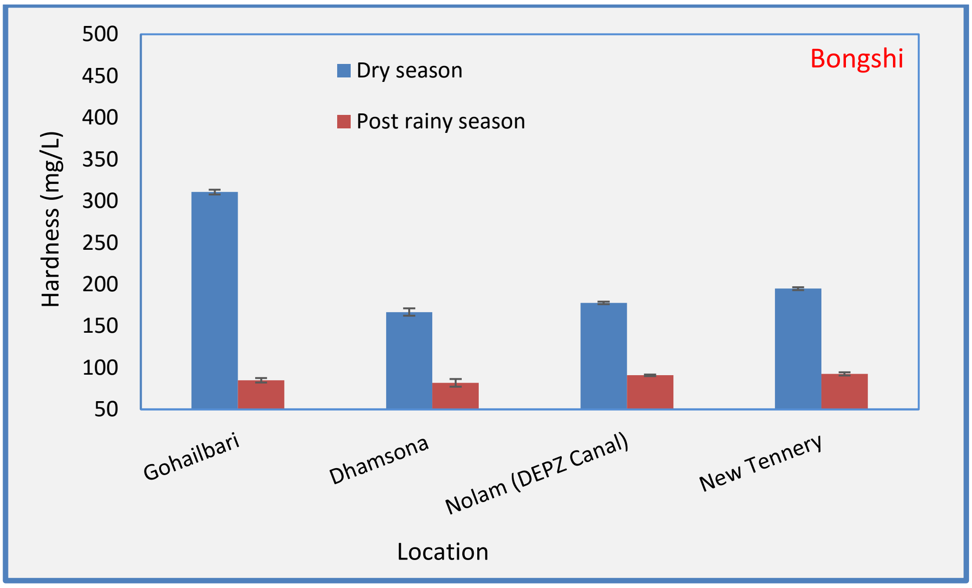


Figure 4.1.38: Variation in Hardness level in mg/l between dry season and post rainy season at four locations along the Bongshi. Bars represent standard error of the mean.

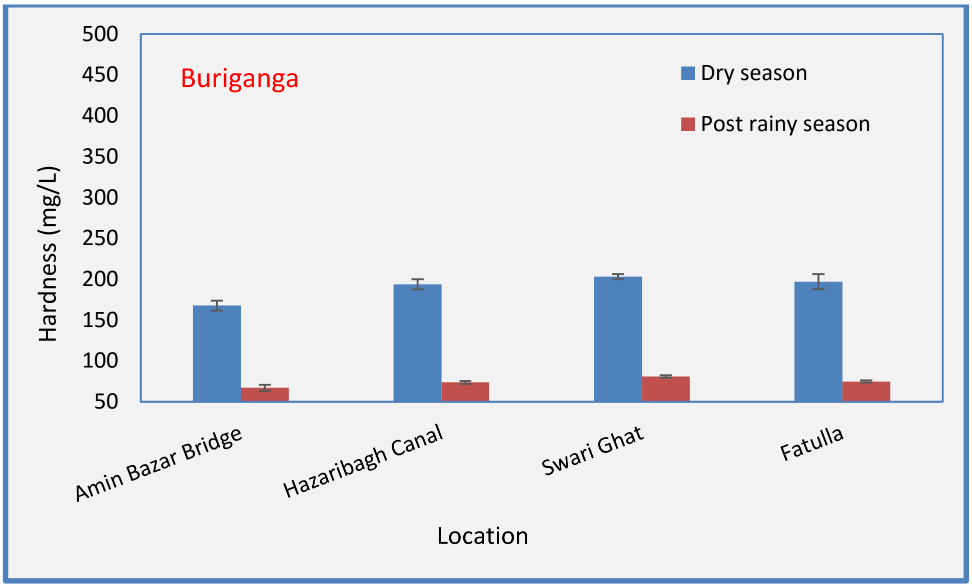


Figure 4.1.39: Variation in Hardness level in mg/L between dry season and post rainy season at four locations along the Buriganga. Bars represent standard error of the mean.

Similar to Bongshi, hardness was greater in dry season than the post rainy season (**Figure 4.1.39**). Hardness value ranged from 166.67 to 203.0 mg/l in dry season and 67.0 to 81.0 mg/L in post rainy season at 4 locations. Hardness was similar at all locations from upstream to downstream in both seasons.

4.1.6.3 Variation of Hardness among the rivers

The average hardness of Buriganga, Bongshi, Balu, Turag, Karnatoli, and Shitalakhya in dry season and post rainy season is shown in **Figure 4.1.40** and **Figure 4.1.41,** respectively**.** The Hardness values of all water samples of Bongshi river were within the range of 82.00 to 92.67 mg/l (post rainy season) and 166.67 to 310.67 mg/l (dry season) and the average value of Hardness is 87.67 (SD±5.01) mg/l in post rainy season and 212.50 (SD±66.48) mg/l in dry season. The Hardness values of all water samples of Buriganga river were within the range of 67.00 to 81.00 mg/l (post rainy season) and 167.67 to 203.00 mg/l (dry season) and the average value of Hardness is 74.09 (SD±5.73) mg/l in wet season and 190.34(SD±15.60) mg/l in dry season. The Hardness values of all collected water samples of Turag river were within the range of 55.00 to 103.00 mg/l (post rainy season) and 161.67 to 177.33 mg/l (dry season) and the average value of Hardness is 75.89(SD±17.25) mg/l in post rainy season and 168.17(SD±5.92) mg/l in dry season. The Hardness values of all water samples of Balu river were within the range of 163.33 to 205.33 mg/l (dry season) and the average value of Hardness is 186.00(SD±18.18) mg/l in dry season. The Hardness values of all water samples of Shitalakhaya river were within the range of 97.00 to 313.00 mg/L (dry season) and the average value of Hardness is 192.11(SD±69.80) mg/l in dry season. The Hardness values of all water samples of Karnatoli river were within the range of 203.00 to 236.00 mg/L (dry season) and the average value of Hardness is 214.56(SD±18.59) mg/l in dry season.

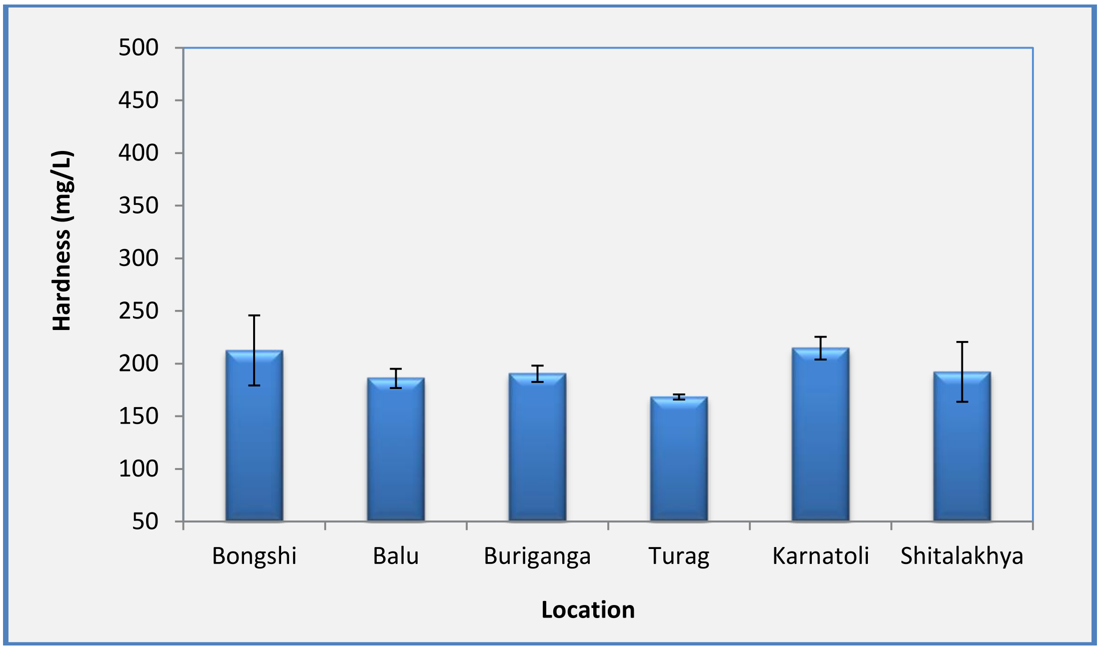


Figure 4.1.40: Variation in average hardness in mg/L among the rivers in dry season.

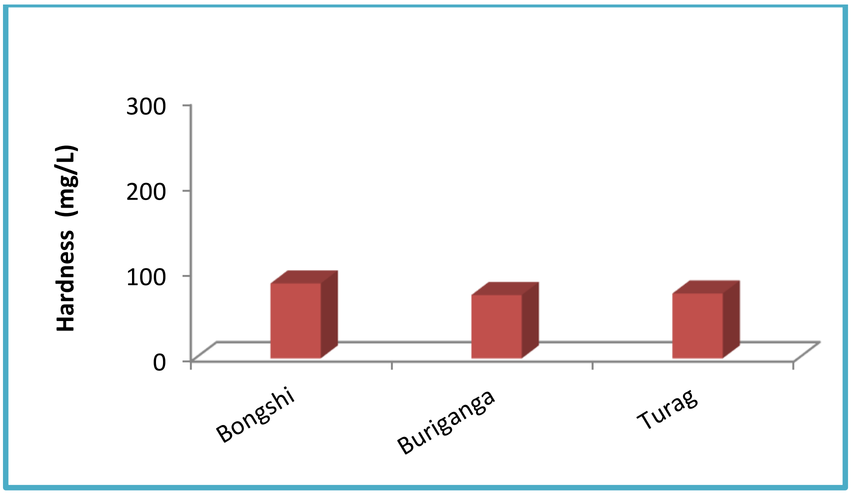


Figure 4.1.41: Variation in average hardness in mg/l among the rivers in post rainy season.

According to the Department of Environment (DoE) standard permissible limit of hardness of drinking water is 200 to 500 mg/l (ECR, 1997). According to WHO (2011), the hardness standard is 500 mg/l for drinking water. According to these standards, all measured hardness of six rivers surrounding Dhaka are within the standard limit in both seasons. On the basis of total hardness, water can be classified as soft (<75 mg/l), moderately hard (75- 150 mg/l), hard (150-300 mg/l) and very hard (>300 mg/l) (Sawyer and McCarty, 1967). According to these criteria, water samples were graded as hard in all locations. But in the post rainy season water was moderately hard.

4.1.7 Chloride

Chloride is an indication of salinity in water. Surface water containing significant amount of chloride also tend to have high amount of Na ions indicating the possibility of contacts with water of marine origin. From an environmental standpoint, chloride is basically a conservative parameter and may serve as an index of pollution occurring in natural freshwater from primary sources such as industrial and municipal outlets. The most important source of chloride in natural water is discharge of sewage and it play vital role in photophosphorylation reaction in autotrophs.

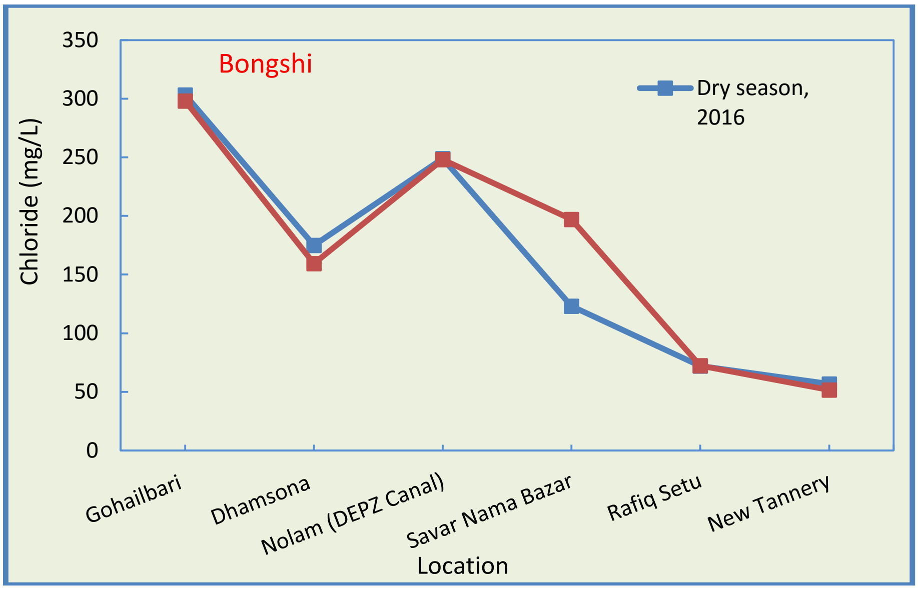


Figure 4.1.42 Cloride in mg/L along the Bongshi at different locations in dry season. Bars represent standard error of the mean.

At 6 locations in Bongshi, the cloride concentration was varied from 51.61 to 298.33 mg/l in 2015 and 56.33 to 303.33 mg/l in 2016 (**Figure 4.1.42**). The highest chloride concentration was found at Gohailbari which was attributed by higher pollution due to higher industrial organic waste containing chloride salt surrounding of the Zirani area and agricultural waste including fertilizer surrounding of the Gohailbari. The chloride concentration was decreased after Nolam to New Tannery area possible due to lower wastes disposal and increase of water volume of these areas. The chloride concentration is within the standard value of Cloride set by DoE (ECR, 1997) which is 150-600 mg/l for drinking water and according to CCME (2007) the chloride level is 120 mg/l for aquatic life.

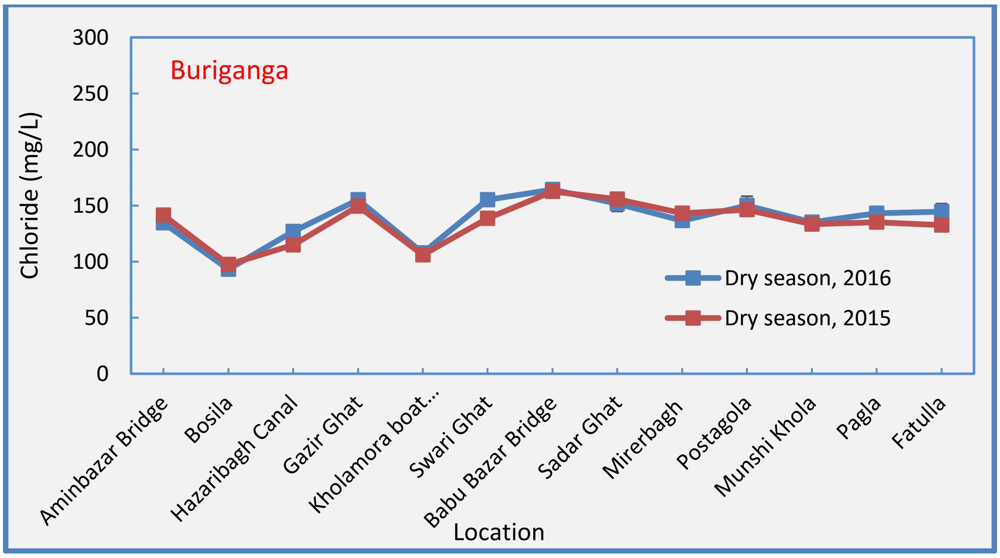


Figure 4.1.43 Cloride concentration in mg/l along the Buriganga at different locations in dry season. Bars represent standard error of the mean.

Cloride concentration was flucted from Amin bazar to Swari Ghat after that it was relatively stable to downstream of the Buriganga in dry season (**Figure 4.1.43**). At 13 locations, it was varied from 93 to 164.33 mg/l in 2015 and 97.33 to 162.67 mg/L in 2016. The cloride concentration was not significantly differed between 2015 and 2016 among the locations. The chloride contamination occurred possibly due to organic content of sewage/municipality/industrial wastes disposed to throughout the Buriganga. The chloride concentration is within the standard value of Cloride set by DoE (ECR, 1997) which is 150-600 mg/l.

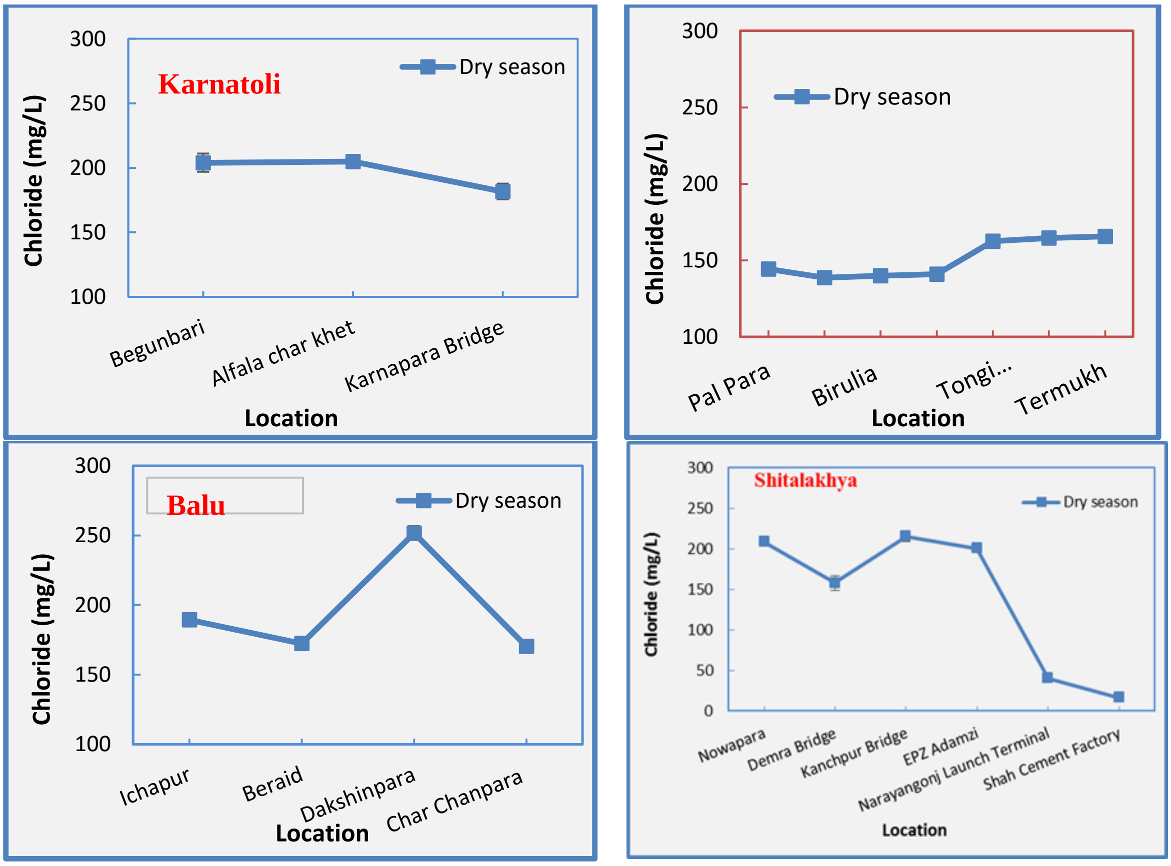


Figure 4.1.44: Chloride concentration in mg/l along the Karnatoli, Turag, Balu and Shitalakhya rivers at different locations in dry season. Bars represent standard error of the mean.

The chloride concentration was varied from 181.67 to 204.0 mg/l at 3 locations in Karnatoli, from 140.95 to 162.51 mg/l at 6 locations in Turag, from 170.33 to 251.67 to 4 locations in Balu and varied from 16.50 to 215.0 mg/l at 6 locations in Shitalakhya in dry season 2016 (**Figure 4.1.44**). In Shitalakhaya, the maximum level was reached at Kachpur Bridge and minimum was at near to Shah Cement Factory, Mukterpur. The TDS and EC levels of this study support to get these levels of hardness at Kachpur and Near to Shahcement factory in Shitalakhya.

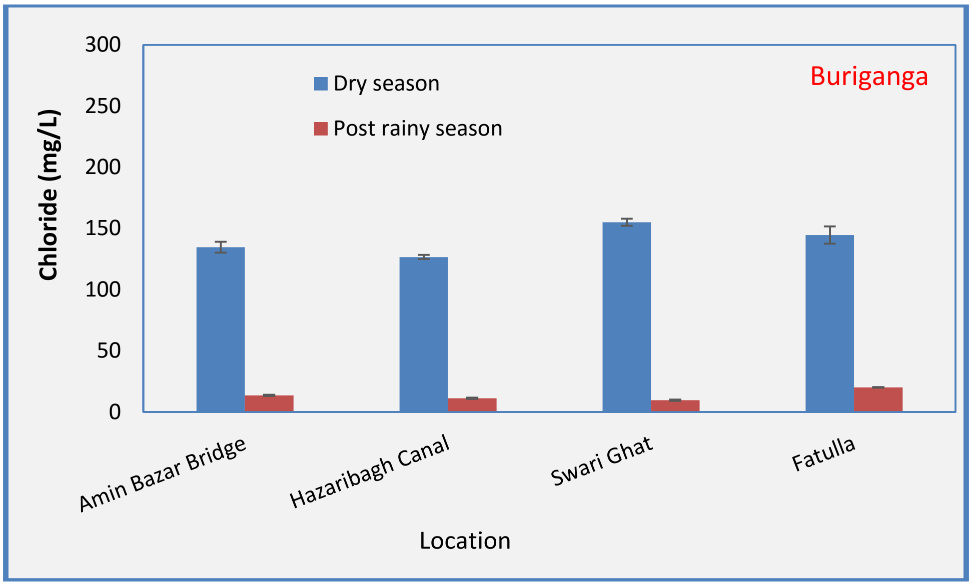


Figure 4.1.45: Variation in chloride concentration in mg/l Between dry season and post rainy season in the Buriganga. Bars represents standard error of the mean.

The average value of chloride in Buriganga, Bongshi, Balu, Turag, Karnatoli, and Shitalakhya in dry season and post rainy season is shown in **Figure 4.1.46** and **Figure 4.1.47,** respectively**.** The Chloride of all water samples of Bangshi River were within the range of 7.50 to 13.20 mg/l (post rainy season) and 56.67 to 303.33 mg/l (dry season) with average values of 5.18 (SD±4.03) mg/l and 196.60 (SD±106.74) mg/l respectively. The Chloride of all water samples of Buriganga river were within the range of 9.77 to 20.20 mg/l (post rainy season) and 126.67 to 155.0 mg/l (dry season) with average values of 13.77 (SD±4.59) mg/l and 140.25 (SD±12.28) mg/L respectively. The Chloride of all water samples of Turag river were within the range of 138.67 to 165.67 mg/l (dry season) with average values of 148.69 (SD±12.12). The Chloride of all water samples of Balu river were within the range of 170.33 to 251.67 mg/l (dry season) with average values of 195.92 (SD±38.13). The Chloride of all collected water samples of Shitalakhya river were within the range of 16.50 to 215.00 mg/L (dry season) with average values of 139.81 (SD±88.87).

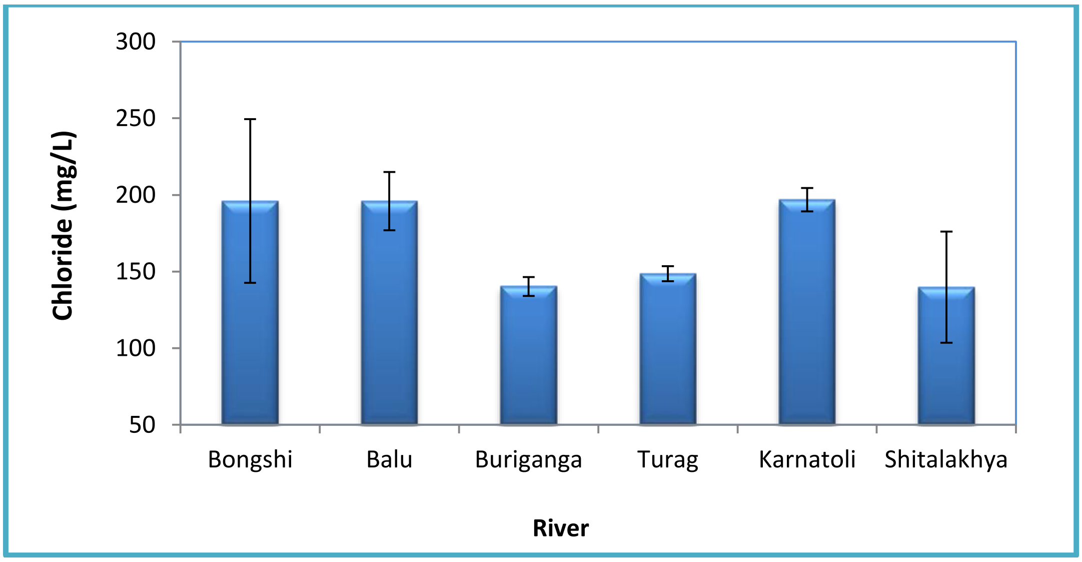


Figure 4.1.46: Variation in average chloride concentration in mg/l among the rivers in dry season. Bars represents variation in chloride among the locations of each river.

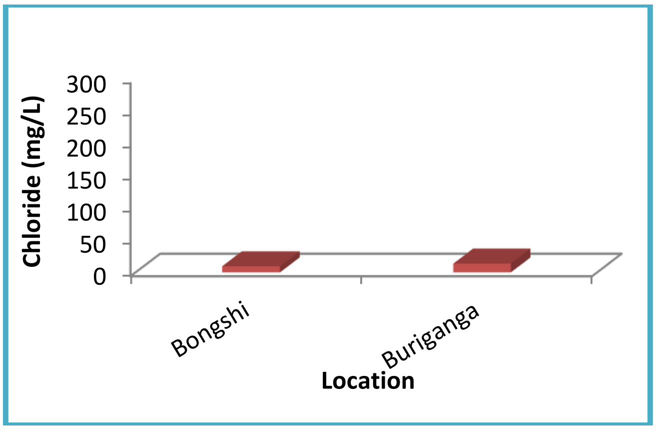


Figure 4.1.47: Variation in average chloride concentration in mg/l of the Bongshi and Buriganga rivers in Post rainy season.

4.1.8 Alkalinity

In chemical terms, alkalinity is defined as the total amount of titratable bases in water expressed as mg/L equivalent calcium carbonate ($CaCO_3$). Alkalinity of natural water is generally due to presence of bicarbonates and it favors to zooplankton populations (Singh et al., 2002; Kiran *et al.,* 2007). The high value of alkalinity indicates the presence of bicarbonate, carbonate, and hydroxide in the water body (Jain, 2000). pH has direct relationship with total alkalinity as reported by (Bharadwaj and Sharma, 1999).

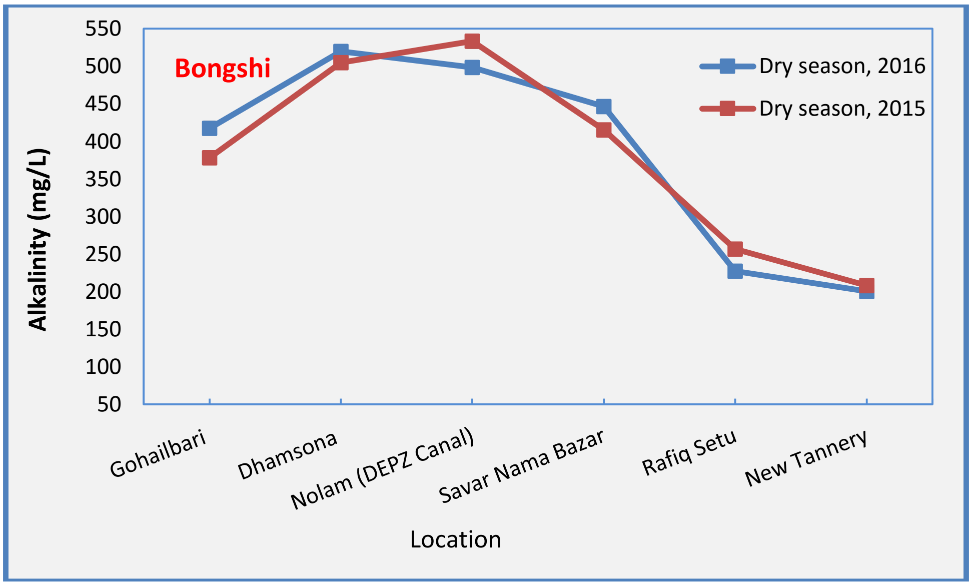


Figure 4.1.48 Alkalinity in mg/l along the Bongshi at different locations in dry season. Bars represent standard error of the mean.

Observed alkalinity in dry season at Gohailbari, Dhamsona, Nolam (DEPZ), Saver Namabazar, Rafiq setu and New Tannary was 417.67, 417.67, 520.00, 498.33, 446.33, 227.33, 200.67 mg/l, respectively in 2015 in Bongshi river. Alkalinity concentration is similar between 2015 and 2016 in dry season (**Figure 4.1.48)**. Alakalinity concentration was relatively higher at Dhamsona, Nolam and Saver Namabazar is likely because of presence of bicarbonate, carbonate, and hydroxide coming from industries surrounding this locations.

Alkalinity varied from 254 to 375 mg/l among the 15 locations along the Buriganga in dry season. There is no significant difference between 2015 and 2016 in alkalinity. A slight increased in alkalinity was observed from upstream to downstream in the Buriganga.

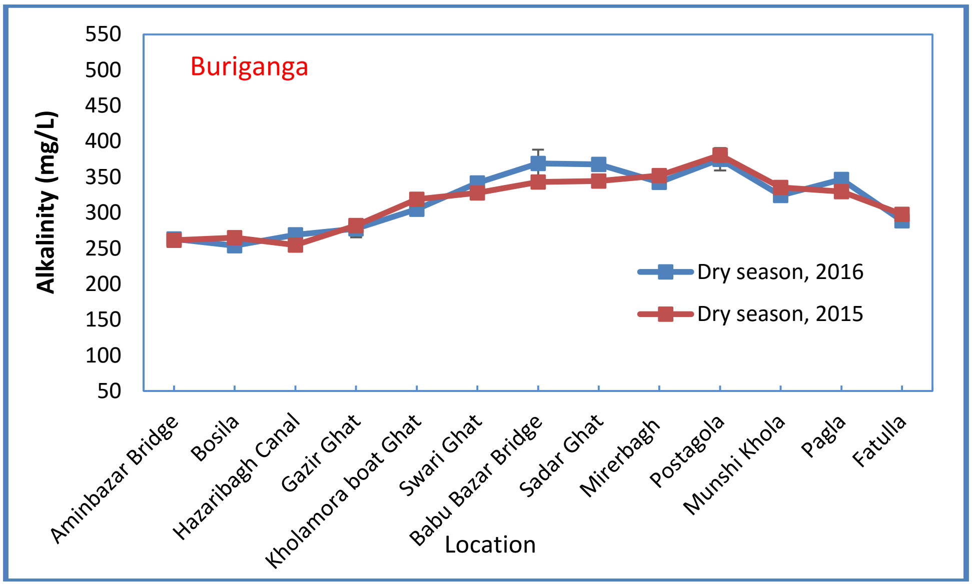


Figure 4.1.49 Alkalinity in mg/l along the Buriganga at different locations in dry season. Bars represent standard error of the mean.

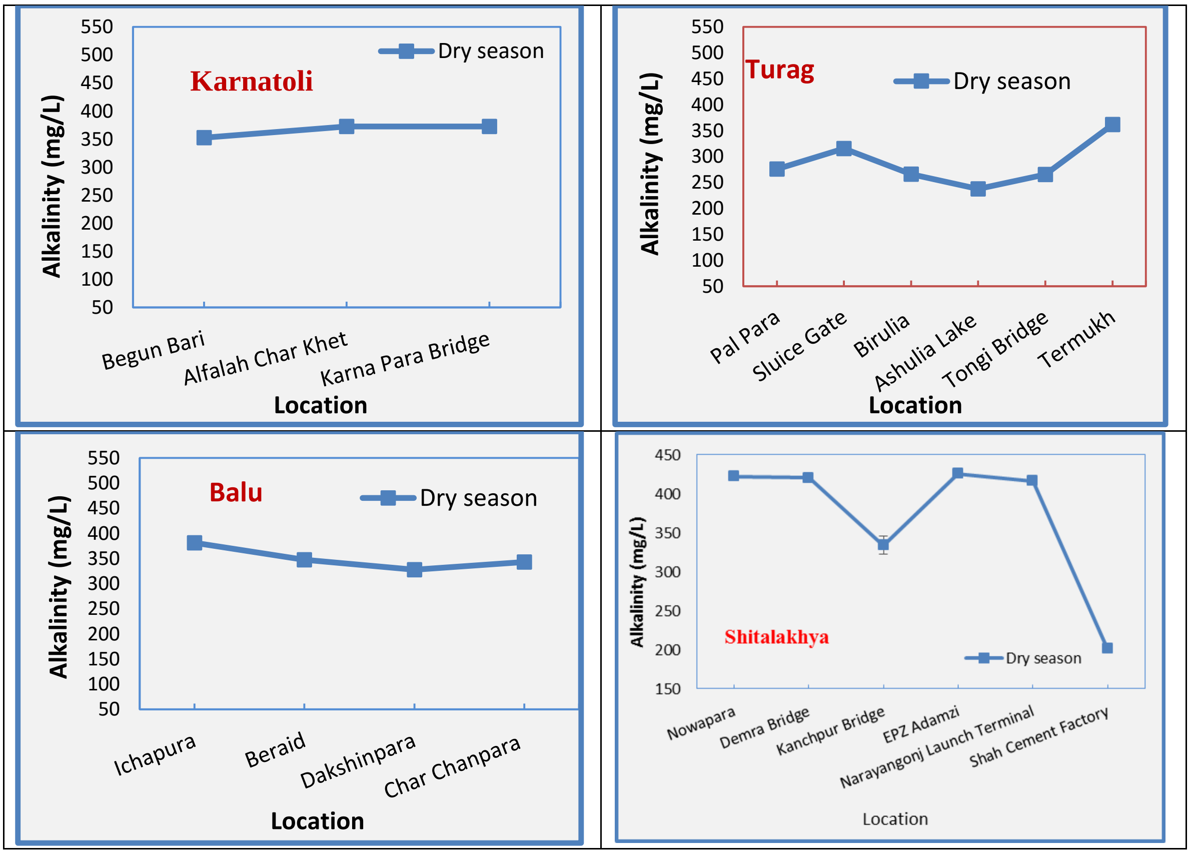


Figure 4.1.50 Alkalinity in mg/l along the Karnotali, Turag, Balu and Shitalakhya at different locations in dry season. Bars represent standard error of the mean.

Alkalinty varied from 352.5 to 372.5 mg/l at 3 locations in Karnatoli, from 238.0 to 461.66 mg/l at 6 locations in Turag, from 327.67 to 381.33 mg/l at 4 locations in Balu and varied from 201.33 to 425.67 mg/l at 6 locations in Shitalakhya in dry season 2016 (**Figure 4.1.50**). The alkalinity was relatively stable at different locations of the Karnatoli and Balu. In Shitalakhya, the maximum level was at Adamzi EPZ and minimum was at near to Shah Cement Factory, Mukterpur.

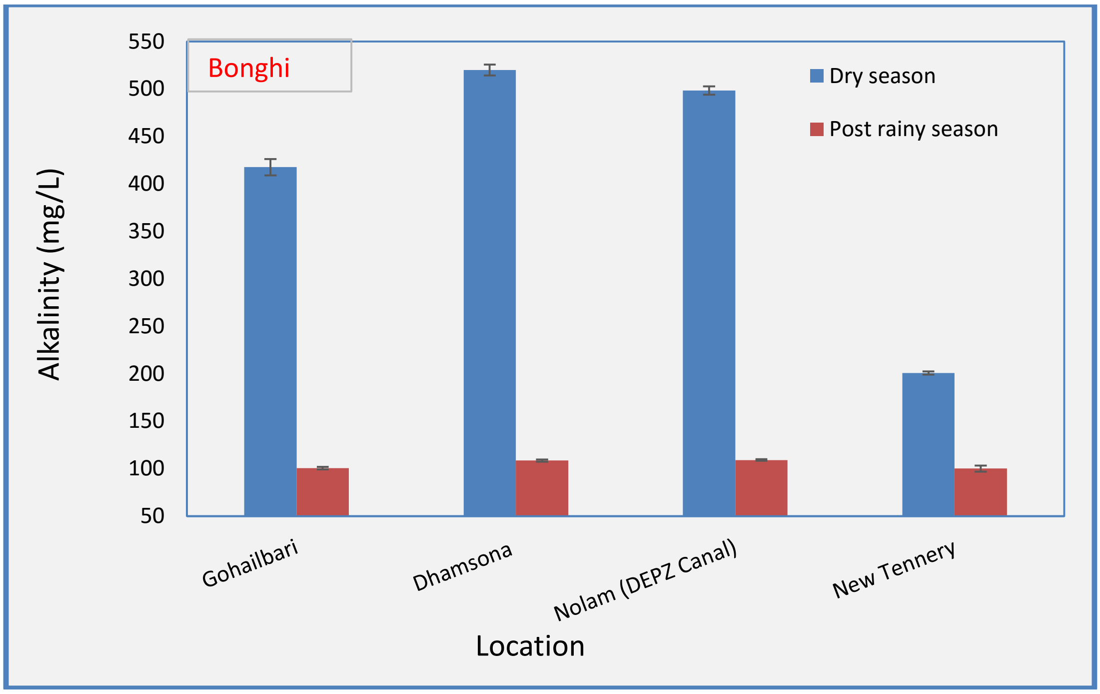


Figure 4.1.51: Variation in Alkalinity level in mg/l between dry season and post rainy season at four locations along the Bongshi. Bars represent standard error of the mean.

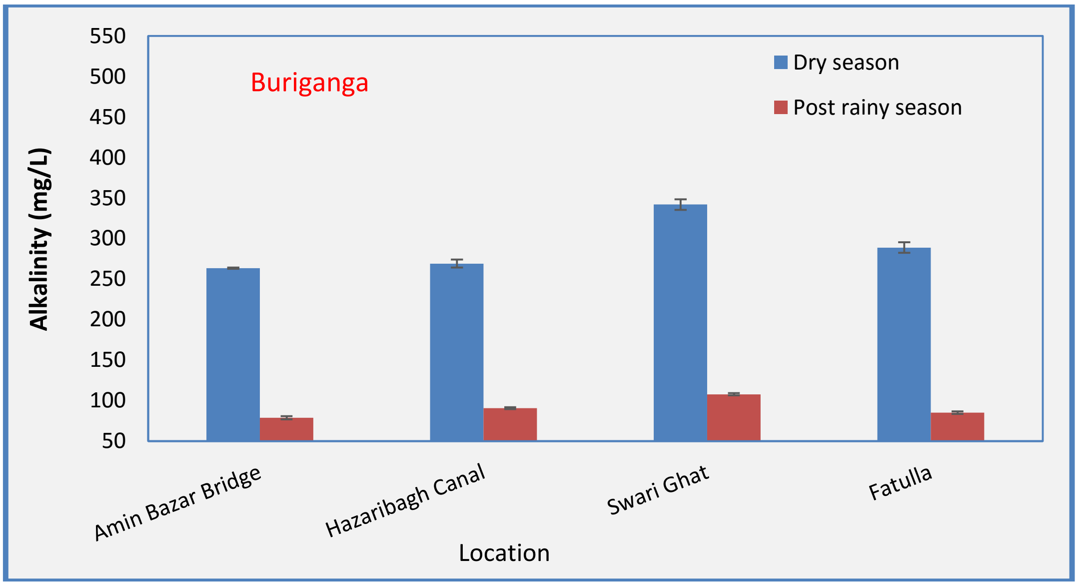


Figure 4.1.52: Variation in Alkalinity level in mg/l between dry season and post rainy season at four locations along the Buriganga. Bars represent standard error of the mean.

The average value of alkalinities of six rivers is shown in **Figure 4.1.53** in dry season and the average alkalinity of Bongshi, Buriganga aand Turag river water in post rainy season is shown in **Figure**

4.1.53. The average alkalinity values of Bongshi river water was 409.17 (SD±145.81) mg/l in dry season and the average value of alkalinity is 104.50(SD±4.92) mg/l in post rainy season. In Buriganga, the average value of alkalinity is 90.50 (SD±12.45) mg/l in post rainy season and 290.75(SD±35.85) mg/l in dry season. Alkalinity values of Turag river water was 104.89 (SD±30.72) mg/l in post rainy season and 303.89(SD±81.28) mg/l in dry season. Alkalinity values of Balu river water samples were varied between 327.67 to 381.33 mg/l and the average value of Alkalinity is 349.92(SD±22.60) mg/l in dry season. Alkalinity values of Shitalakhya river water samples were varied between 201.33 to 425.67 mg/l and the average value of Alkalinity was 364.89 (SD±93.09) mg/l in dry season. Alkalinity values of Karnatoli river water samples were varied between 352.5 to 372.5 mg/l and the average value of alkalinity is 365.83(SD±11.55) mg/l in dry season.

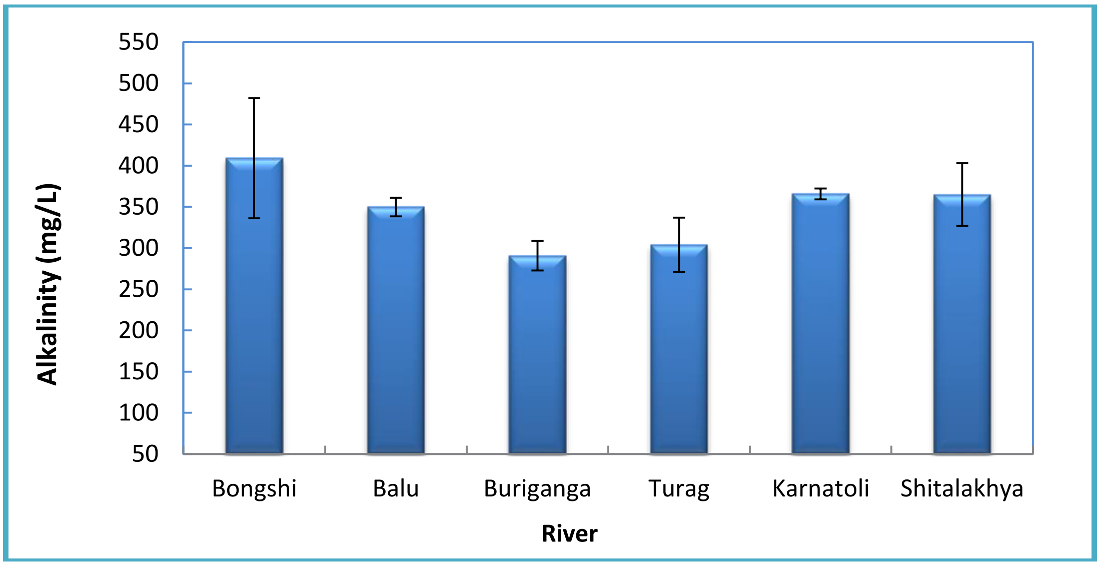


Figure 4.1.53: Variation in average alkalinity in mg/l among the six rivers in dry season. Bars represent the variation alkalinity among the locations of each river.

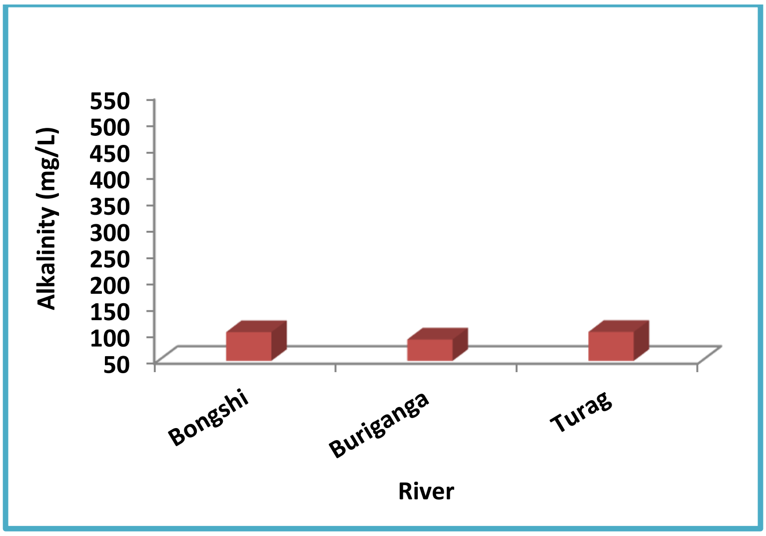


Figure 4.1.54: Variation in average alkalinity in mg/l among the three rivers in post rainy season.

4.1.9 Ammonia (NH_3)

Ammonia is a nutrient that containts nitrogen and hydrogen. Ammonia is produced by microbial activity of organic nitrogenous matter and its presence is mainly due to decaying plants, sewage, industrial discharge and fertilizer containing ammonia. The presence of ammonia in fish water is normal due to natural fish metabolism and microbiological decay of organic matter. Nitrate and ammonia are the most common forms of nitrogen in aquatic systems. In water, ammonia nitrogen can exist in two forms, un-ionized ammonia (NH_3) and ammonium ion (NH_4^+). Un-ionized ammonia is toxic to fish and other aquatic life and the ammonium ion is non-toxic except at extreamly high levels. The pH and temperature of water regulate the proportion of each form. Therefore, the toxicity of ammonia is critically dependent on pH and temperature. As pH increses, NH_4^+ is converted to NH_3 and the toxicity increases.

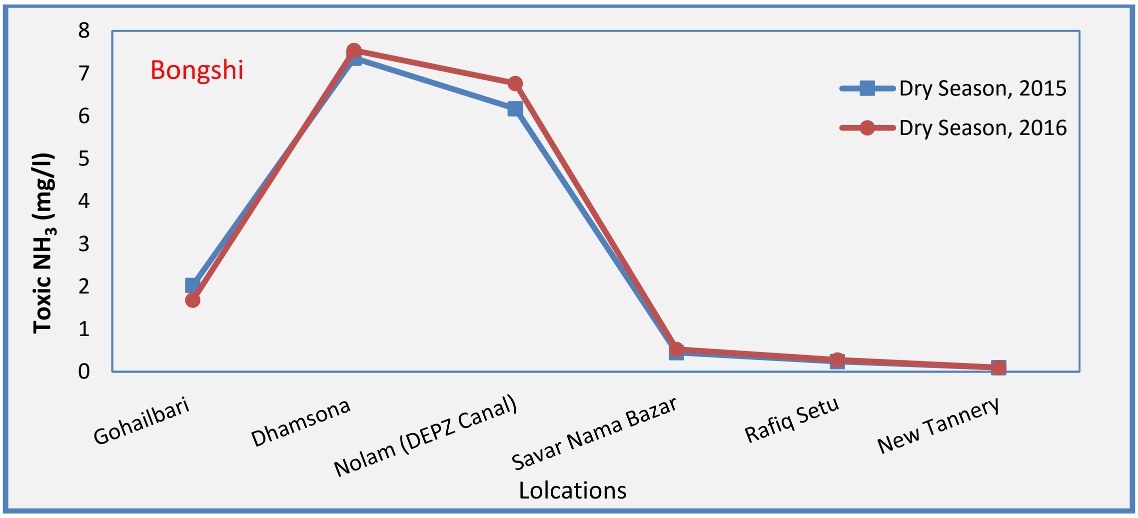


Figure 4.1.55: Variation in toxic ammonia in mg/l at different locations in Bongshi in dry season.

The toxic ammonia concentrations were 2.03, 7.36, 6.18, 0.45, 0.24, 0.10 mg/l at Gohailbari, Dhamsona, Nolam, Saver Namabazar, Rafiq Setu and New Tannery, respectively in dry season in 2015. The similar concentrations were found in 2016 in dry season. The standard un-ionized ammonia that means toxic ammonia concentration provided by WHO (2011) is 0.2 mg/l, by DoE (ECR, 1997) is 0.05 mg/l and by CCME (2007) is 0.019 mg/l (**Table 4.1**). The extreme level of ammonia in Gohailbari, Dhamsona and Nolam (DEPZ canal) were probably due to huge industrial effluent containing ammonium salt enters to surrounding of these areas. The toxic ammonia concentrations were much lower at Rariq setu and new tannery is like to occur because of less industrial wastes enter and greater water flow of these locations.

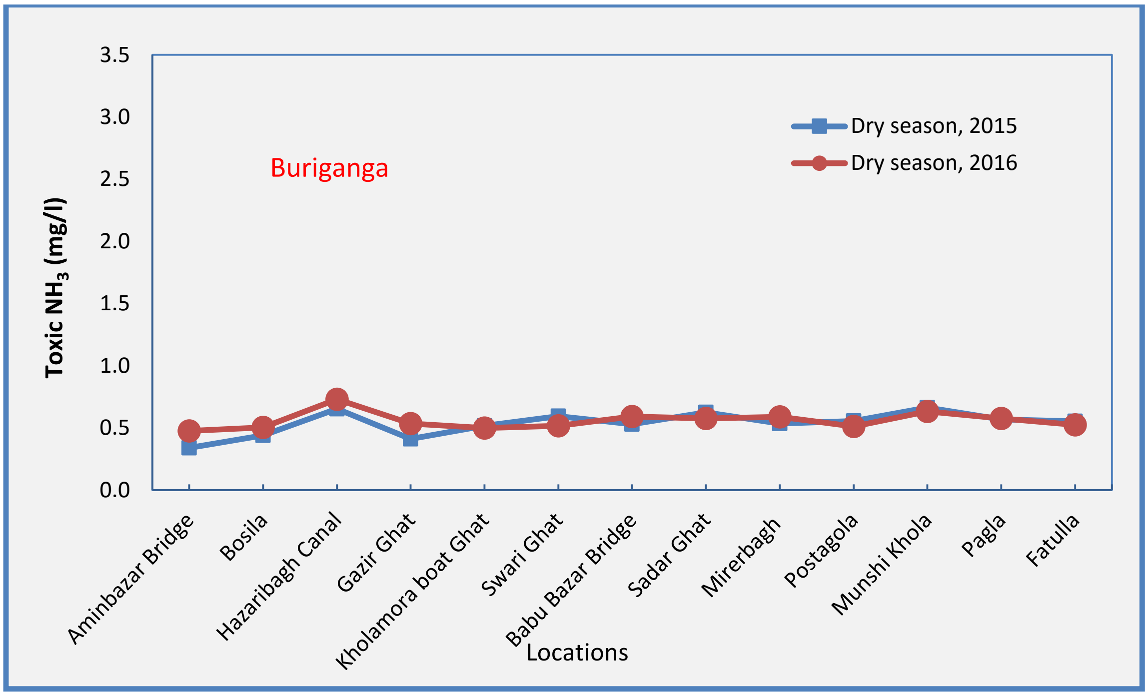


Figure 4.1.56: Variation in toxic ammonia in mg/L at different locations in Buriganga in dry season.

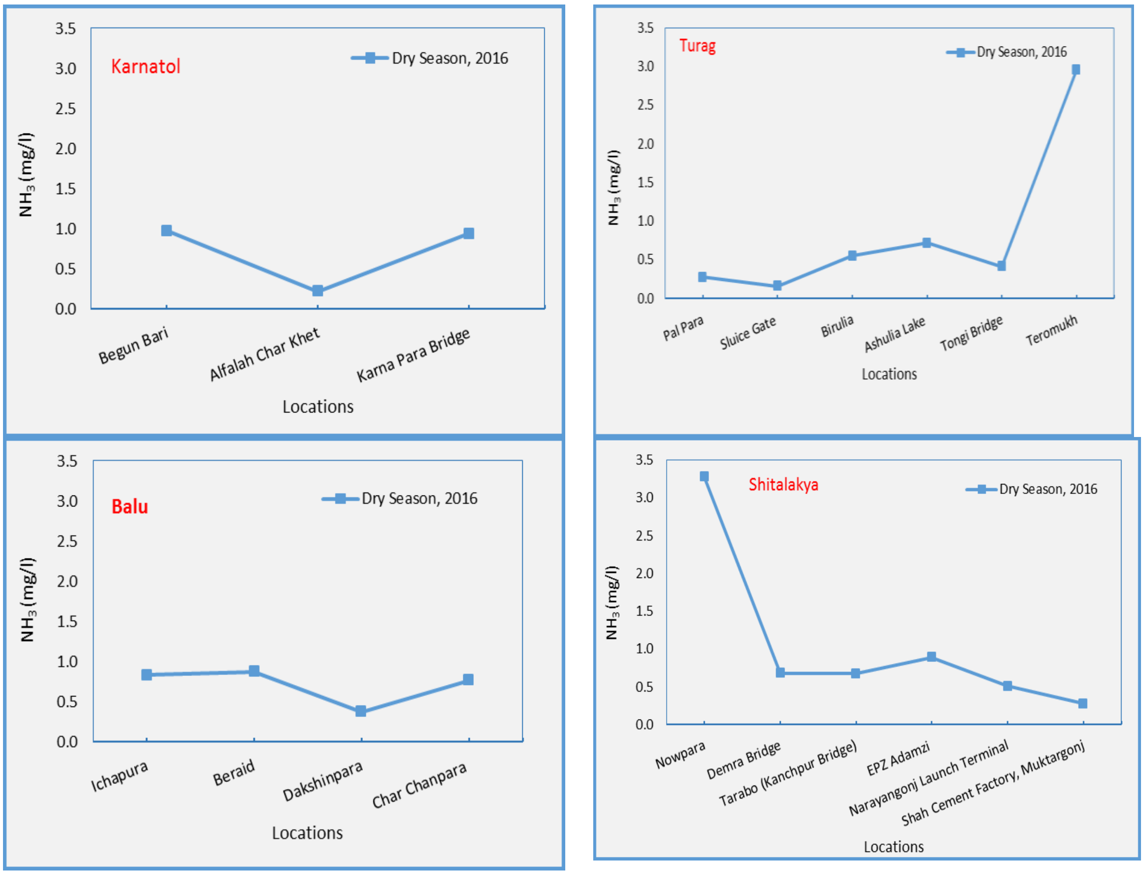


Figure 4.1.57: Variation in toxic ammonia in mg/L at different locations in Karnatoli, Turag, Balu and Shitalakhya in dry season.

The level of toxic ammonia varied from 0.41 to 0.67 mg/l among the 13 locations of Buriganga in dry season. These ammonia levels were far above the standard value set by WHO (2011), DoE (ECR, 1997) and the CCME (2007) shown in **Table 4.1**. These toxic concentrations were relatively stable through the upstream to downstream of the Buriganga is likely to occur because of municipalities and industrial wastes enter throughout the river which causes toxicity of ammonia throughout the river.

The toxic ammonia at Ichapur, Beraid, Dakshinpara and Chanpara were 0.83, 0.87, 0.37 and 0.76 mg/l, respectively in Balu in dry season. However, the toxix ammonia concentrations were fluctuating in karnotoli which were 0.97, 0.22, 0.94 mg/l at Begunbari, Alfalah Char khet and Karna para Bridge, respectively. In Turag, the concentrations were 0.28, 0.16, 0.55, 0.72, 0.41, 2.96 mg/l at Pal Para, Sluice gate, Birulia, Ashulia Lake, Tongi Bridge and Teromukh, respectively. The toxic ammonia concentrations were 3.28, 0.68, 0.68, 0.89, 0.51 and 0.28 mg/l at Nowapara, Demra Bridge, Kanchpur Bridge, EPZ Adamzi, Narayangonj Launch Terminal and Shah Cement Factory, Muktargonj, respectively in Shitalakhya.

4.1.10 Carbon di-oxide (CO_2)

The amount of free Carbon di oxide (CO_2) in stagnant water is generally maintained by diffusion from atmosphere, respiration by animals along with plants and bacterial decomposition of organic matter (Misra et al., 1993). The CO_2 content of water depends upon the water temperature, depth, rate of respiration, decomposition of organic matter, chemical nature of bottom and geographical features of the terrain surrounding the water body (Sakhare and Joshi, 2002). In water bodies CO_2 react with water and forms carbonic acid. This carbonic acid soon dissociates into carbonates and bi carbonates which alters pH of water. CO_2 is present in all surface waters in amounts generally less than 10 mg/L, although higher concentrations in ground waters are not uncommon. High concentrations of CO_2 may be tolerated by fish if dissolved oxygen concentrations are also high. Fish are known to avoid areas of high CO_2 levels. The fish are known to avoid areas of high CO_2 levels. The relationship of CO_2 to fish respiration and photosynthesis creates daily fluctuations in CO_2 concentrations. Levels usually increase during the night and decrease during the day. High levels of CO_2, such as those that occur after plankton di-off, will suppress absorption by fish and may become toxic when dissolved oxygen levels are critically low.

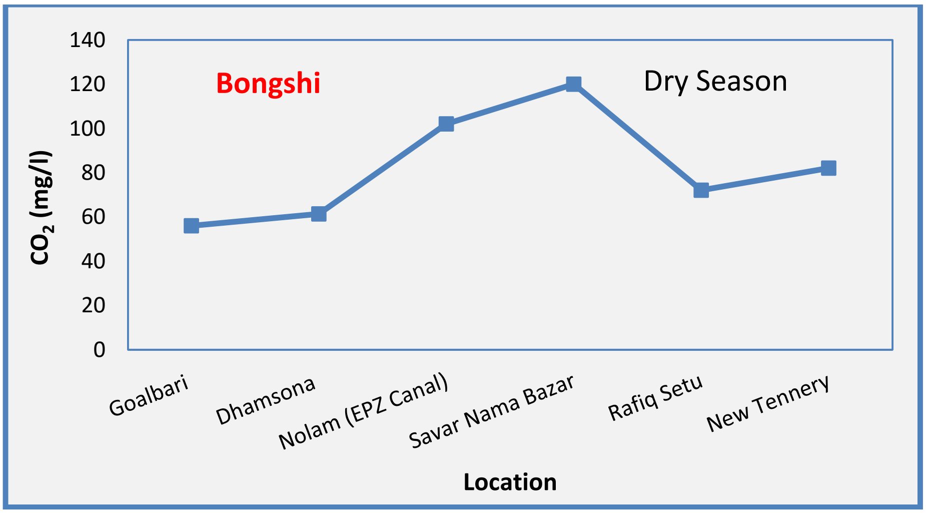


Figure 4.1.58: Variation in free CO_2 in mg/l at different locations in Bongshi in dry season.

The free CO_2 concentration was fluctuated at different locations of Bongshi in dry season. The CO_2 concentration were 56.0, 61.3, 102.0, 120.0, 72.0, and 82.0 mg/l at Goalbari, Dhamsona, Nolam (EPZ canal), Saver Namabazar, rafiq setu and New tannery in dry season in Bongshi. This may be due to decay of organic matter and presence of carbon as ash particles in wastewater. This is strengthened by the observation of Joshi et.al. (1995), who have observed the addition of anthropogenic and industrial waste was the main causal factor for increase in CO_2 in water bodies. The highest CO_2 concentration was found at Savernama Bazar is likely to occur as this this place is dumping ground of solid waste which release more CO_2. High concentrations of CO_2 may be tolerated by fish if DO concentrations are high. High levels of CO_2 will suppress absorption by fish and may become toxic when DO levels are critically low. In this study, DO concentrations were approximately zero at Goalbari, Dhamsona, Nolam and Saver Namabazar with such high concentration of CO_2 indicates no sustaining fish in these four locations.

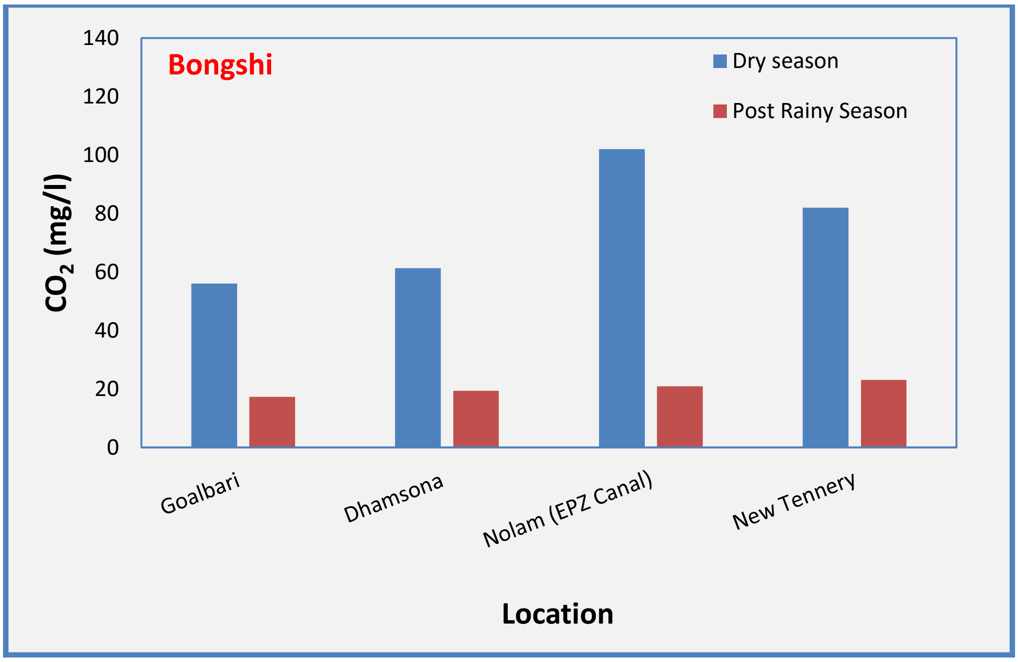


Figure 4.1.59: Variation in free CO_2 in mg/l between dry season and post rainy season at different locations in Bongshi

In Bongshi, CO_2 concentration fluctuates in dry season at different locations but similar in post rainy season. CO_2 varied from 61.33 to 102.0 mg/l in dry season and 17.30 to 23.07mg/l in post rainy season at four locations namely Goalbari, Dhamsona, Nolam (EPZ canal) and New tannery. The CO_2 concentration was higher in dry season than the dry season and the highest value was 152.0 mg/l. The increase in CO_2 level during dry season due to decay and decomposition of organic matter as the addition of anthropogenic and industrial waste is the main causal factor for increase in CO_2 in water bodies. High concentrations of CO_2 may be tolerated by fish if DO concentrations are high. High levels of CO_2, such as those that occur after plankton die-offs, will suppress absorption by fish and may become toxic when DO levels are critically low. In this study, the DO is approximately zero with very high CO_2 concentration indicating availability of fish is impossible at these three locations namely Goalbari, Dhamsona and Nolam in dry season.

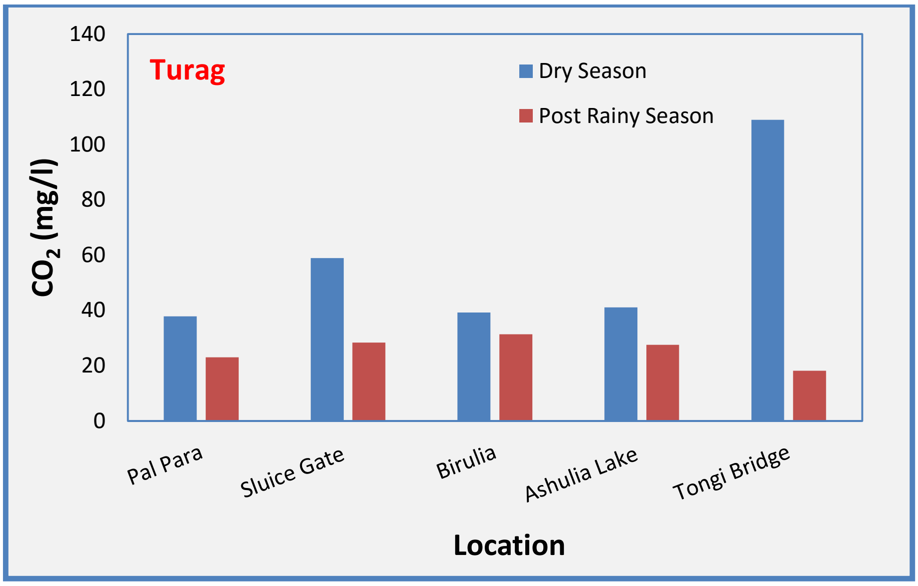


Figure 4.1.60: Variation in free CO_2 in mg/l between dry season and post rainy season at different locations in Turag

4.2 Laboratory analysis of Heavy metals & COD and Interpretation of results

Water, sediment/soils, crops and vegetables samples were collected for heavy metal analysis and was analyzied using AAS in the laboratory.

4.2.1 Heavy metals in Water

The fate of heavy metals in aquatic systems depends on partitioning between soluble and particulate solid phases. Adsorption, precipitation, co-precipitation and complexation are processes that affect partitioning.These same processes are influenced by pH, redox potential, the ionic strength of the water, the concentration of complexing ions, and the species and concentration of the metal, affect the adsorption of heavy metals to soil (Harasim, 2015).

Water samples were collected from 16 locations from the Buriganga and 9 locations from the Bongshi River for quantifying the concentrations of heavy metals in dry season. The concentration of Cr, Cd, Pb, Ni, Fe, Zn and Cu showed a wide variation of concentrations among them but slightly differed among the location of each river. Among all the metals studied in the water, Fe concentration was the highest while Cd concentration was the lowest. Anthropogenic activities are mainly responsible for elevated levels of the measured metals in river water. The metal concentrations were compared with several standard Guideline values provided by different organizations like WHO, DoE, FAO and CCME. The following table represents the standard values of metals set by different organizations:

Table 4.2.1: Guideline value for heavy metals set by different organizations for Drinking water, Irrigation water and Aquatic life Purposes

Parameter	Drinking water		FAO (1994) Irrigation water	CCME (2007) Aquatic Life
	WHO (2011)	DoE (ECR,1997)		
Chromium	0.05 mg/l	0.05 mg/l	0.10 mg/l	0.02 µg/l, To protect fish 2.0 µg/l, To protect aquatic life including zooplankton and phytoplankton
Cadmium	0.003 mg/l	0.005 mg/l	0.01 mg/l	0.2 µg/l for Hardness 0–60 mg/l ($CaCO_3$) 0.8 µg/l for Hardness 60–120 mg/l ($CaCO_3$) 1.3 µg/l for Hardness 120–180 mg/l ($CaCO_3$) 1.8 µg/l for Hardness > 180 mg/l ($CaCO_3$)
Copper	2 mg/l	1 mg/l	0.20 mg/l	2.0 µg/l for Hardness 0–120 mg/l ($CaCO_3$) 3.0 µg/l for Hardness 120–180 mg/l ($CaCO_3$) 4.0 µg/l for Hardness > 180 mg/l ($CaCO_3$)
Iron	0.3 mg/l	0.3–1.0 mg/l	5.0 mg/l	0.3 mg/l
Lead	0.01 mg/l	.05 mg/l	5.0 mg/l	1.0 µg/l for Hardness 0–60 mg/l ($CaCO_3$) 2.0 µg/l for Hardness 60–120 mg/l ($CaCO_3$) 4.0 µg/l for Hardness 120–180 mg/l ($CaCO_3$) 7.0 µg/l for Hardness > 180 mg/l ($CaCO_3$)
Nickel	0.07 mg/l	0.1 mg/l	0.20 mg/l	25 µg/l for Hardness 0–60 mg/l ($CaCO_3$) 65 µg/l for Hardness 60–120 mg/l ($CaCO_3$) 110 µg/l for Hardness 120–180 mg/l ($CaCO_3$) 150 µg/l for Hardness > 180 mg/l ($CaCO_3$)
Zinc		5 mg/l	2.0 mg/l	0.03 mg/l

4.2.1.1 Spatial distribution of metals in water along the Bongshi and Buriganga in dry season

In Bongshi, Cr concentration varied from 234.28 to 301.39 µg/L (**Figure 4.2.1**) which is approximately six to five times greater than standard value (50 µg/L) provided by WHO and DoE (**Table 4.2.1**). According to CCME (2007) required Cr concentration is 0.02 µg/L to protect fish and 2.0 µg/L is required to protect aquatic life including zooplankton and phytoplankton. Therefore, according to CCME (2007), aquatic life impossible in this severe Cr polluted river water. At Gohailbari, Cr concentration was 250.82 µg/L. In dry season, Bongshi is a very narrow canal in this location and it carries only the waste water of various industries indicating Cr containing industrial wastes enter to this location. After this location, Cr concentration was slightly increased at Jhapna and Ronosthol location and got maximum level 301. 31 µg/L at Dhamsona after a big muddy canal connect to Bongshi which discharges industrial wastes (Beximco Company and other). A slight decrease in Cr concentration was observed at Nolam, Dockyard, Saver Nama bazar, Rafiq Bridge and New Tannery (Harin Jhara) which were 278.85, 257.07, 262.41 and 234.28 µg/L, respectively. The comperative lower concentration at Rafiq Bridge and New tannery due to lower industrial waste entered to these locations with Cr polluted water carried from upstream locations. The non-point sources of Cr may also find their way into the Bongshi River with rain water and sewage.

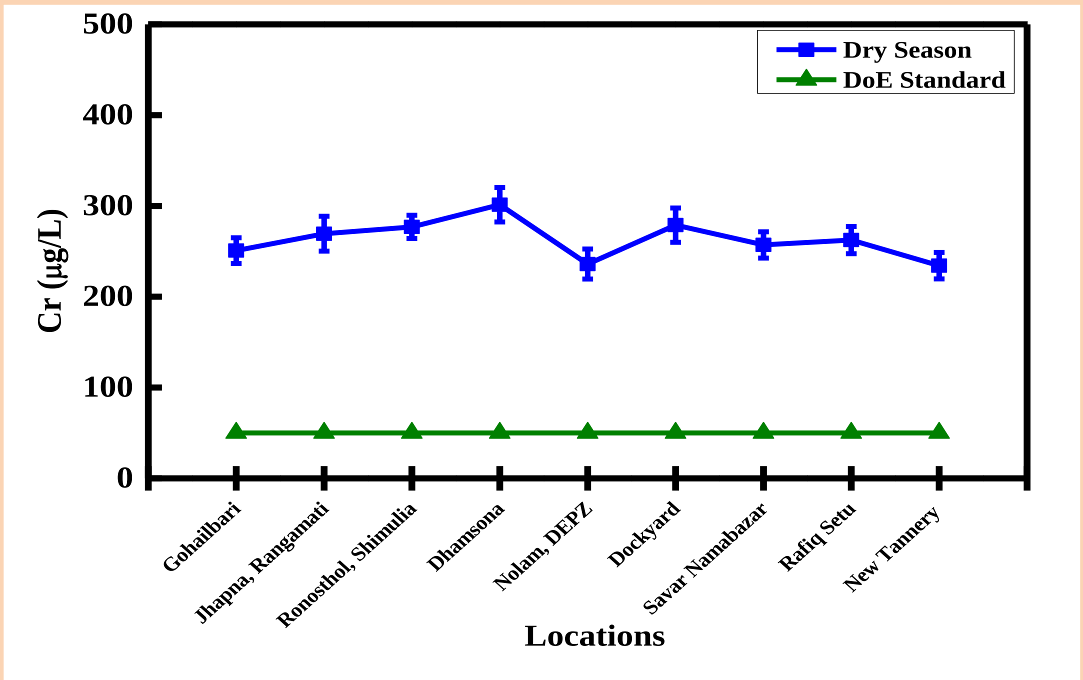


Figure 4.2.1: Variation in Cr concentration in µg/L at different locations along the Bongshi in dry season. Bars represent standard error of the mean. Green line indicates DoE standard level (ECR, 1997) for water.

The Cd concentration was relatively stable at different locations in Bongshi in Dry season. The highest Cd concentration was 28.40 at Jhapna and the lowest was 17.43 µg/L at New Tannery (Harin Jhara) in Bongshi. These levels are far above the standard value as the standard value of Cd provided by WHO (2011) is 3 µg/L and Provided by DoE (ECR,1997) is 5 µg/L. The Cd pollution mainly attributed by different industrial wastes and dockyard besides the Bongshi.

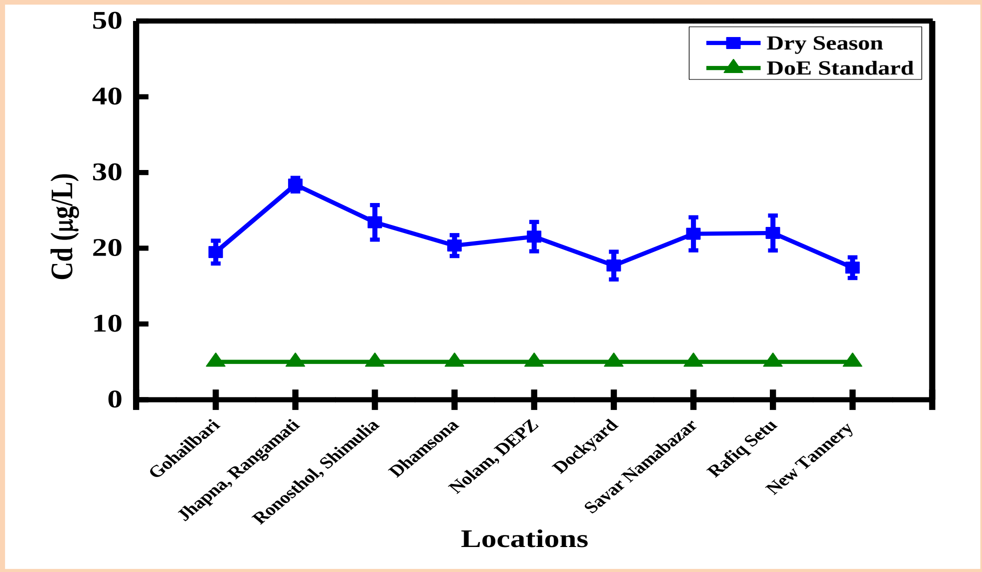


Figure 4.2.2: Variation in **Cd** concentration in µg/L at different locations along the Bongshi in dry season. Bars represent standard error of the mean. Green line indicates DoE standard level (ECR, 1997) for water.

Pb concentration was fluctuated along the Bonshi at different location in dry season. Pb concentration in Bongshi exceeded the standard value set by WHO and DoE (**Table 4.2.1**; **Figure 4.2.3**). The Pb concentration were 124.61, 150.65, 117.61, 84.18, 80.37, 122.17, 41.82 and 51.71 µg/L at Gohailbari, Jhapna, Ronosthol, Dhamsona, Nolam (d/s of DEPZ canal), Dockyard, Saver Namabazar, Rafiq Bridge and New Tannery (HarinDhara), respectively. The lower concentration of Pb at Rafiq setu and Newtannery due to lower industrial waste enters to these locations.

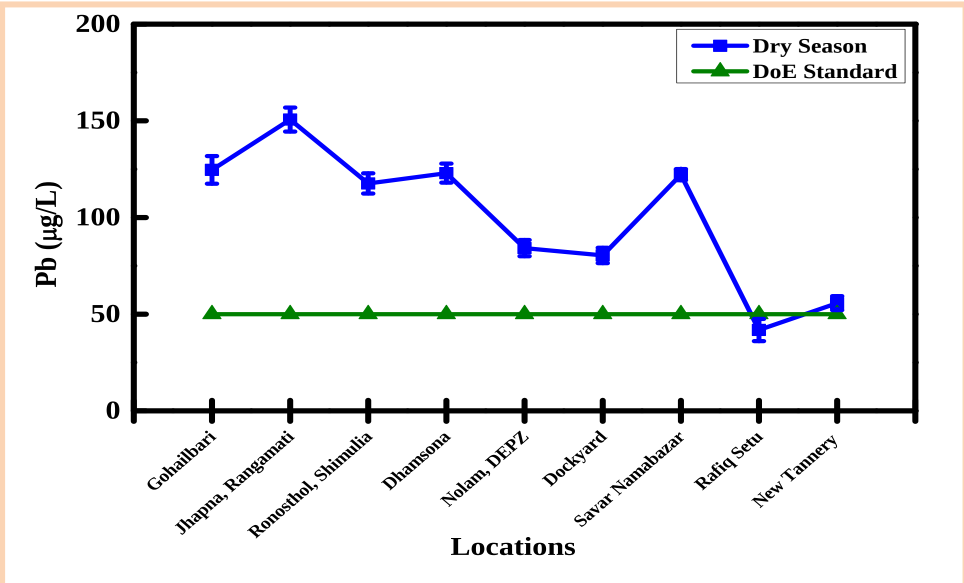


Figure 4.2.3: Variation in Pb concentration in µg/L at different locations along the Bongshi in dry season. Bars represent standard error of the mean. Green line indicates DoE standard level (ECR, 1997) for water.

Similar to Cr, Cd & Pb. The Ni concentration was varied from 150.23 to 177.38 µg/L and not significantly diffed among the locations.

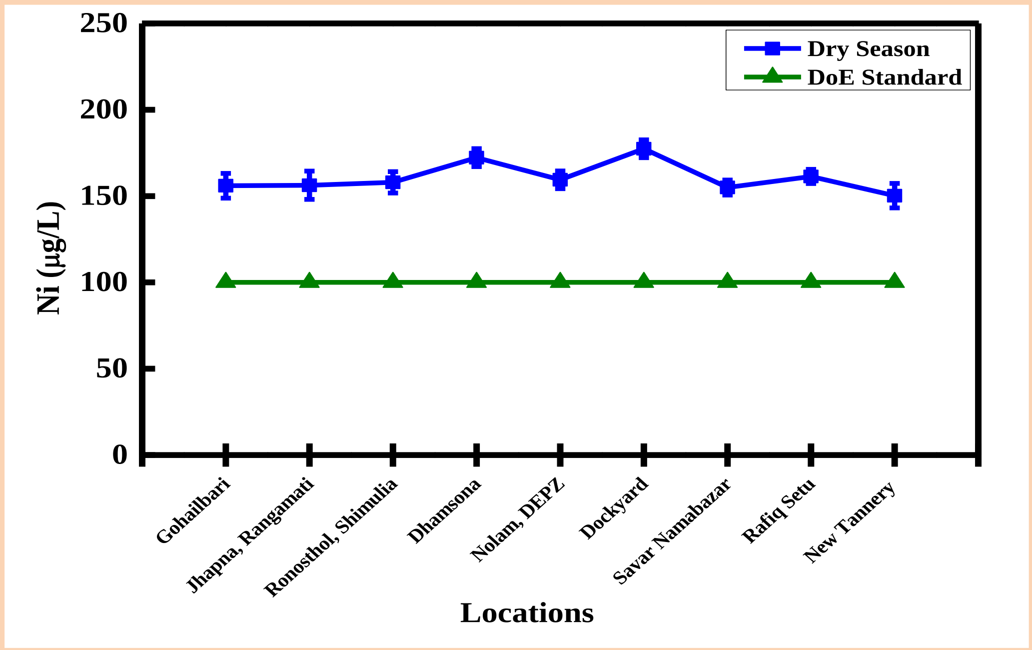


Figure 4.2.4: Variation in Ni concentration in µg/L at different locations along the Bongshi in dry season. Bars represent standard error of the mean. Green line indicates DoE standard level (ECR, 1997) for water.

The maximum concentration of Cu was found 101.72 µg/L at Jhapna and minimum was 54.00 µg/L at Nolam which are lower than the standard limit given by WHO and DoE (**Table 4.2.1; Figure 4.2.5**).

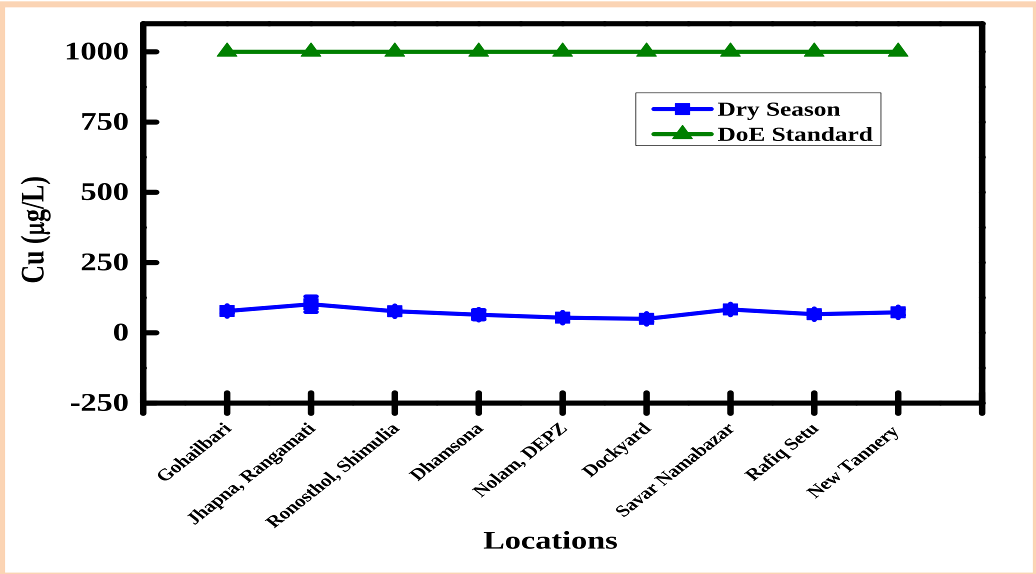


Figure 4.2.5: Variation in Cu concentration in µg/L at different locations along the Bongshi in dry season. Bars represent standard error of the mean. Green line indicates DoE standard level (ECR, 1997) for water.

Similar to Cu, Zn concentration was lower than the standard limit given by DoE (500 µg/L) and the concentration varied from 120.31 to 64.36 µg/L.

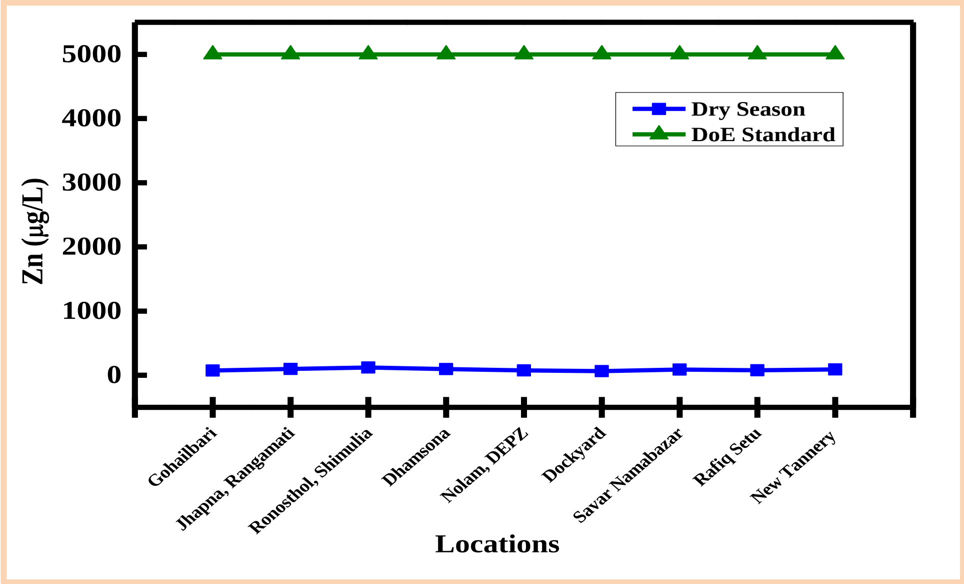


Figure 4.2.6: Variation in Zn concentration in µg/L at different locations along the Bongshi in dry season. Bars represent standard error of the mean. Green line indicates DoE standard level (ECR, 1997) for water.

Among the analyzed metals, Fe concentration was the greatest at all locations in all rivers. The wide variation of Fe concentration was observed among the locations along the Bongshi. Concentrations of Fe were found 4004. 75, 3680.57, 1488.81, 4435.57, 2789.08, 2690.91, 1373.05 µg/L at Gohailbari, Jhapna, Ronosthol, Nolam, Dockyard and Saver Namabazar which were above the standard limit given by DoE (1000 µg/L). The high concentration of Fe indicates significant Fe discharging metal industries such as the iron pipes, stailless still and dockyard are available sorroundings of these locations. At Rafiq Bridge and New tannery, concentration of Fe were 910.96 and 886.02 µg/L, respectively which were slight lower than the standard value of DoE. The Fe concentration was the lowest at Ronsthol is likely as the river at this location is comparatively wider and flow of water higher with very lower industries located sorroundings of this place.

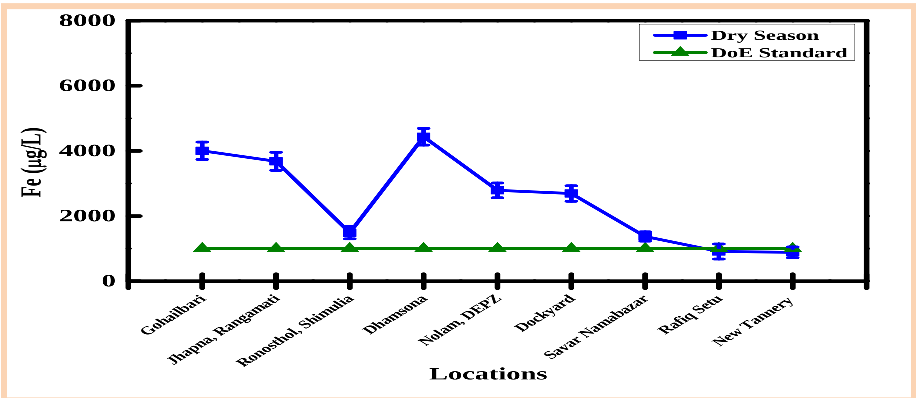


Figure 4.2.7: Variation in Fe concentration in µg/L at different locations along the Bongshi in dry season. Bars represent standard error of the mean. Green line indicates DoE standard level (ECR, 1997) for water.

Among the 16 locations in Buriganga, the maximum Cr concentration was 346.76 µg/L which is approximately seven times greater than standard value (50 µg/ L) provided by WHO & DoE and the minimum was 223.82 µg/L which is approximately four times greater than standard value (50 µg/ L) provided by WHO and DoE. Also, Cr concentration was not significantly differed among the locations indicating whole path of the river is severely Cr polluted. It is possible as the Hazaribagh tannery industries discharging their solid wastes and liquid effluent containing rotten flesh, fat, blood and skin, toxic chemicals, dissolved lime, chromium sulfate and alkali, hydrogen sulfide, sulfuric acid, bleach, dyes, oil, formic acid, heavy metals, suspended solids, organic matters, etc., in most cases without any treatment drain directly to the river Buriganga (Jahid, 2006) at different places such as Basila, Hazaribagh, Kamrangir char etc. Ministry of Environment (MoE) also reports that the tanneries collectively dump 22,000 liters of toxic waste including cancer-causing chromium into Buriganga every day (Barton, 2011). Moreover, Bongshi is situated up stream of Buriganga and this study reveals that Bongshi also carries considerable amount of Cr which flowing though the Buriganga. In this study, the excess amount of Cr in Buriganga due to upstream Cr along with Cr containing tannery wastes. Islam et al. (2014) showed that Cr concentration in Buriganga 110 µg/L in summer which is lower than this study. However, Ahmad, et al. (2010) revealed that Cr concentration were 645.26, 605.87, 613.25 µg/L at Balughat, Shawaryghat, Foridabad, respectively, in the Buriganga in Pre monsoon which were greater than this study. Difference in concentration was possibly due to the difference in collection season, time, place, amount of wastage discharge and measurement method in different studies.

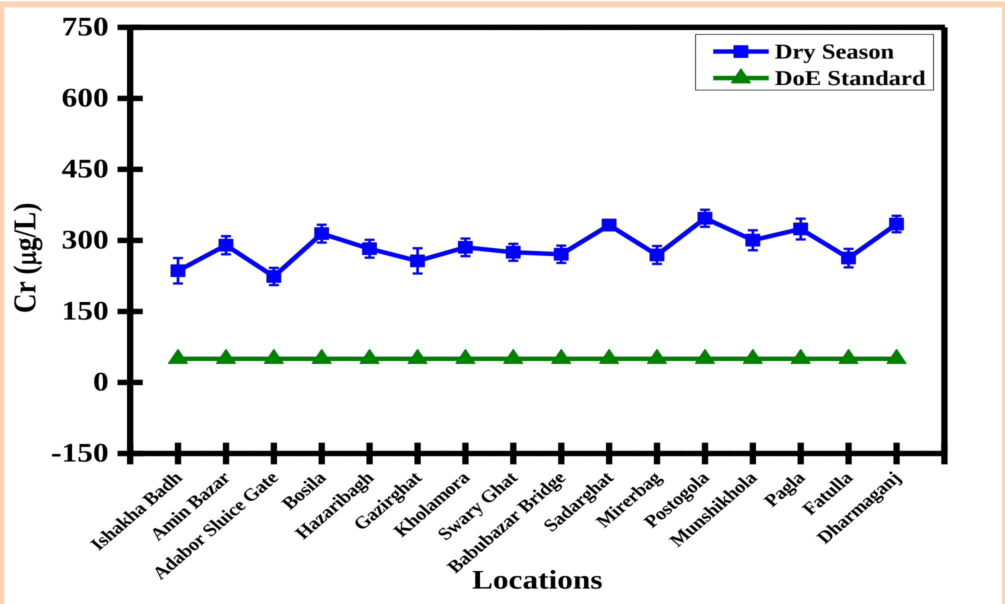


Figure 4.2.8: Variation in **Cr** concentration in µg/L at different locations along the Buriganga in dry season. Bars represent standard error of the mean. Green line indicates DoE standard level (ECR, 1997) for water.

The highest Cd concentration was 22.25 at Sadarghat and the lowest was 11.67 µg/L at Munshikhola in Buriganga that are far above the standard value as the standard value of Cd provided by WHO is 3 µg/L and Provided by DoE is 5 µg/L. However, different studies showed that variation in Cd concentration in Buriganga. For example Ahmed et al. (2010) found that Cd concentration varied from 9.21 to 10.03 µg/L; Sikder et al. (2012) found 3.03 µg/L and Islam et al. (2014) found 10 µg/L in Buriganga.

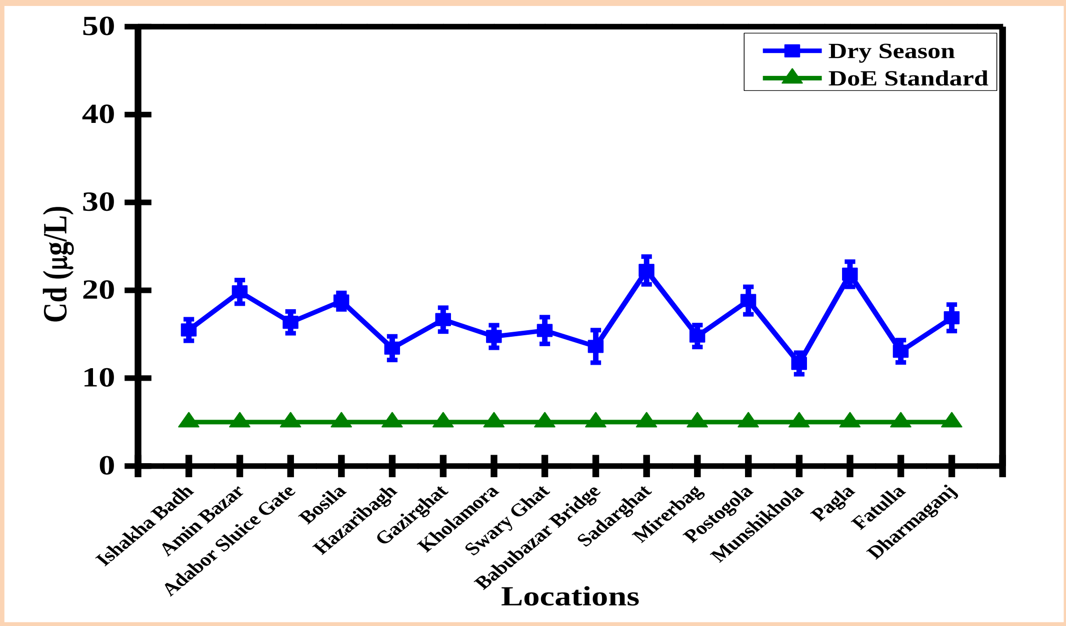


Figure 4.2.9: Variation in **Cd** concentration in µg/L at different locations along the Buriganga in dry season. Bars represent standard error of the mean. Green line indicates DoE standard level (ECR, 1997) for water.

The Pb concentration fluctuated from 52.24 to 97.30 µg/L through the whole path of the Buriganaga (Ishakha Badh to Dharmaganj) which is approximately five to nine fold greater than WHO standard limit and one to two fold greater value provided by DoE (ECR, 1997). Similar Pb concentrations were observed Ahmed et al. (2010) in some places like Swaryghat, Gazirghat, Balughat in Buriganga in Pre-Monsoon.

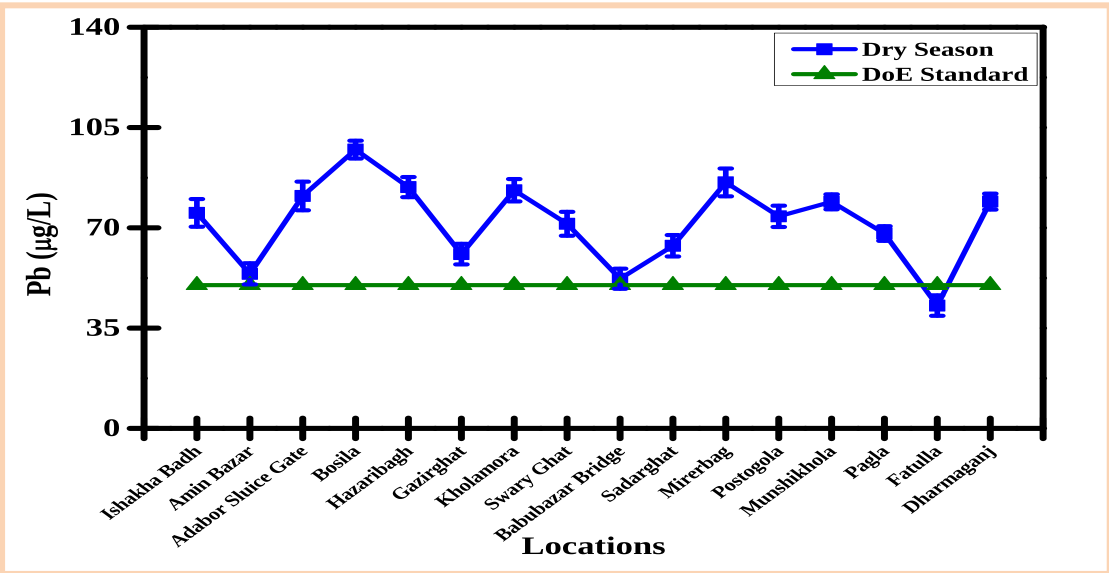


Figure 4.2.10: Variation in **Pb** concentration in µg/L at different locations along the **Buriganga** in dry season. Bars represent standard error of the mean. Green line indicates DoE standard level (ECR, 1997) for water.

Concentration of Ni varied from 129.87 to 208.15 µg/L which are exceeded the recommended value provided by WHO and DoE. However, Ahmed et al. (2010) observed far lower Ni concentration than this study in Buriganga.

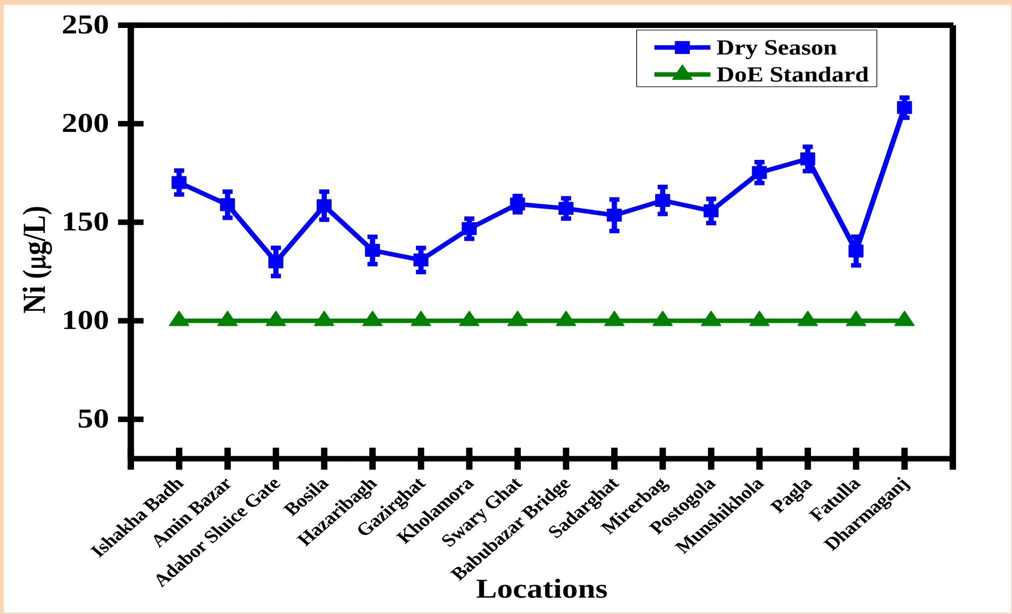


Figure 4.2.11: Variation in **Ni** concentration in µg/L at different locations along the **Buriganga** in dry season. Bars represent standard error of the mean. Green line indicates DoE standard level (ECR, 1997) for water.

Concentration of Cu varied from 44.57 to 89.89 µg/L and Zn varied from 58.75 to 151.48 µg/L which were lower that the recommended value provided by WHO and DoE. Concentration of Cu at Swaryghat was 68.18 µg/L whereas Ahmed et al. (2010) observed that Cu concentration was 132.18 µg/L at Swaryghat in Pre monsoon.

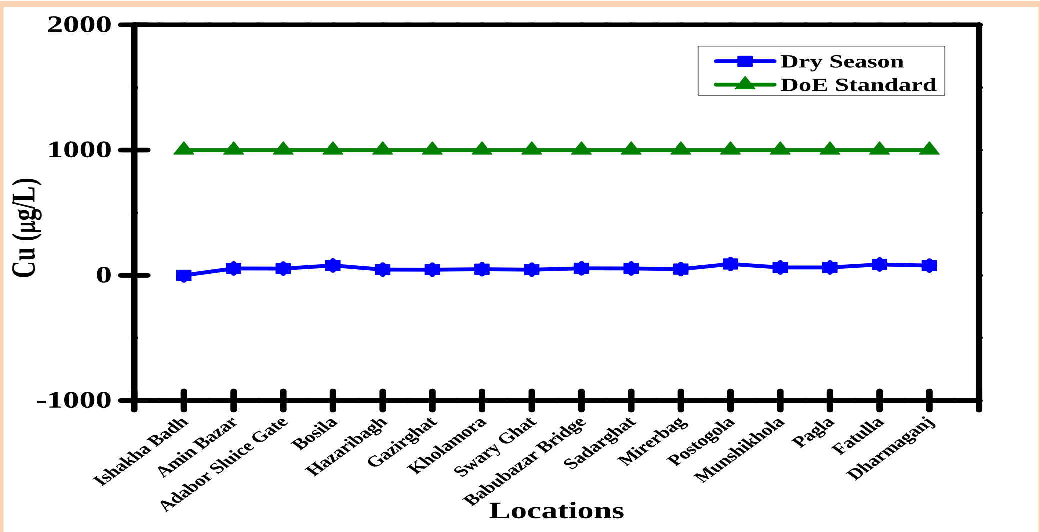


Figure 4.2.12: Variation in **Cu** concentration in µg/L at different locations along the Buriganga in dry season. Bars represent standard error of the mean. Green line indicates DoE standard level (ECR, 1997) for water.

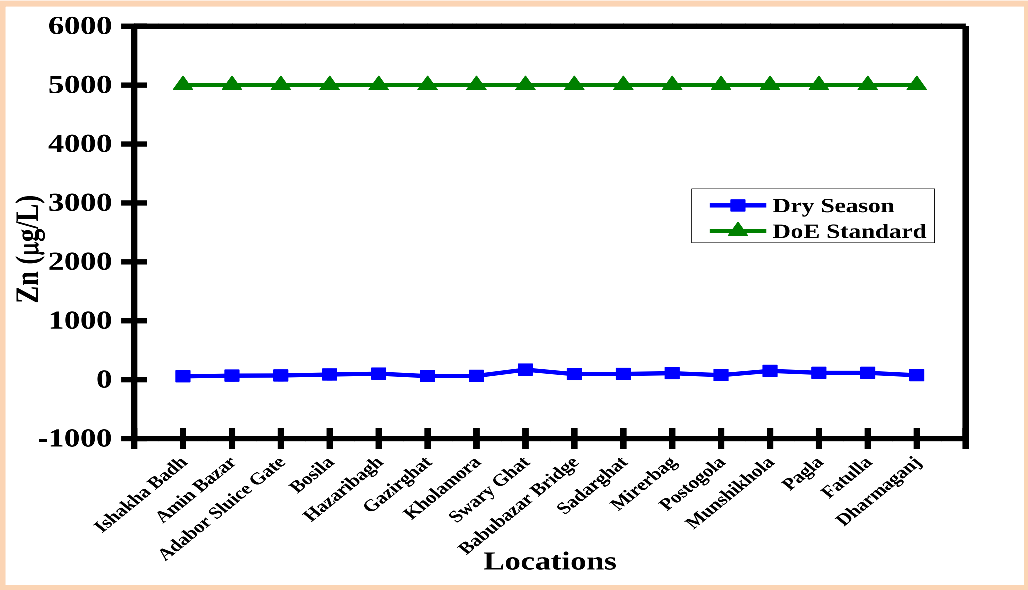


Figure 4.2.13: Variation in **Zn** concentration in µg/L at different locations along the **Buriganga** in dry season. Bars represent standard error of the mean. Green line indicates DoE standard level (ECR, 1997) for water.

In Buruganga, concentration of Fe was fluctuated at different locations and varied from 995.55 to 1909.19 µg/L. The standard value provided by DoE (ECR, 1997) is 300 to 1000 µg/L for drinking water and 300 µg/L for aquatic life (CCME, 2007) which is lower than the values found in this study indicating iron contamination occur in Buriganga. The Fe concentration is mainly attributed by water vehicle and dockyard in this river. However, Fe concentration was much lower than this study observed by Sikder et al. 2012.

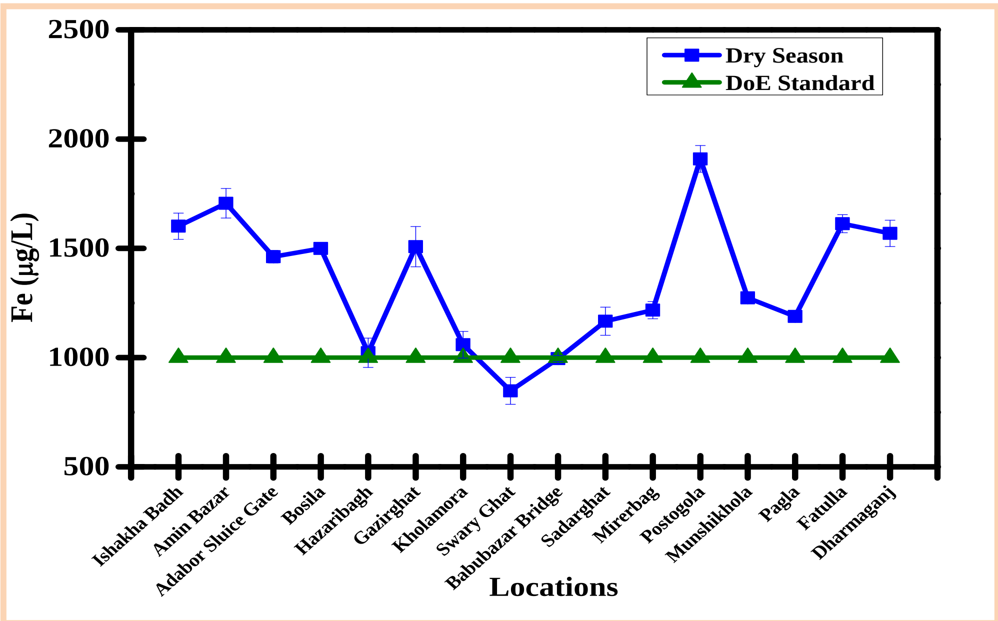


Figure 4.2.14: Variation in **Fe** concentration in µg/L at different locations along the **Buriganga** in dry season. Bars represent standard error of the mean. Green line indicates DoE standard level (ECR, 1997) for water.

The concentrations of heavy metals in water collected from 16 locations along the Buriganga and 9 locations along the Bongshi River are summarized in **Table 4.2.2.** The concentration of Fe, Zn, Cu, Cr, Cd, Pb and Ni showed a wide variation of concentration among the metals but slightly differed among the location of each river. The concentration of metals significantly differed among them ($P < 0.001$) and was found in order of Fe> Cr > Ni > Zn > Pb > Cu > Cd. Among the investigated metals, Cr, Cd, Pb and Ni which are very toxic and exceeded the standard levels provided by WHO (2011), DoE (ECR, 1997) and CCME (2007) in all locations of these rivers. These findings may be related to the adsorption of the heavy metals by metal oxides or hydroxides. Major sources of these elements in river water include industrial wastes including Tanneries, manufacturing processes related to chemicals and metals, contamination of water in natural geologic deposits, discharges of municipal waste, domestic wastes and atmospheric deposition.

Table 4.2.2. Concentration of heavy metals in the water of Buriganga and Bongshi River at different locations in dry season in µg/l

River Name	Location	Cr	Cd	Pb	Ni	Fe	Zn	Cu
Bongshi	Gohail Bari	250.82	19.49	124.61	155.97	4004.75	73.03	77.47
	Jhapna	269.39	28.40	150.65	156.28	3680.57	98.13	101.72
	Ronosthol, Shimulia	276.91	23.42	117.61	157.97	1488.81	120.31	76.94
	Dhamsona	301.39	20.35	122.93	172.26	4435.57	97.01	64.47
	Nolam, d/s of DEPZ	236.03	21.52	84.18	159.02	2789.08	75.36	54.00
	Dockyard	278.85	17.71	80.37	177.38	2690.91	64.36	49.61
	Savar Namabazar	257.07	21.91	122.17	154.95	1373.05	88.44	83.36
	Rafiq Setu	262.41	22.01	41.82	161.36	910.96	78.18	66.22
	New Tannery, Hemayetpur	234.28	17.43	55.71	150.23	886.02	91.67	73.13
Buriganga	Ishakha Badh	236.06	15.48	75.21	170.15	1601.27	58.75	58.79
	Amin Bazar	289.90	19.82	53.94	158.91	1706.23	70.33	54.30
	Adabor Sluice Gate	223.82	16.35	81.12	129.87	1461.91	73.15	54.07
	Bosila	314.36	18.77	97.30	158.40	1499.36	89.04	78.38
	Hazaribagh	282.46	13.42	84.23	135.69	1022.34	104.01	46.03
	Gazirghat	256.82	16.66	60.84	130.84	1507.68	61.93	44.57
	Kholamora Boat Ghat	285.50	14.74	83.10	146.74	1058.89	66.86	48.45
	Swaryghat	296.28	13.54	74.50	172.89	1219.73	141.69	68.18
	Babubazar Bridge	270.82	13.61	52.24	157.03	995.55	94.06	55.06
	Sadarghat	332.53	22.25	63.74	153.60	1166.57	98.98	54.22
	Mirerbag, Balighat	269.25	14.79	85.85	161.07	1216.96	111.77	49.73
	Postogola	346.76	18.83	74.01	155.75	1909.19	78.84	89.89
	Munshikhola	300.41	11.67	79.09	175.21	1273.56	151.48	62.18
	Pagla	324.14	21.83	68.02	182.14	1188.59	118.41	62.62
	Fatulla	262.72	13.06	42.87	135.40	1612.55	118.39	86.32
	Dharmaganj	334.61	16.87	79.16	208.15	1568.41	76.61	77.39

4.1.2.2 Seasonal variation of metals along the rivers

To observe the seasonal variation of metals, water samples were collected from 8 locations of Bongshi and Buriganga in post rainy season (October 2015). Water samples were collected from Gohailbari, Dhamsona, DEPZ, New tannery in Bongshi and from Amin Bazar, Hazarribagh, Saderghat, Fatulla in Buriganga and determined metals in the laboratory. As expected, concentrations of heavy metals were greater in dry season compared to post rainy season. In post rainy season, the concentration of metals was diluted due to volume of water increased from upstream, runoff and rainfall.

In Bongshi, Cr concentration varied from 234.28 to 301.39 µg/L in dry season whereas 94.88 to 124.34 µg/L in post rainy season. Concentration of Cr in dry season was significantly different ($P < 0.05$) than that of post rainy season. In post rainy season even though Cr concentration was much lower than dry season, it was approximately double than the standard level provided by WHO and DoE. The concentration of Cr at Gohailbari, Gohailbari, Dhamsona, DEPZ, New tannery were 269.39, 301.39, 240.82 and 234.28 µg/L, respectively in dry season whereas 99.94, 124.34, 94.88, 95.34 µg/L in post rainy season. In Buriganga, Cr concentration were 289.90, 282.46, 332.52 and 262.72 µg/L at Amin Bazar, Hazarribagh, Sadorghat, Fatulla in dry season whereas 127.70, 97.49, 121.22 and 116.60 µg/L in post rainy season at same places.

Table 4.2.3. Seasonal variation of Concentration of metals in the water of Buriganga and Bongshi rivers in µg/l

River Name		Location	Cr	Cd	Pb	Ni	Fe	Zn	Cu
Bongshi	Dry season	Gohailbari	269.39	28.40	150.65	156.28	3680.57	98.13	101.72
		Dhamsona	301.39	20.35	122.93	172.26	4435.57	97.01	64.47
		DEPZ, Nolam	240.82	21.22	73.01	158.61	2203.47	65.34	52.24
		New Tannery	234.28	17.43	55.71	150.23	886.02	91.67	73.13
	Post rainy season	Gohailbari	99.94	38.71	29.23	57.09	2424.09	39.02	22.45
		Dhamsona	124.34	36.90	32.33	61.38	3280.81	34.71	13.49
		DEPZ, Nolam	94.88	36.81	59.90	61.14	3189.15	37.87	21.49
		New Tannery	95.34	37.65	38.96	60.58	1436.073	65.92	72.58
Buriganga	Dry season	Amin Bazar	289.90	19.82	53.94	158.91	1706.23	70.33	54.30
		Hazaribagh	282.46	13.42	84.23	135.69	1022.34	104.01	46.03
		Sadarghat	332.53	22.25	63.74	153.60	1166.57	98.98	54.22
		Fatulla	262.72	13.06	42.87	135.40	1612.55	118.39	86.32
	Post rainy season	Amin Bazar	127.70	39.28	28.94	56.37	1418.59	38.12	34.29
		Hazaribagh	97.49	39.75	21.97	56.72	1174.02	41.99	24.75
		Sadarghat	121.22	40.12	30.47	60.75	1249.41	43.60	33.23
		Fatulla	116.60	38.33	28.67	57.87	1239.97	34.97	21.19

4.2.1.3 Variation of metal among the rivers in post rainy season

Pollution of heavy metal concentration in Buriganga, Bongshi and Turag has decreased in post rainy season. Even though the toxic metals concentration has decreased in post rainy season, some severe toxic heavy metals like Cr, Cd, Ni and Pb are far above the safe recommended value. The lower level of these metals during post rainy season is due to dilution by rain water as well as runoff. Among the toxic metals, Cr concentration was the gretest in the Bongshi, Buriganga and Turag in post rainy season flowed by Zn, Ni, Pb, Cd and Cu in post rainy season.

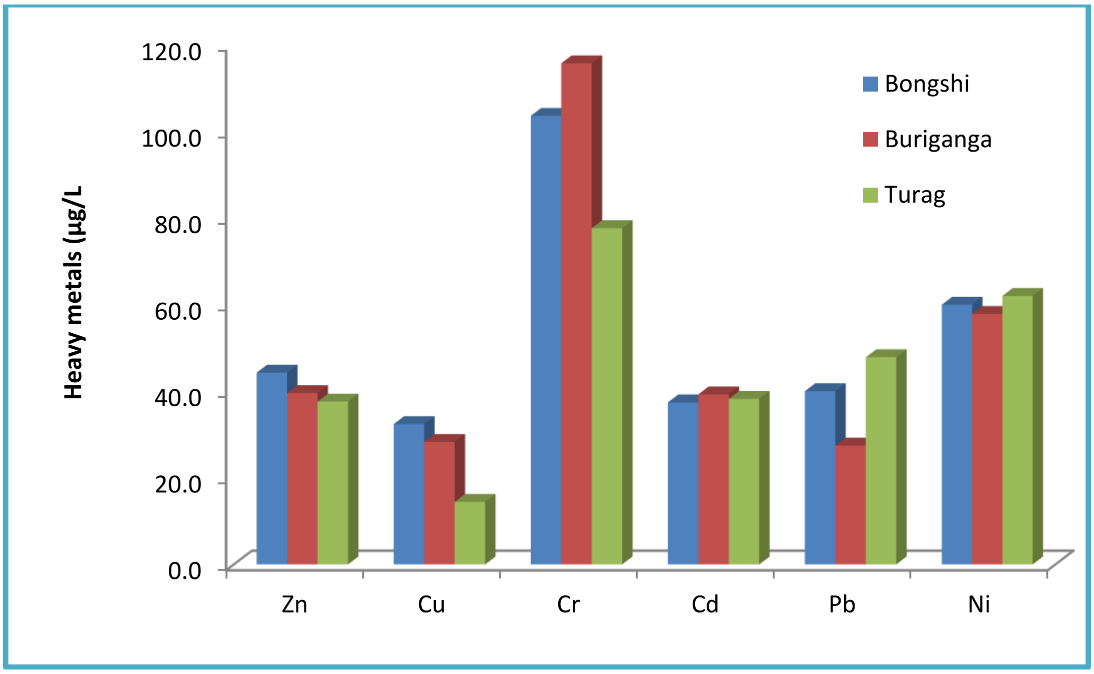


Figure 4.2.15: Average heavy metals concentration in µg/L in Buriganga, Bongshi and Turag in post rainy season

As heavy metals are non-degradable and not decomposable it is likely to exist with the flow of water in post rainy season shoed in **Figure 4.2.16**. During July to November Rivers are full of water in Dhaka and generally the water seems good in terms of odour and colour. Therefore, it is very alarming that it is polluted with heavy metals during this period too. Usually when volume of water increased contaminant will be diluted, however, these toxic metals still exist in to the environment. That means if flow can increase in dry season but also toxic metals contamination will be on going.

4.2.2 Heavy metals in river bank soils/sediment

Sediment/ soil contamination poses one of the worst environmental problems in ecosystems, acting as sinks and sources of contaminants in aquatic systems. Sediment analysis plays an important role in assessing the pollution status of the environment (Mucha et al. 2003). The bioavailability of sediment-bound trace metals is dependent not only on the total metal concentration, but also on the strength of the association between the metal and sediment compounds.

Table 4.2.4 showed heavy metal concentration within soil/sediments that has been collected from four rivers at different locations in dry seasons. From the results, it is found that considerable amount of all seven metals are present in collected soil/sediments. The highest heavy metal concentration in soil/sediment was found for 27259.44 mg Fe soil/kg among four rivers. In contrast, the lowest heavy metal concentration in soil/sediment was found for 0.19 mg/kg Ni soil among four rivers. However, Cr, Pb, Cd and Ni were toxic among all heavy metals.

Comparing the results of heavy metals in soil/sediment with their level of concentration, it is observed that average heavy metal concentrations were highest in Bongshi followed by Buriganga, Turag and Shitalakhya rivers respectively. It is also obserbed that the average Cr, Pb, Cd, Ni, Cu, Zn and Fe were 61.12, 39.82, 14.06 and 18.44 mg/kg soil respectively for these rivers.

Table 4.2.4. Concentration of heavy metals in river bank soil/sediment at different locations of the four rivers in dry season in mg/kg

River	Location	Cr	Pb	Cd	Ni	Cu	Zn	Fe
Bongshi	Gohailbari	76.79	91.86	2.41	51.60	57.27	113.83	26619.50
	Dhamsona	45.44	12.18	2.32	52.25	60.16	118.68	27259.44
Buriganga	Kholamora	22.20	16.10	2.70	5.02	14.02	59.14	11364.59
	Pagla	57.43	9.92	2.42	26.90	32.43	94.74	23418.24
Turag	Tongi Bridge	13.70	6.11	2.78	5.55	19.05	90.65	14109.12
	Sluice Gate	14.41	9.40	2.30	4.41	11.94	48.54	11718.26
Shitalakhya	EPZ Adamzi	17.64	1.82	2.45	0.77	15.01	45.24	10369.70
	Kanchpur Bridge	19.23	2.92	2.32	0.19	11.03	34.88	12216.19

Concentration of heavy metals in river bank soil was greater compared to river water at the same location indicating accumulation of heavy metals in soil/sediment. The high concentrations of the studied elements may be attributed to the effect of intrusion of water borne Cr, Pb, Cd, Ni, Cu, Zn and Fe coming from mainly industrial effluents, sewarege, municipalities, agricultural wastes and grain size of the sediment facilitates the adsorption of these metals to bottom sediments. The proportion of exchangeable metals in given sediment is also dependent on other environmental variables. These include the physical and chemical characteristics of both the sediment pore water and the overlying waters. Bouraie (2010) reported that heavy metals concentrations in sediment, especially in the fine grained sediment acts as a transport agent in the water column and the magnitude at least three orders higher than the same metals in surrounding water.

4.2.3 Accumulation of heavy metals in Vegetables

Levels of heavy metals in tomato, pumpkin and red amaranth from Gohailbari location at the bank of Bongshi has shown in **Figure 4.2.18**. The heavy metal contamination in vegetables was found in order of red amarangth (lal shak) > tomato > pumpkin. Red amaranth accumulates higher concentration of metals than tomato and pumpkin. For example, chromium concentration was 10.40 mg/kg in red amarangth whereas 4.13 mg/kg in tomato and 3.42 mg/kg in pumpkin. Wuana (2011) reported that higher concentrations of metals are more likely to be found in leafy vegetables (e.g., lettuce) and on the surface of root crops. Among the metals, Fe concentration was the highest in vegetables. Severe toxic metals like Cr, Pb and Ni were found considerable amount in vegetables. Moreover, Cd concentration was lower in vegetables compared to Cr, Pb and Ni concentration. Accumulation of heavy metals in vegetables depends on environmental condition, metal species and plant available forms of heavy metals (Lokeshwari and Chandrappa, 2006) and soil physio-chemical properties.

The accumulation of these heavy metals in vegetables occurs due to the use of industry/sewage-fed river water for cultivation. Industry/sewage-fed river water contains metals which accumulate to soil, and vegetables plants take up these metals from soil. Most of the laboratory research on bio-sorption of heavy metals indicates that no single mechanism is responsible for metal uptake (Lokeshwari and Chandrappa, 2006). In adsorption and absorption general two mechanisms are known to occur. Adsorption refers to binding of metals onto the surface and absorption implies penetration of metals into the inner matrix. Either one of these or both the mechanisms might take place in the transportation of the metals into the plant body. For example, the concentration of Pb in contaminated river water was 0.125 mg/L. This Pb accumulated to river bed for long time and increased the concentration which was 91.9 mg/kg. Plant up taken Pb from the soil either adsorption or absorption or both the mechanisms might take place in the transportation of the metals into the plant body in red amaranth 5.55mg/kg, in tomato 5.11 mg/kg and in pumpkin 2.84 mg/kg.

Stasinos and Zabetakis (2013) found that certain vegetables take up heavy metals from contaminated water used for irrigation. A research carried out at greenhouses similar to field conditions using heavy metal contaminated irrigation to grow onions, potato and carrots in Greece. They found that concentrations of nickel and chromium increased in potatoes and onions, but not in carrots at the same condition. The authors explained that possibly the metals may accumulate in parts of the plant other than the vegetable itself. The authors also suggested that comprehensive study will be required to know the metal uptake mechanisms for vegetables.

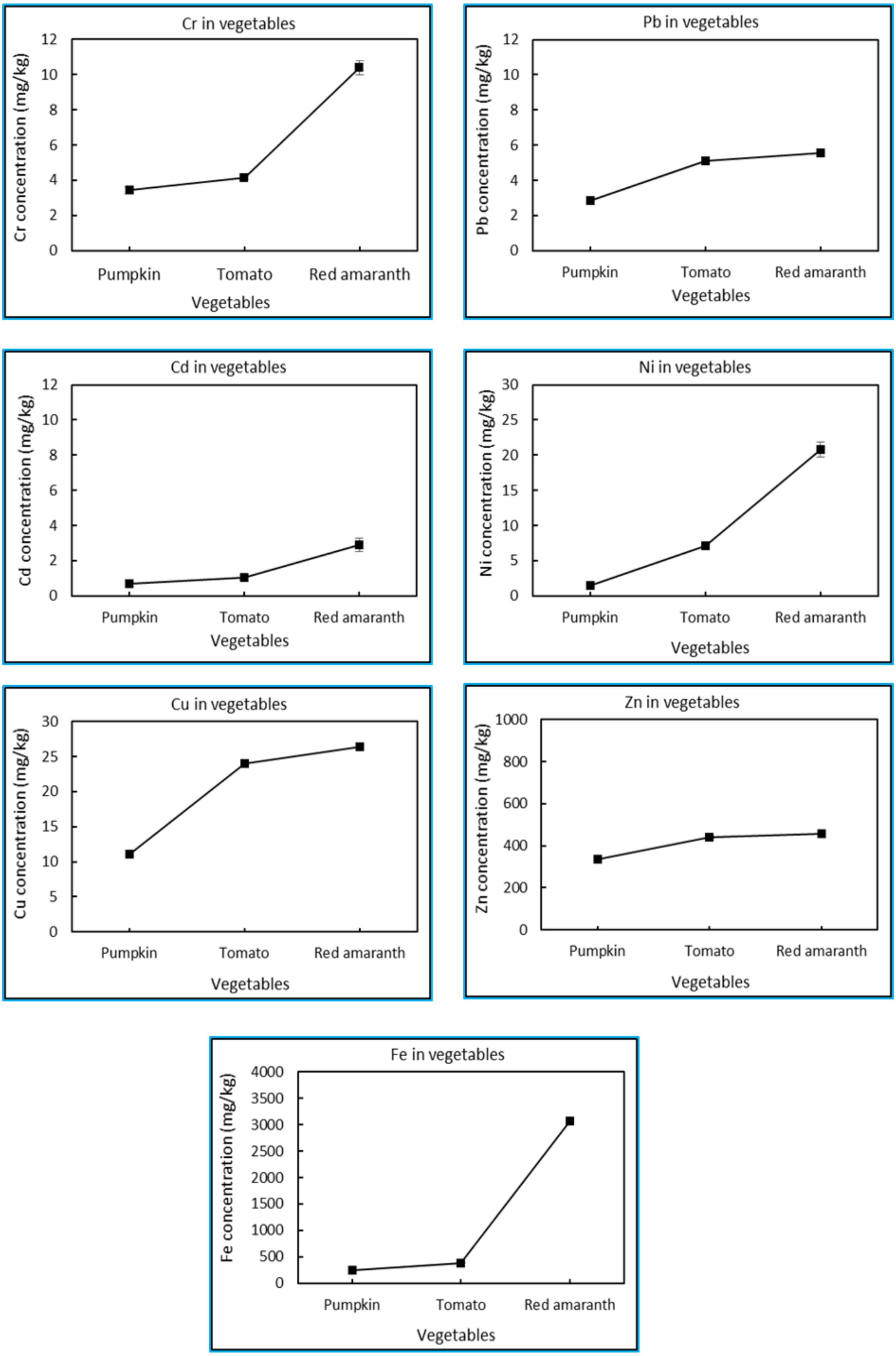


Figure 4.2.16: Concentration of metals in pumpkin, tomato and red amaranth in mg/kg at Gohailbari. Bar represent standard error of the mean. Note that scales are different in Y-axis.

4.2.4 Accumulation of Heavy metals in rice plant

The accumulation of heavy metals in rice grain, straw and root (mg/kg dry wt.) of the plant have presented in Figure 3. It is found that all metals in the roots of the plant are present in high concentration compared to other parts of plant followed by straw and grain. Metal concentrations were significantly ($P < 0.001$) differed among the metals and also among the parts of the plants. Chromium concentration was found in paddy crop ranges from 4.80 to 24.40 mg/kg; Pb ranges from 4.98 to 21.51; Cd ranges from 0.61 to 0.83; Ni ranges from 1.72 to 23.11; Cu ranges from 10.58 to 63.61; Zn ranges from 52.78 to 243.24 and Fe ranges from 1257.30 to 7219.90 (Figure 3). Metals concentration were observed in order of Fe> Zn> Cu for root, straw and grain. However, toxic metals Cr, Pb, Ni and Cd were accumulated at different concentrations for different parts of the plant. Metals concentration were in order of Cr> Ni> Pb > Cd, Pb> Cr > Ni> Cd and Cr> Pb> Ni> Cd for root, straw and grain, respectively. Plants take up heavy metals by absorbing them from deposits on the parts of the plants exposed to the air from polluted environment as well as from contaminated soils (Singh, 2010).

It was found that Fe, Zn, Cu, Pb and Cr in the roots of the rice crop were present in high concentration compared to other parts of plant. Since paddy crop is usually planted in flooded soils, the uptake of metals through roots depends on the presence of metal concentrations in water as well as in the soil. This uptake mechanism of heavy metals includes both adsorption from soil and absorption from water and takes place through the roots. Hence Pb concentration in paddy roots is the highest compared to other parts. The distribution of lead subsequently takes place to other parts of the plant from the root. Uptake of metals in plants is regulated by pH, particle size and cation exchange capacity of the soil as well as by root exudation and other physio-chemical parameters.

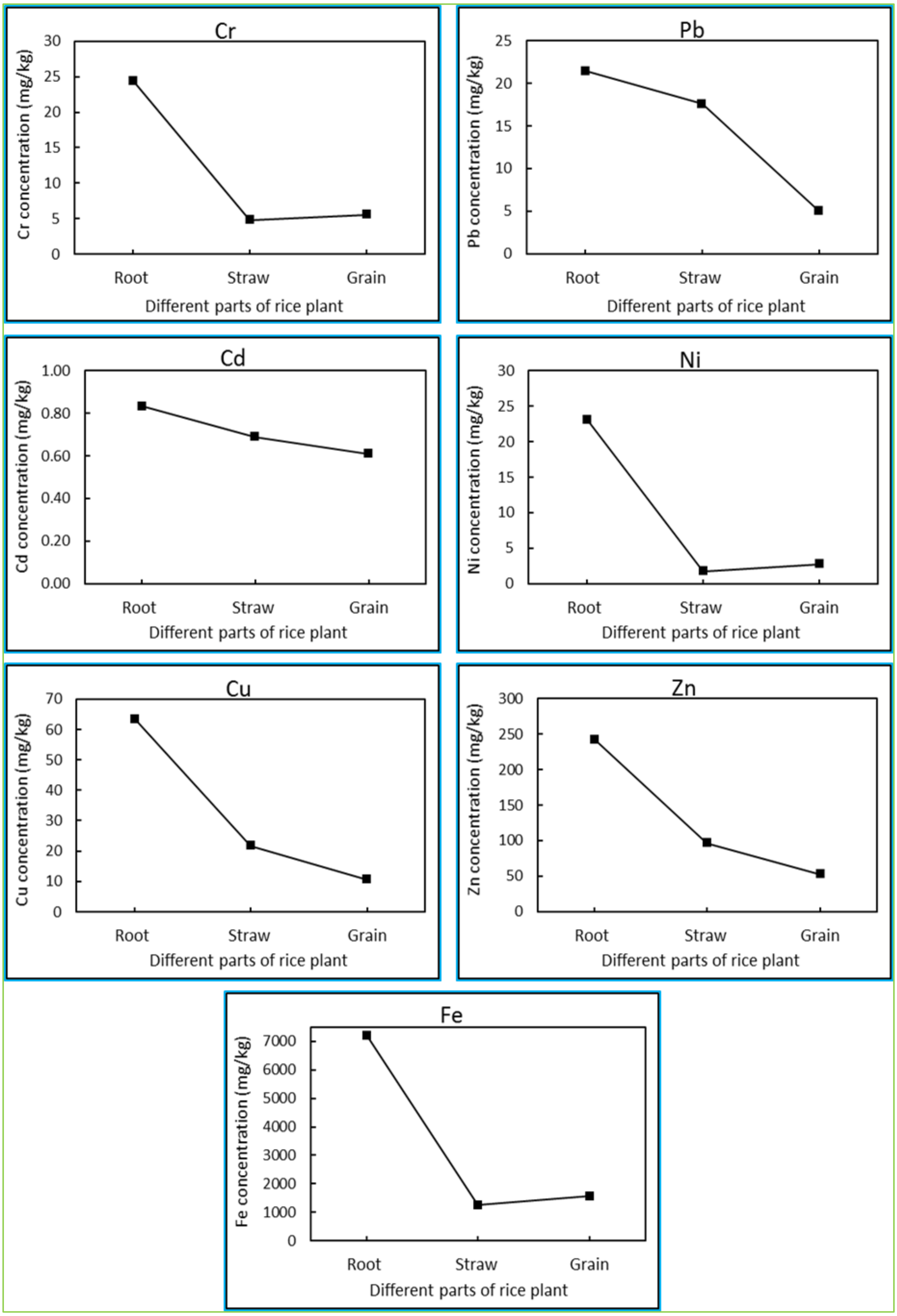


Figure 4.2.18: Concentration of metals in different parts of rice plant in mg/kg at Gohailbari. Note that scales are different in Y-axis.

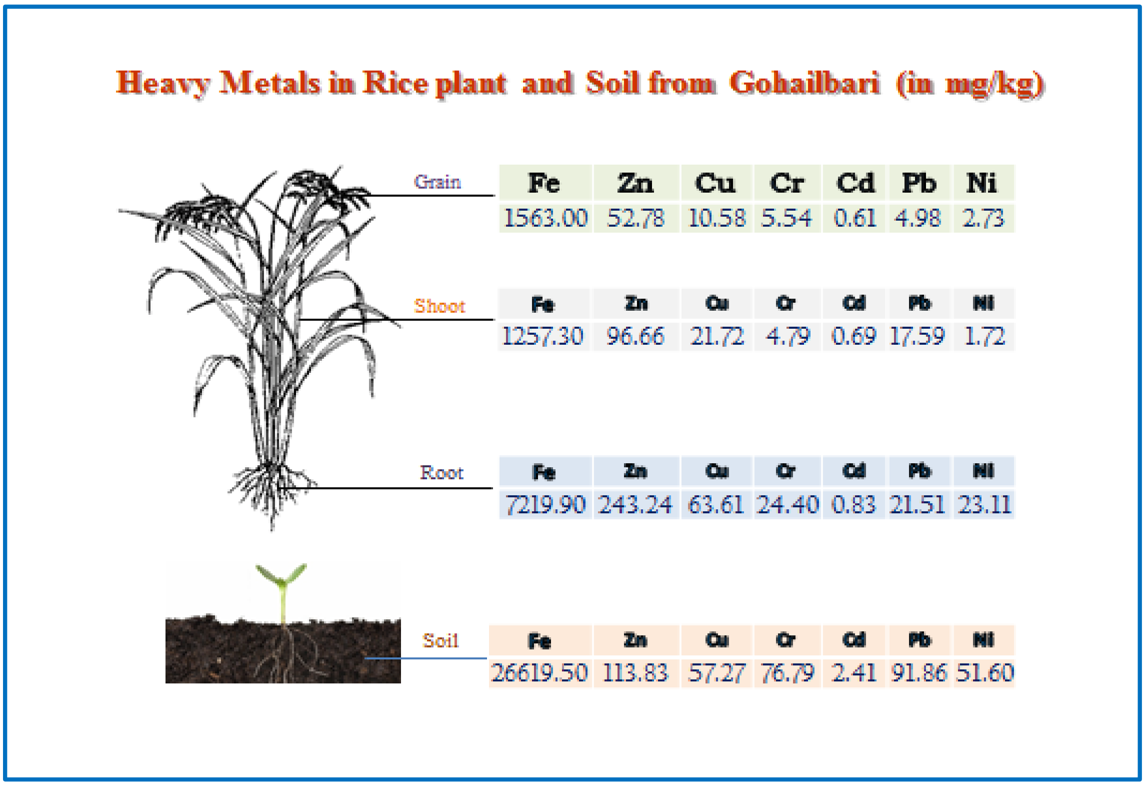


Figure 4.2.18: Variation in **metals** concentration in different parts of rice plant at Gohail Bari in Bongshi mg/Kg in dry season.

4.2.5 Accumulation of heavy metals in river bank soil at Gohailbari

The heavy metal concentration in the river water which was used for irrigation purposes has shown in **Table 4.2.8**. The concentrations of Cr, Cd, Pb, Ni, Cu, Zn and Fe were 0.251, 0.019, 0.125, 0.156, 0.077, 0.073 and 4.005 mg/L, respectively. The Cr and Cd concentrations were above the recommended maximum value set by FAO (1994) and CCME (2007) for irrigation, and lower Pb, Ni, Cu, Zn and Fe. Water was collected at surface level from the river for quantifying heavy metals. Therefore, it is possible that measured concentrations may lower concentration than which pumped to paddy field for irrigation.

Table 4.2.5: Concentration of heavy metals in river bank soil in mg/kg and river water in mg/L at Gohailbari, and recommended maximum concentration set by FAO (1994) and CCME (2007) for irrigation water in (mg/l)

Parameter	Cr	Cd	Pb	Ni	Cu	Zn	Fe
River water	0.251	0.019	0.125	0.156	0.077	0.073	4.005
Soil	76.8	2.4	91.9	51.6	57.3	113.8	26619.5
FAO (1994) for irrigation	0.10	0.01	5.0	0.20	0.20	2.0	5.0
CCME (2007) for irrigation	0.1	0.01	0.2	0.2	0.2 (for sensitive crop) 1.0 (for tolerant crop)	5 pH> 6.5	5.0

Table 4.2.8 also represents the heavy metal concentration in river bank soil that has been collected at Gohailbari location in dry season. The results showed that considerable amount of all seven metals were present in collected soil. The Fe concentration was the highest which was 26619.5 mg/kg among the metals in soil. In contrast, the lowest heavy metal concentration was found Ni which was 51.6 mg/kg. The concentration of heavy metals in soil was far above the concentrations in river water. The possible reason is that heavy metal is continuously flowing with water which also deposited to river bed continuously depending on soil adsorption and cation exchange capacity.

4.2.6 Accumulation of Heavy metals in Fish

Analysis of heavy metal accumulations in fishes were carried out at spatial, temporal and species basis. Concentrations of seven heavy metals Cr, Pb, Cd, Ni, Cu, Zn and Fe were quientified in whole fish and represent results in mg/Kg in dry weight basis. Table 4.2.9 showed the spatial variation heavy metal accumulations of fishes *Channa Punctatus* locally known as Taki and *Heteropneustes fossilis* locally known as Shing collect in dry season from the rivers Bangshi, Turag and Shitalakhya. All the heavy metals are found higher in Bangshi River then Shitalakhya River for Taki fish while in Turag River has the lowest heavy metal concentration among the rivers except Cr, Ni and Zn. In Turag River, Cr and Zn is found to be higher than Shitalakhya River but lower than Bongshi River. Ni is found to be highest in Turag River (2.32mg/Kg) than the other two. The highest and lowest values of Cr, Pb, Cd, Ni, Cu, Zn and Fe are found to be 5.01-6.83mg/Kg, 0.63-1.06 mg/Kg, 0.18-0.54 mg/Kg, 1.35-2.32 mg/Kg, 0.70-4.15 mg/Kg, 57.83-70.80 mg/Kg and 85.34-132.39 mg/Kg respectively. For Shing fish, Cr is highest in Shitalakhya River (8.07mg/Kg) and lowest in Turag River (4.30mg/Kg). Pb, Cu and Fe showed an analogous trend as Taki i.e. the concentration varies as Bangshi>Shitalakhya>Turag. Highest value for Pb, Cu and Fe are 3.84mg/Kg, 2.42mg/Kg and 424.3mg/Kg respectively while the lowest values are 0.83mg/Kg, 1.32mg/Kg and 195.1mg/Kg respectively. These variations of concentrations occurred mainly due to the level of pollutants falls into the river from banks which includes industrial waste, agricultural waste, human waste etc. and chemical form of freshwater environment. Organism uptake metals directly or with food particles from water body. These uptake metals then being bound into the different parts of the body of the organism and may cause harmful effect.

Table 4.2.6: Spatial Variation of heavy metal accumulations in fish in mg/Kg in dry season.

Name	Season	River	Cr	Pb	Cd	Ni	Cu	Zn	Fe
Channa Punctatus **(Taki)**	Dry	Bongshi	6.83	1.06	0.54	2.13	4.15	70.80	132.39
		Turag	5.96	0.63	0.18	2.32	0.70	63.82	85.34
		Shitalakhya	5.01	1.01	0.33	1.35	1.20	57.83	109.71
Heteropneustes fossilis **(Shing)**	Dry	Bongshi	6.65	3.84	0.54	0.29	2.42	86.82	424.3
		Turag	4.30	0.83	0.21	1.46	1.32	65.36	195.10
		Shitalakhya	8.07	1.52	0.88	0.19	2.17	113.74	253.33

Ahmed et al. (2009) studied the heavy metal concentration in fish and lobster of Shitalakhya River and found that seasonal variation of Cr, Pb, Cd, Ni and Cu ranged from 8.12-9.07mg/Kg, 9.16-13.09mg/Kg, 1.09-1.21mg/Kg, 8.19-9.07 mg/Kg and 5.47-8.19 mg/Kg respectively. This study showed lower concentration than their report. This may be due to species variation, season variation and location variation of sample collection. Mandal *et al.* (2013) investigated the heavy metal accumulation in Shing in Turag River and found Cr (1.46mg/Kg), Pb (0mg/Kg), Cd (0.22mg/Kg) and Cu (13.27mg/Kg). This present study showed higher concentration in terms of Cr and Pb but slightly lower for Cd and lower for Cu concentration. This variation is due to the temporal variation of sampling. In thsis study, sampling time was February which is considered as dry season compared to their sampling time October to December which may classified as post rainy season.

River	Fe	Zn	Cu	Cr	Cd	Pb	Ni
Bangshi	132.39	70.80	4.15	6.83	0.54	1.06	2.13
Turag	85.34	63.82	0.70	5.96	0.18	0.63	2.32
Shitalakhya	109.71	57.83	1.20	5.01	0.33	1.01	1.35

River	Fe	Zn	Cu	Cr	Cd	Pb	Ni
Bangshi	424.3	86.82	2.42	6.65	0.54	3.84	0.29
Turag	195.10	65.36	1.32	4.30	0.21	0.83	1.46
Shitalakhya	253.33	113.74	2.17	8.07	0.88	1.52	0.19

Figure 4.2.19: Variation in **metals** concentration in Taki and Shing in Bongshi, Turag and Shitalakhya in mg/Kg in dry season.

Table 4.2.10: showed the seasonal variation of heavy metal concentration in *Channa Punctatus, Puntius spp. and Mystus vitatus* locally known as Taki, Puti and Tengra respectively. For all the fishes the heavy metal concentration was higher in dry season than the post rainy season. This is due to

the increase flow of water in rainy season. As the flow increased in rainy season, the concentration of heavy metal in water decreased and thus fishes uptake lesser amount of heavy metal through the rainy season, which decreased the concentration of heavy metal in the body of fishes in post rainy season. The highest amount of Cr was found in Puti (8.94mg/Kg) in dry season while lowest found in Tengra (4.27mg/Kg) in post rainy season. The concentrations of Pb, Cd, Zn and Fe were found to be highest 1.55 mg/Kg, 0.66 mg/Kg, 164.5 mg/Kg and 133.3mg/Kg respectively in Puti in dry season and lowest 0.46 mg/Kg, 0.19 mg/Kg, 47.21 mg/Kg and 65.22mg/Kg respectively in Taki in post rainy season. Highest concentration of Ni and Cu were 2.13mg/Kg and 4.15mg/Kg respectively in Taki in dry season and lowest is 0.66mg/Kg in Tengra and 0.40 in Taki respectively in post rainy season.

Table 4.2.7: Seasonal variation of heavy metal accumulations in fish in Bongshi River in mg/Kg.

Name	Season	River	Cr	Pb	Cd	Ni	Cu	Zn	Fe
Channa Punctatus **(Taki)**	Dry	Bongshi	6.83	1.06	0.54	2.13	4.15	70.80	132.39
	Post Rainy	Bongshi	5.44	0.46	0.19	1.28	0.40	47.21	65.22
Puntius spp. **(Puti)**	Dry	Bongshi	8.94	1.55	0.66	2.03	3.03	164.5	133.30
	Post Rainy	Bongshi	6.31	1.47	0.44	0.94	1.64	141.01	108.38
Mystus vitatus **(Tengra)**	Dry	Bongshi	6.35	0.91	0.43	0.81	1.32	89.88	115.75
	Post Rainy	Bongshi	4.27	0.51	0.35	0.66	0.83	78.96	89.10

In dry season, as the water level decreased, the concentration of heavy metal in water increased. This increased concentration of heavy metal were uptake by the fishes and accumulated in their body consequently shows a higher concentration of heavy metal in fishes in dry season compared to post rainy season, where the fishes uptake a lower amount of heavy metal through the rainy season, which lowers the concentration in their body in post rainy season. This variation of concentration with seasons is analogous to Ahmed *et al.* (2009b) and Haque *et al.* (2006).

Variation of Heavy Metal with season in Taki, Puti and Tengra Fish in Bangshi river

Taki
in (mg/kg)

Season	Fe	Zn	Cu	Cr	Cd	Pb	Ni
Dry	132.39	70.80	4.15	6.83	0.54	1.06	2.13
Post Rainy	65.22	47.21	0.40	5.44	0.19	0.46	1.28

Puti
in (mg/kg)

Season	Fe	Zn	Cu	Cr	Cd	Pb	Ni
Dry	133.30	164.5	3.03	8.94	0.66	1.55	2.03
Post Rainy	108.38	141.01	1.64	6.31	0.44	1.47	0.94

Tengra
in (mg/kg)

Season	Fe	Zn	Cu	Cr	Cd	Pb	Ni
Dry	115.75	89.88	1.32	6.35	0.43	0.91	0.81
Post Rainy	89.10	78.96	0.83	4.27	0.35	0.51	0.66

Figure 4.2.20: Variation in **heavy metals** concentration with season in Taki , Puti and Tanga in Bongsh in mg/Kg.

Table 4.2.11 represents the heavy metal concentration in various species of fishes in Bangshi and Buriganga River in post rainy season. Heavy metal concentrations were carried out for *Channa Punctatus* (Taki), *Mastacembelus armatus* (Bam), *Dendrobranchiata* (Chingri), *Notopterus notopterus* (Foli), *Xenentodon cancila* (Kakila), *Puntius spp.*(Puti) and *Mystus vitatus* (Tengra) in Bangshi River and for *Gudusia chapra* (Chapila), *Cirrhinus reba* (Tatkini), *Eutropiichthys vacha* (Bacha) and *Clupisoma garua* (Ghaura) in Buriganga River.

Table 4.2.8: Variation of heavy metal accumulations in mg/kg in different fishes in Bangshi and Buriganga Rivers in post rainy season.

Name	Season	River	Cr	Pb	Cd	Ni	Cu	Zn	Fe
Channa Punctatus **(Taki)**	Post Rainy	Bongshi	5.44	0.46	0.19	1.28	0.40	47.21	65.22
Mastacembelus armatus **(Bam)**			4.89	0.50	0.97	1.21	3.06	81.67	147.32
Dendrobranchiata **(Chingri)**			7.08	0.13	1.02	2.32	11.92	150.86	219.03
Notopterus notopterus **(Foli)**			3.91	1.18	0.18	1.21	0.45	52.13	70.58
Xenentodon cancila **(Kakila)**			7.67	1.41	0.51	0.57	1.52	195.47	108.70
Puntius spp. **(Puti)**			6.31	1.47	0.44	0.94	1.64	141.01	108.38
Mystus vitatus **(Tengra)**			4.27	0.51	0.35	0.66	0.83	78.96	89.10
Gudusia chapra **(Chapila)**	Post Rainy	Buriganga	6.02	1.75	0.79	0.08	2.09	112.82	463.75
Cirrhinus reba **(Tatkini)**			3.78	0.72	0.34	0.32	4.09	69.03	80.82
Eutropiichthys vacha **(Bacha)**			3.89	0.52	0.37	0.04	2.40	84.15	110.46
Clupisoma garua **(Ghaura)**			2.14	0.36	0.19	0.65	1.49	49.39	111.70

In Bongshi River the highest concentration of Cr found in Kakila (7.67mg/Kg) and lowest in Tengra (4.27mg/Kg). Pb concentration was highest in Puti (1.47mg/Kg) and lowest in Chingri (0.13mg/Kg). Cd (1.02mg/Kg), Ni (2.32mg/Kg), Cu (11.92mg/Kg) and Fe (219.03mg/Kg) are found to be highest in Chingri and lowest in Foli (0.18mg/Kg), Kakila (0.57mg/Kg), Taki (0.40mg/Kg) and Taki (65.22mg/Kg) respectively. Zn has been found highest in Kakila (195.47mg/Kg) and lowest in Taki (47.21mg/Kg).

In Buriganga River, the highest value of Cr, Pb, Cd, Zn and Fe is found to be 6.02mg/Kg, 1.75 mg/Kg, 0.79 mg/Kg, 112.82 mg/Kg and 463.75 mg/Kg respectively in Chapila. Ni and Cu has the highest value 0.32 mg/Kg and 4.09 mg/Kg respectively in Tatkini. The lowest concentration of Cr, Pb, Cd, Cu and Zn were 2.14mg/Kg, 0.36 mg/Kg, 0.19 mg/Kg, 1.49 mg/Kg and 49.39 mg/Kg in Ghaura respectively while Ni has the lowest value 0.04mg/Kg in Bacha and Fe has the lowest value 80.82mg/Kg in Tatkini. These variations of heavy metal concentration in different species of fishes is mainly due to food habit, the layer they live in the water, chemical form of freshwater environment and detoxification processes of the fishes.

Ahmed et al. (2010) studied the heavy metal concentration in fish of Buriganga River and found the concentration of Cr, Pb, Cd, Ni and Cu ranged from 5.39-7.38mg/Kg, 8.16-11.45mg/Kg, 0.73-1.17mg/Kg, 8.41-10.26 mg/Kg and 3.36-6.34 mg/Kg respectively in post rainy season. In our present study the concentration of Cr, Cd and Cu shows a closer result while Pb and Ni shows lower concentration compared to their study. This may be due to the different sample preparation techniques used in these two studies. Despite of this anomaly, Chapila show to be highly polluted in both the study compared to Tatkini in terms of Cr, Pb and Cd while Ni concentration is found to be higher in Tatkini than Chapila.

Another recent study shows that, concentration of Cr, Pb, Cd, Ni and Cu ranges from 3.57-18.84mg/Kg, 1.77-6.98mg/Kg, 0.01-0.04mg/Kg, 0.73-6.64mg/Kg and 5.90-18.77mg/Kg respectively (Ahmed *et al.* (2016)) in some different species of fishes than our study. Our study shows slightly lower values than this study. This may be attributed to the fact that different species takes different foods, lives in a different layer of water and their detoxifying process of body is different.

Variation of Heavy Metal (in mg/kg) with Fish in post rainy season in Buriganga river

Fish	Fe	Zn	Cu	Cr	Cd	Pb	Ni
Chapila	463.75	112.82	2.09	6.02	0.79	1.75	0.08
Tatkini	80.82	69.03	4.09	3.78	0.34	0.72	0.32
Bacha	110.46	84.15	2.40	3.89	0.37	0.52	0.04
Ghaura	111.70	49.39	1.49	2.14	0.19	0.36	0.65

Figure 4.2.21: Variation in heavy metals concentration in post rainy season in Buriganga in mg/Kg.

4.2.7 Intake level of heavy metals

Trace amount of heavy metals can tolerate by human being. This study reveals that the toxic metals contamination has occur in water, vegetable, rice and fish. The **Table 4.2.12** shows the Tolerable Daily Intake (TDI) of Heavy metals (per kg of body weight) for a person. According to this table intake of metals per day should be lower than this recommended value. The high levels of these heavy metals take place the consumers of these vegetables/ crops/fish grown within the study area at health risk with time unless an urgent step is taken by Government/ relevant agencies in address this issue. Therefore, consumers around Dhaka might intake toxic metal through their food including vegetables and crops which indicates they are facing severe toxic threat from their daily food intake.

Table 4.2.9: Tolerable Daily Intake (TDI) of heavy metals (per kg of body weight) according to WHO, 1996

Heavy metals	TDI (WHO, 1996)in mg
Cadmium	0.001
Chromium	0.0005-0.002
Lead	0.0035
Nickel	0.005
Zinc	1.0
Copper	0.5
Iron	0.8

4.3 Chemical Oxygen Demand (COD):

Chemical oxygen demand (COD) tests of river water are carried out in 5 different locations of Bongshi, 5 locations of Buriganga, 7 locations of Turag River, 2 locations of Balu and 2 locations of Shitalakhya River in May 2016 (pre rainy season). The results of COD tests have shown shown in **Table 4.2.12**.

Table 4.2.10: COD values at different locations of Bangshi, Buriganga, Turag, Balu and Shitalakhya River.

River	Location	COD (mg/L)
Bangshi	Gohailbari	6
	Dhamsona	5
	EPZ Canal	6
	Nayarhat	9
	New Tannery	19
Buriganga	Amin Bazar	12
	Bosila	12
	Hazaribagh	12
	Sowarighat	19
	Fatulla	28
Turag	Palpara	13
	Birulia Launch Terminal	7
	Rustompur	7
	Ashulia Bridge	10
	Kamarpara Bridge	10
	Tongi Bridge	21
	Termukh	17
Balu	Ichapura	30
	Demra Bridge	34
Shitalakhy	Kanchpur Bridge	26
	Narayanganj Launch Terminal	28

Results show that in all the rivers at all the points, COD is higher than the acceptable limit set by DoE for drinking water standard (4.00mg/L) but within the maximum level of inland surface water standard (200mg/L). In Bangshi River COD value ranges 5-19mg/L. COD is relatively lower at Gohailbari up to EPZ canal and shows increasing tendency through Nayarhat to New Tannery region. During rainy season, upstream flow contributes to the Bangshi River which increased the water level and hence decreased pollution. This water flow uplift the DO level increased and consequently decreased the COD value. During Dry season, the new tannery point shows a better DO level as there is no flow contributes from upstream to Bangshi River, which makes the river water almost stagnant. Almost all the industrial effluents falls into the Bangshi is at the upstream ranges from Gohailbari to EPZ canal. With very low or no flow cannot carry the pollutions up to new tannery points, which keeps the place relatively better in terms of water quality such as higher DO, lower pH, EC, TDS etc. But with the heavy flow in rainy season, the pollution may flow from upstream to downstream. As there is low depth down to new tannery point, in the junction of Buriganga River, this pollution accumulates in the surroundings of new tannery region. This may decrease the DO level and increased pH, EC, TDS etc. and hence raises the COD value at new tannery point.

In Buriganga River, COD is consistent and lowest (12mg/L) from Amin Bazar to Hazaribagh, but rises slightly at Sowarighat and greatly in Fatulla. Bongshi and Turag are the main source of Buriganga from Amin Bazar end. Turag falls directly and Bongshi connect to Turag at Amin Bazar point to feed Buriganga through Karnatali River. Karnatali is a small river connects Turag and Bangshi. The high COD value of Bangshi joins with the low COD value of Turag and form a relatively moderate COD for Buriganga. It is shown that, Palpara point of Turag has higher value of COD compared to upstream points of Turag. This is because; Palpara is a very close point where Karnatali connects Bangshi to Turag. The pollution of Bangshi may spreads slightly upstream of the joining point as Buriganga is a tidal river. As Buriganga has good flow in rainy season, this pollution continues to flow downstream. Sowarighat is a business place where various goods come to Dhaka from different places of southern region of Bangladesh. There is also a canal called Sowarighat canal which carries waste of small industries and significant amount of human waste to Buriganga. That is why, the COD level increased in the Sowarighat point. As all the pollution flows to downstream along with the pollution of various dockyard situated in both side of Buriganga, the downstream point Fatulla has highest value of COD (28mg/L).

Birulia Launch Terminal and Rustompur points have the lowest COD in Turag River as these points are fed from the immense reservoir of water in Ahulia Lake during rainy season. But from Ahulia Bridge to Kamarpara Bridge, COD increased slightly due to diffusion of pollution from Tongi Bridge where flow does not increases expectedly and water remains highly polluted even in rainy season leaving COD level 21mg/L, highest in Turag River. This relatively lower amount of water in Tongi Bridge point may be due to the wastes released by the surrounding residence to the river raises the bed of the river at that point. At Termukh point, another river named Unukhola connects to Turag which lowers the COD value at that point.

At the connection of Turag and Unukhola River, there forms another river called Balu River. COD value of Balu River is highest among the rivers. At Ichapura, COD value is 30mg/L and at Demra Bridge 34mg/L. Dhaka is spreading in the both side of Balu River now a days. The 300ft Purbachal expressway built over the Balu River through Ichapura. The ongoing construction works and human wastes coming from this newly building residents along with the huge amount of agricultural wastes falls in Balu River at various points near Ichapura, which makes the COD value higher at this point. The Hatirjheel Lake carries a huge amount of human and other wastes of Dhaka City connects through Banasree canal to Balu River at Dakshinpara; an upstream point of Demra Bridge, which raises the COD level of Demra Bridge to highest among all the points of all the rivers.

In the both sides of Shitalakhya River, there are plenty of various kinds of industries, from whose; huge amount of industrial effluents falls to Shitalakhya River. Shitalakhya joins with Balu at Demra Bridge point and continues to flow downstream as Shitalakhya to fall in to Meghna. The COD values of Kanchpur Bridge (26mg/L) and Narayanganj Launch Terminal (28mg/L) is very close. Narayanganj Launch Terminal point has a slightly higher COD because of Adamzee EPZ and other industrial effluents along with the human waste of Narayanganj City falls in to the Shitalakhya River at the downstream points of Kanchpur Bridge.

5. Socio-economic impact of river pollution

5.1 Introduction

Impacts are potential changes caused – directly or indirectly, in whole or in part, for better or for worse – by industrial development activities.

Socio-economic impact assessment (SEIA) is a useful method to help understand the potential limit of impacts of a proposed change. It can be used to assess impacts of a wide range of types of change, from a proposal to build a new freeway to a proposal to change access to a natural resource such as a forest or the ocean. This understanding can help design impact mitigation strategies to minimize negative and maximize positive impacts of any change.

It is important to determine not only the full range of impacts, such as changes to levels of income and employment, access to services, quality of life, but also the implications of each particular change. It is important therefore to identify the key source of impact and to separately identify impacts arising from other sources.

The purpose of the study was to assess the socio-economic impact of water pollution to the people with the vicinity of Bongshi and Buriganga river bank. The socio-economic condition of the river bank community depending on river resources is expected to deteriorate due to water pollution of the river. The aforesaid impact was scaled through some socio-economic indicators such as reduction in income, professional transformation, health hazards, agricultural change, fish production, transfer of dwelling from river bank and adverse effect of pollution in social life and most affected occupation of the people of the river bank. River bank people is being affected with some independent parameters such as industrial waste, municipal waste, solid waste, sewerage and agricultural pesticides or fertilizers. There are also other parameters that can play a vital role to assess the socio-economic impact. These parameters may include act or rules concerning environmental activities, role of Department of Environment (DOE), role of local administration, participation of local government and role of NGO and media.

5.2 Analytical Framework

All the research studies need an analytical framework. However it depends on the nature of the research study that have to be done. According to Jane Ritchie and Liz Spencer (1994) framework is an analytical process which involves a number of distinct though highly interconnected stages. The approach involves a systematic process sifting, charting and sorting of different parameters according to key issues and themes. By using these parameters and social impact measurement indicators alluded in the previous section the analytical framework can be drawn to carry out this study.

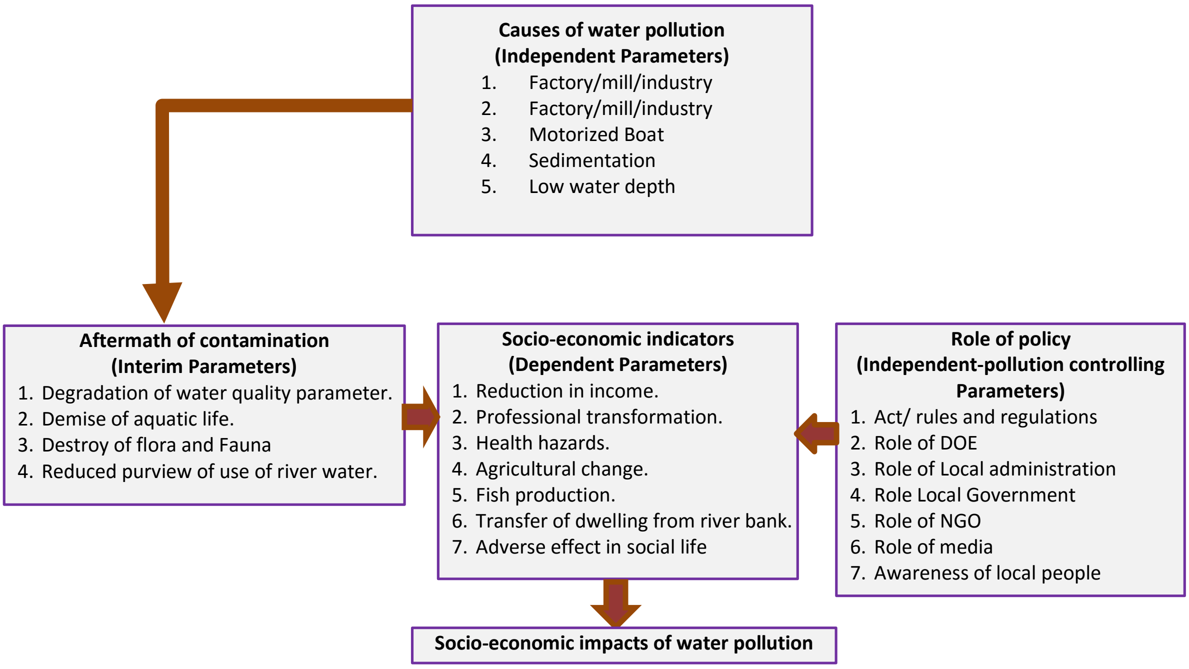


Figure 5.1: Analytical Framework of the Study.

5.3 Legal aspect of water pollution in Bangladesh

Leal protection is a prime issue for the well-functioning for all activities of a country. Environmental aspect is not exception from this subject. In this regard Bangladesh government has made some acts and rules under acts for the water pollution prevention and control in Bangladesh. The government of Bangladesh has modified environmental acts, rules and laws to improve environmental condition Environment court has already been established to take prompt legal action against environmental pollution. The DOE has been empowered to punish the offenders of environmental rules.

The laws are-

- The Bangladesh Environment Conservation Act-1995,
- The Environment Conservation Rules-1997,
- Environment Court Law-2000,
- Bangladesh Water Act-2013, and
- National River Protection Commission Act-2013.

5.4 Methodology

Research methods are the tools and techniques for effectuating research. Research is a term used liberally for any kind of investigation that is intended to uncover interesting or new facts (N. Walliman). A research method germane to research objectives should be adopted by the researcher. The three common approaches to conducting research are quantitative, qualitative and mixed methods. Researchers typically select the quantitative approach to respond to research questions requiring numerical data, the qualitative approach for research questions requiring textural data and the mixed methods approach for research questions requiring both numerical and textural data (C. Williams, 2007). As we had both numerical and textural data, here we had used mixed method to assess the socio-economic impact.

5.4.1 Primary Data

Primary data was collected with the help of a questionnaire survey with the respondents. Information was collected from both male and female of the study area.

5.4.2 Secondary Data

Secondary data were in need to have information about the degree of water pollution of the river, understand the studied area history, livelihood, economic condition etc. The fundamental sources of secondary data for assessing socio-economic impact were previous studies, journals, reports, books and different websites.

5.4.3 Data collection

Simple random sampling method is a method for collecting data used in various research field ranging from social science to medical science. In this study simple random sampling method was used. The study was done on the basis of data collection through questionnaire survey, observation and discussion with limited participation of the people of the study area. Like other survey research a standardized questionnaire was used to collect information. Sample of respondents were selected from the river bank community randomly both male and female and they were interviewed through structured questionnaire. It was appeared from the survey that the problem of water pollution of the river has started about 25 or 20 years before. The people who aged above 45 years have seen both the clean and polluted water of the Bongshi and Buriganag river. Young aged river bank community could not see the contamination free water of the rivers.

Figurre 5.2: Questionnaire Survey in Bongshi river bank community.

5.4.4 Selection of Sample Size

Sample size is one of the four inter-related features of a study design that can influence the detection of significant differences, relationships or interactions (Peers, 1996).

A sample size for the collection of the socio-economic data was determined using the Yamane (1967) formula: $n = \frac{N}{1+Ne^2}$
where,
n= the sample size
N = the size of population
e= the error of 5 percentage points or the level of significance (0.05).

Using Google earth pro the total length of the study area of Bongshi river was measured 26.7 km. Keeping a 1 km projection from the river bank to the locality a 22.62 km^2 was determined using Google earth pro as surveying area. The area of Savar Upazila is 280.12 km^2 and as of the 2011 Bangladesh census, Savar upazila has population of 1442885 (Bangladesh National Portal, Savar Upazila). From the above information the size of population was estimated as 116515. Then using the (Yamane 1967) formula the sample size was calculated as 400 assuming 0.05 level of significance. Same procedure was followed for Buriganga river and sample size was calculated as 400.

5.4.5 Data analysis method

Data analysis is the most important tusk for interpretation of a research and also important to make prediction for further study. Data analysis can be thought of as analogous to distillation. A collection of data from various sources is drawn together and through a process of segregation, tabulation and conflation, it is gradually honed to allow distillates. When all the distillation is completed, a picture of the whole study can be gleaned from the analysis (A. Hramiak, 2005).

The collected data were articulated in tabular form, analyzed through MS EXCELL software, presented by charts and transcribed into texts. Results are presented through narrative text, simple computations with logical reasoning.

5.5 Analysis and findings of Bongshi River

5.5.1 Profile of the Respondents

The different profile parameter of the respondents especially gender, age, occupation, change of occupation and health hazards due to pollution had been analyzed to show the socio-economic status of the people in the vicinity of the river bank.

5.5.2 Gender of the respondents

Both male and female respondents had been questioned for the better accuracy of the study. A total of 400 respondent was interviewed of them 87% were male and 13% were female.

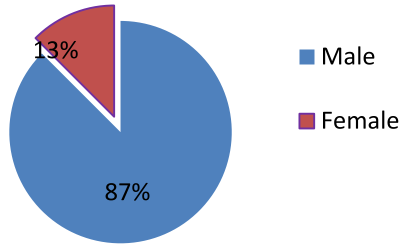


Figure 5.3: Gender of the respondents in Bongshi r iver.

5.5.3 Age of the Respondents

The age of the respondents are categorized into six groups with discrete class interval (15-24, 25-34, 35-44, 45-54, 55-64, 65+). The age group 35-44 represents the highest percentage (31%) of the total respondents. The detail information of respondents regarding age is shown in the Figure-5.4.

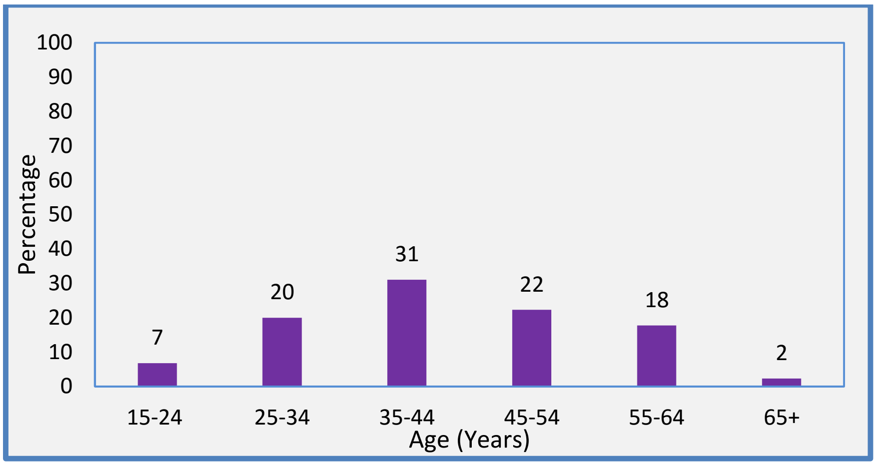


Figure 5.4: Age of the respondents in Bongshi river.

5.5.4 Occupation of the respondents

From the data in the table-, it is observed that Agriculture is the occupation which holds the highest number of the respondent's percentage (29.25%). Second highest is the businessman group which represent 19.25% of the total respondents. Industry worker and house wife are in third place representing both individually 12.50% of the total respondents. Similarly 7.50% belongs to fisheries group, 8% belongs to other group, 6.75% belongs to student group, and 4.25% belongs to boatman group. The local drivers, unemployed persons and servicemen were included in the other group.

Table 5.1: Occupation of the respondents in Bongshi river

Occupation of the respondents	Frequency	Percentage (%)	Rank
Agriculture	117	29.25	1st
Fisheries	30	7.50	5th
Industry worker	50	12.50	3rd
Business	77	19.25	2nd
Student	27	6.75	6th
Boatman	17	4.25	7th
House wife	50	12.50	3rd
Other	33	8.00	4th
Total	400	100	

5.5.5 Usage of Bongshi River Water

Bonghi river is only water route of Savar, Nabinagar, Nolam, Nayarhat and Dhamrai area to communicate with the capital city Dhaka. The sand traders and other businessmen are also using the river for their business purposes. The water of Bongshi River is being used mostly by the residents of the surrounding area and owners of industry for various purposes. Construction materials and industrial raw materials are being transported by the river. All respondents out of 400 said they did not use river water in house hold works and all of them said river water was used in agriculture.

Table 5.2: Usage of river water

Usages of River water	Answer	
	Yes	No
House hold	0	400
Agriculture	400	0

5.5.6 Causes of water pollution

The following table shows conjecture of the respondents about the causes of the water pollution of the Bongshi river. From table below it can be assumed that the industrial waste is the main cause of river water pollution.

Table 5.3: Causes of water pollution

Causes of Pollution	Frequency	Percentage	Rank
Factory/mill/industry	307	76.75	1st
Excessive pesticide/ fertilizer use	20	5.00	4th
Motorized Boat	27	6.75	3rd
Sedimentation	33	8.25	2nd
Low water depth	0	0.00	
Aquatic plant/water hyacinth	0	0.00	
Others	13	3.25	5th
Total	400	100	

5.5.7 Availability of Fish

All the respondents opined that no fish found in dry season (March and April). It is reasonable because there was acute scarcity of dissolved oxygen into the river water in dry season obtained from this study (Figure 4.1, 4.2, 4.3, 4.4), a situation not suitable for aquatic life to sustain. All the respondents answered some fish were found in rainy season. It is correct because level of dissolved oxygen increases in the rainy season (Figure 4.5, 4.6).

Table 5.4: Availability of Fish on different seasons

Fish found	Answer	
	Yes	No
Dry season	0	400
Rainy season	400	0

5.5.8 Crop Production scenario

Well varieties of winter crops and summer monsoon crops are cultivated near to the river bank area of Bongshi river all through the year. The winter crops like tomato, cabbage, cauliflower, pumpkin, red spinach etc. and summer monsoon crops like paddy, ladies finger etc., were found during the visiting time of Bongshi river. From the analysis of collected data mixed opinions were found about crop production. Some 61% respondents answered that crop production was decreased. They accused river pollution of decreasing the crop production. They said stem got rotten and numerous insects attack their crop if they use river water in agriculture. Some people did not use river water in their agricultural land instead they used ground water. Those people (14%) answered that crop production was increased. The questionnaire survey was conducted using simple random sampling method. For this reason there were some respondents who had not knowledge about crop production. This type of respondents answered crop production remains the same (19.5%) and could not say.

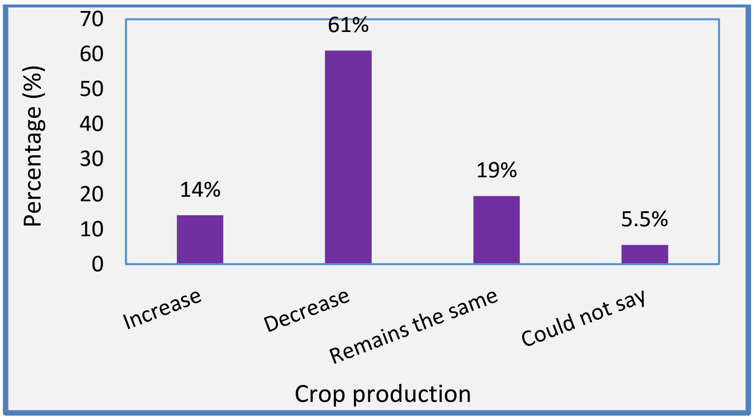


Figure 5.5: Crop Production scenario in Bongshi river

Table 5.5: Crop Production scenario in Bongshi river bank area

Crop Production	Frequency	Percentage	Rank
Increase	56	14	3rd
Decrease	244	61	1st
Remains the same	78	19.5	2nd
Could not say	22	5.5	4th
Total	400	100	

5.5.9 Health Hazards due to Pollution

Impact of water pollution on human health is a major concern for the people living in the vicinity to the river bank. But from the table it is observed that 60 percent of the respondent answered they did not have any disease because of using river water. No one respondent suffer from Kidney inflammation, arsenicosis. Probably these answer came from the respondent for their inadequate knowledge about diseases that could be caused by the use of polluted river water. Nonetheless 23.25 percent of the respondent answered they suffered from skin disease due to using river water. Suffering of eye burning was felt by 10 percent of the respondent and 6.25 percent of the respondents answered they did not use river water in any works, so they said they would not able to say anything about disease regarding to use of polluted river water. The following table summarize the impact of water pollution on human health those who use river water in daily life for various purposes.

Table 5.6: Health Hazards due to Pollution

Types of Hazards	Frequency	Percentage	Rank
Skin Disease	93	23.25	2nd
Eye Burning	40	10.00	3rd
Arsenicosis	0	0.00	
Kidney inflammation	0	0.00	
Others	0	0.00	
No Disease	240	60.00	1st
Not Use	27	6.75	4th
Total	400	100	

5.5.10 Change of occupation of the respondents

Nearly all of the respondents (90.75%) answered, they did not change their occupation. On the other hand only 9.25% respondents changed their occupation due to various reasons. Some fisherman changed their occupation to various jobs such as factory worker, goldsmith, street vendor etc. Some farmer shifted to as factory worker. Acquisition of land in the area of Hemaeytpur, Savar, for the sake of establishing new tannery zone by the Government led some farmer to adopt occupation other than agriculture. It is shown in the following table.

Table 5.7: Change of Occupation of the respondents

Change of Occupation	Frequency	Percentage
Yes	37	9.25
No	363	90.75
Total	400	100

5.5.11 Reduction of Income due to pollution

Reduction of income is an inevitable upshot of river pollution to some income group. From the data analysis it was observed that 93.25% respondents out of 400 deemed, the occupations that depend on river like fisheries, agriculture, boatman etc., got affected due to river pollution and 6.75% respondents answered they did not think river pollution had any impact on income.

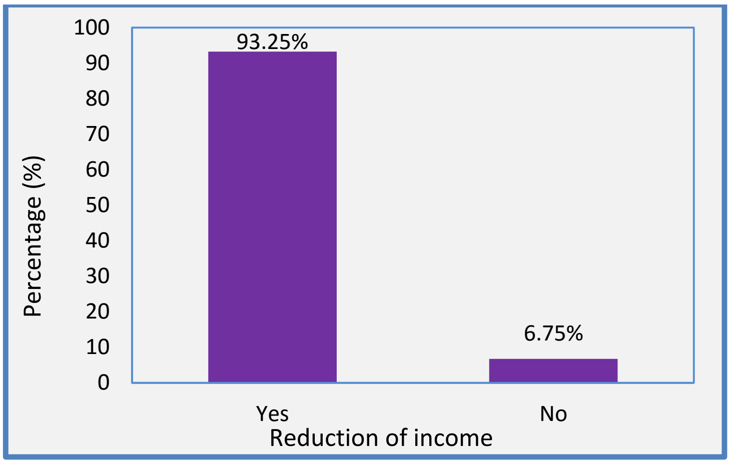


Figure 5.6: Reduction of Income due to pollution in Bongshi river.

Table 5.8: Reduction of income due to Pollution

Reduction of income	Frequency	Percentage
Yes	373	93.25
No	27	6.75
Total	400	100

The number of respondents out of 400 who answered yes i.e. river pollution had an impact on income was 373. Of the 373 respondents 70.80% of them said fisherman as affected income group, 3.45% said boatman as affected income group and 19% said farmer as affected income group. So those who are still in fish monger occupation they did not get more income than the past. Once the amount they earned was better.

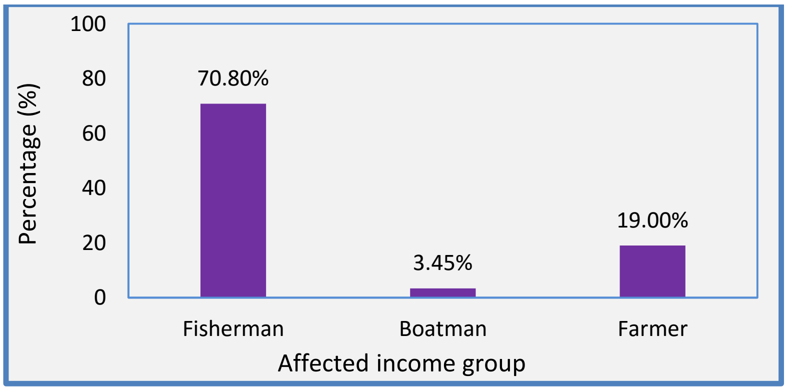


Figure 5.7: Affected income group due to pollution in Bongshi river.

Table-5.9: Affected income group due to Pollution

Affected Occupation	Frequency	Percentage
Fisheries	283	70.80
Boatman	14	3.45
Agriculture	76	19.00
Total	373	100.00

5.5.12 Adverse Effect of Pollution in social life

Some fishermen were interviewed in the village named Hajipur, Dhamrai near dockyard. They said pollution of the river has destroyed the ecosystem of the river and its flood plains, robbing them of fish and other aquatic life. Shukumar Rajbongshi, a fisherman living in that village, said they abandoned their profession about 10 years ago as the fish disappeared from the river. "Now it has become a dream to net any fish in the Bongshi," he added. They said because of income reduction, they had complexities in their conjugal life. From the questionnaire survey it was found that 31.82% respondent answered "yes" i.e. river pollution contributed an adverse effect in their social life and 68.18% respondent answered "no" i.e. river pollution did not contribute an adverse effect in their social life

Table 5.10: Whether adverse effect is or not in social life due to Pollution

Adverse Effect	Frequency	Percentage
Yes	127	31.82
No	273	68.18
Total	400	100

The number of respondents who answered that they had adverse effect in their social life was 127. The following table shows details of adverse effect of pollution in social life.

Table 5.11: Types adverse effect in social life due to Pollution

Adverse Effect in social life	Frequency	Percentage	Rank
School	0	0.00	
Communication	0	0.00	
Conjugal Life	78	61.42	1st
Due to income reduction	39	30.71	2nd
Other	10	7.87	3rd
Total	127	100	

5.6 Analysis and findings of Buriganga River

5.6.1 Profile of the Respondents

The different profile parameter of the respondents especially gender, age, occupation, change of occupation and health hazards due to pollution had been analyzed to show the social and economic-status of the people in the vicinity of the river bank.

5.6.2 Gender of the respondents

Both male and female respondents had been questioned for the better accuracy of the study. A total of 400 respondent were interviewed of them 83% were male and 17% were female.

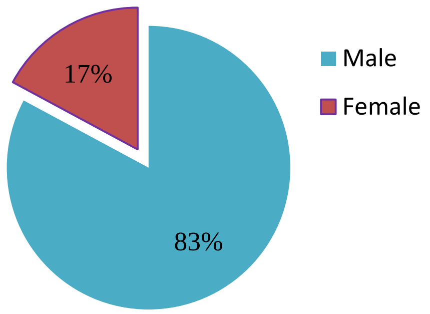


Figure 5.8: Gender of the respondents in Buriganga river.

5.6.3 Age of the Respondents

The age of the respondents are categorized into six groups with discrete class interval (15-24, 25-34, 35-44, 45-54, 55-64, 65+). The age group 35-44 represents the highest percentage (52%) of the total respondents. The detail information about respondents age is shown in the Figure 5.9.

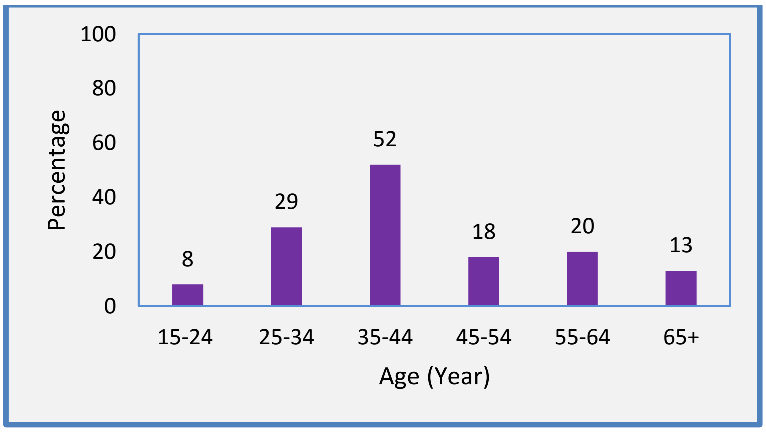


Figure 5.9: Age of the respondents in Buriganga river.

5.6.4 Occupation of the respondents

From the data in the table-, it is observed that Business group holds the highest number of the respondent's percentage (50%). Second highest is the other group which includes local drivers, unemployed persons, and servicemen represents 22% of the total respondents. House wife were in third place representing 9% of the total respondents. Similarly 6% belongs to agriculture group, 6% belongs to student group, 2% belongs to fisheries group, and 2% belongs to boat man group.

Table 5.12: Occupation of the respondents

Occupation of the respondents	Frequency	Percentage (%)	Rank
Agriculture	23	6	4th
Fisheries	9	2	6th
Industry worker	14	4	5th
Business	200	50	1st
Student	23	6	4th
Boatman	8	2	7th
House wife	37	9	3rd
Other	86	22	2nd
Total	400	100	

5.6.5 Usage of Buriganga River Water

Buriganga river has a great contribution transport to the capital city Dhaka. So many lighter cargo, oil tanker, motorized boat are seen to carry goods through Buriganga river. Few passenger carrying water bus are also seen in the Buriganga river. Since both sides of the Buriganga river is flanked by residential and commercial area, maximum of the respondents could not say about the agricultural use of Buriganga river water. But the study team observed little use of Buriganga river water in agriculture at a place named Ishakhabad near up of Aminbazar bridge and a place. All respondents out of 400 said they did not use river water in house hold works and all of them said river water was used in agriculture.

Table 5.13: Usage of river water

Types of Usages of River water	Answer	
	Yes	No
House hold	0	400
Agriculture	29	371

5.6.6 Causes of water pollution

Respondent’s supposition about the causes of the water pollution of the Buriganga river is summarized in the following table. From table below it is shown that the discharge of industrial waste and municipal and urban waste are the two main contributing pollutant.

Table 5.14: Causes of Pollution of Buriganga river water

Causes of Pollution	Frequency	Percentage	Rank
Factory/mill/industry	180	45	1st
Excessive pesticide/ fertilizer use	0	0	
Motorized Boat	46	11	3rd
Sedimentation	0	0	
Low water depth	0	0	
Aquatic plant/water hyacinth	0	0	
Municipal and urban waste	174	44	2nd
Others	0	0	
Total	400	100	

5.6.7 Health Hazards due to Pollution

Impact of water pollution on human health is a major concern for the people living in the vicinity of river bank. From the table it is observed that 32 percent of the respondent answered they had skin disease due to use of river water. Twenty two percent of the respondents answered they did not use river water in any works, so they could answer about health hazard. However 15 percent of the respondent answered they did not know whether there was health hazard in their body for the using of river water. Suffering of eye burning was felt by 12 percent of the respondent. Twelve percent of the respondents answered they had no disease because of using river water. The hazard kidney inflammation was answered by 5% of the respondent. Itching, swell of skin are categorized in other group. The following table summarize the impact of water pollution on human health those who use river water in daily life for various purposes.

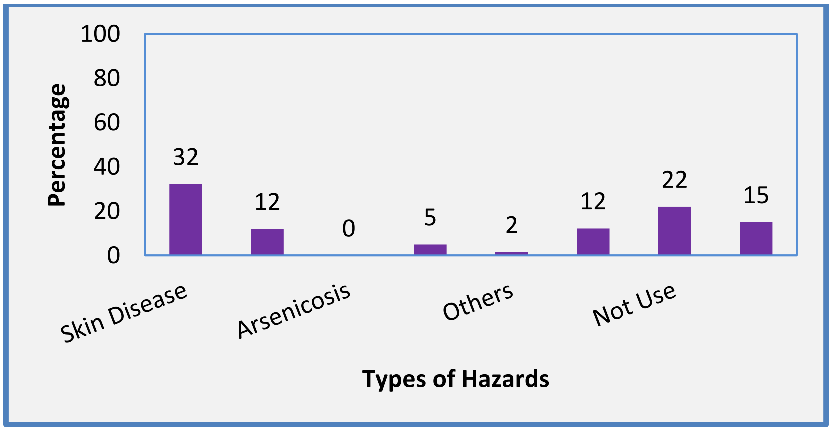


Figure 5.10: Health Hazards due to Pollution in Buriganga.

Table 5.15: Health Hazards due to Pollution

Types of Hazards	Frequency	Percentage	Rank
Skin Disease	129	32	1st
Eye Burning	48	12	4th
Arsenicosis	0	0	
Kidney inflammation	20	5	5th
No Disease	6	2	4th
Do not know	49	12	3rd
Not Use	88	22	2nd
Others	60	15	6th
Total	400	100	

5.6.8 Availability of Fish

All the respondents answered that no fish was found in dry season. It was reasonable because there was severe scarcity of dissolved oxygen into the river water in dry season, a situation not suitable for aquatic life to sustain. All the respondents answered some fish were found in rainy season. It is correct because level of dissolved oxygen increases in the rainy season. For this reason fish was found during rainy season.

Table-5.16: Availability of Fish on different season

Fish found	Answer	
	Yes	No
Dry season	0	400
Rainy season	400	0

5.6.9 Crop Production scenario

Both sides of the Buriganga river bank is covered by buildings built for of residential and industrial purposes. No agricultural field was found during the visit of Buriganga river except at commencing point of Buriganga river. At the starting point a small amount of land was found using in tillage.

5.6.10 Change of occupation of the respondents

As it is mentioned that Buriganga river bank is a residential and commercial area. Few people are engaged in jobs like fishing. Nearly all of the respondents (98.75%) answered, they did not change their occupation. On the other hand only 1.25% respondents changed their occupation. It is shown in the following table-

Table 5.17: Change of Occupation

Change of Occupation	Frequency	Percentage
Yes	5	1.25
No	395	98.75
Total	400	100

5.6.11 Reduction of Income due to pollution

Reduction of income is an obvious upshot of river pollution to some income group. From the data analysis it was observed that 84.50% respondents out of 400 deemed, the occupations that depend on river like fisheries, agriculture, boatman etc., got affected due to river pollution and 15.50% respondents answered they did not think river pollution had any impact on income.

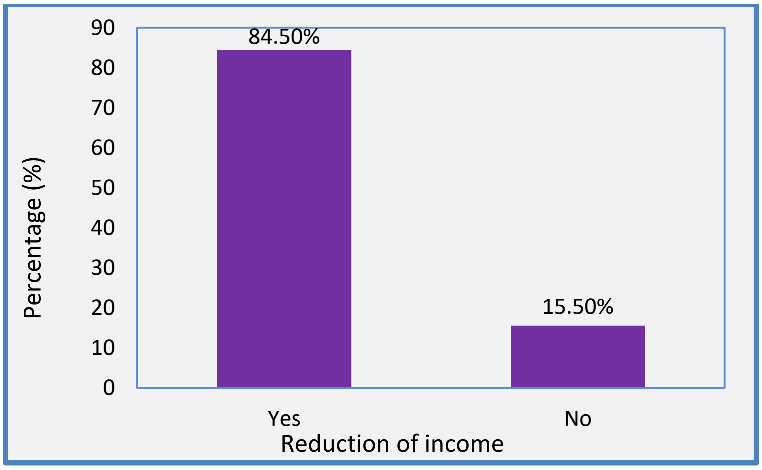


Figure 5.11: Reduction of Income due to pollution Buriganga.

Table 5.18: Reduction of Income due to pollution

Reduction of income	Frequency	Percentage
Yes	338	84.50
No	62	15.50
Total	400	100

The number of respondents out of 400 who answered yes i.e. river pollution had an impact on income was 338. Of the 338 respondents 75.44% of them said fisherman as affected income group, 20.71% said boatman as affected income group and 3.85% said farmer as affected income group. So the few fisherman are still in fish netting occupation do not get more income than the past.

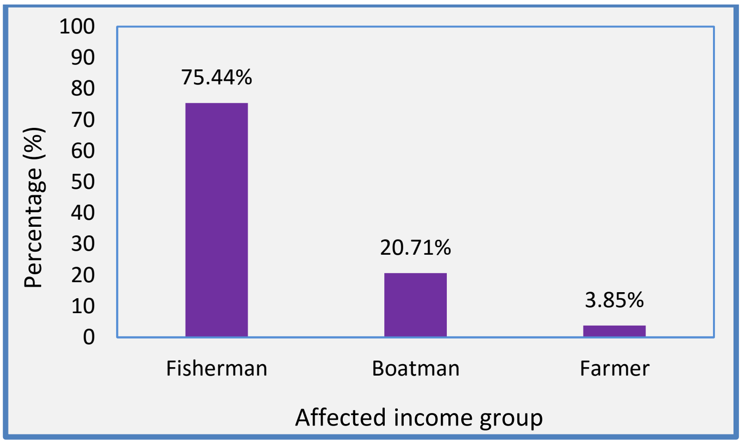


Figure 5.12: Affected income group due to river pollution in Buriganga.

Table 5.19: Affected income group

Affected Occupation	Frequency	Percentage
Fisheries	255	75.44
Boatman	70	20.71
Agriculture	13	3.85
Total	338	100.00

5.6.12 Adverse Effect of Pollution in social life

Once a clean and healthy river Buriganga now becomes a toxic reservoir of water. No fish netting is most time of the year. Being covered by industrial and residential area a small amount of was found at the starting point of the Buriganga river. As few respondents were found to do jobs directly related to river water most of the respondents answered that they did not get any adverse effect in social life. From the questionnaire survey it was found that 11.50% respondent answered “yes” i.e. river pollution contributed an adverse effect in their social life and 88.50% respondent answered “no” i.e. river pollution did not contribute an adverse effect in their social life.

Table-5.20: Adverse Effect of Pollution in social life.

Adverse Effect	Frequency	Percentage
Yes	46	11.50
No	354	88.50
Total	400	100.00

The following table shows details of adverse effect of pollution in social life.

Table-5.21: Types of adverse effect of pollution in social life.

Adverse Effect in social life	Frequency	Percentage	Rank
School	6	13.04	3rd
Communication	14	30.43	2nd
Conjugal Life	20	43.48	1st
Due to income reduction	6	13.04	3rd
Other	6	13.04	3rd
Total	46	100	

6. Conclusions

6.1: River pollution

Six rivers around Dhaka is severe pollution threat including water, fish, sediment and crops due to the various types of industrial/sewerage/municipal waste directly enter to the water body without treatments. Investigation from this study reveals that the Buriganga, Bongshi, Turag, Shitalakha, Balu and Karnatoli rivers are under severe pollution threat. Field and laboratory investigations data showed that the river water severe contaminated by pollutants. Water quality parameters especially Dissolve oxygen (DO), Total Dissolve Solid (TDS), Electrical conductivity (EC), Ammonia (NH_3), and Carbon di-oxide (CO_2), are beyond the tolerable limit of DoE standard (ECR, 1997) in dry season.

In the present investigations, some toxic heavy metals like Cr, Cd, Pb and Ni were found significant amount in Buriganga, Bongshi and Turag water. Even though concentration were reduced in post rainy season, these concentrations were two to five times greater than standard value provided by WHO and DoE. Besides, these toxic metals easily moving with flow from upstream to downstream through the river and enter to the other river as all rivers around Dhaka are connected like as loop (**Figure 3.2**). Among these metals Cr and Cd toxicity are severe in Dkaha river's water. The possible reason is the discharge of high amount of Cr concentrated wastewater from the tannery industries and other industries like DEPZ, BEXIMCO etc. which are closely located to these rivers. The tannery industries located in Hazaribagh and Rayerbazar area depend on chrome tanning process and they do not treat their Cr contaminated wastewater before discharging into the natural environment. This hexavalent chromium is known for its negative health and environmental impact and its extreme toxicity. Health effects related to hexavalent chromium exposure include diarrhoea, stomach and intestinal bleedings, cramps and liver and kidney damage. Moreover, high doses of Cr intake can severe respiratory, cardiovascular, gastrointestinal, hematological, hepatic, renal, and neurological effects as part of the sequelae leading to death (ATSDR, 2008). As this heavy metal is a conservative substance (no decay) in water, it is must to always maintain the level of concentration of this substance below the permissible level.

As heavy metals are non-degradable and not decomposable it is likely to exist with the flow of water in post rainy season. During July to November Rivers are full of water in Dhaka and generally the water seems good in terms of odour and colour. Therefore, it is very alarming that it is polluted with heavy metals during this period too. Usually when volume of water increased contaminant will be diluted, however, these toxic metals still exist in to the environment. That means if flow can increase in dry season but also toxic metals contamination will be on going. Proper care should be enforced to stop heavy metal containing waste dispose to to rivers.

Heavy metals exists in our Food chain as considerable amount of toxic heavy metals like Cr, Pb, Cd, Ni and Cu have found in fish, tomato, pumpkin and red spinach. The heavy metal contamination in vegetables was found in order of red amarangth (lal shak)> tomato> pumpkin and in rice plant root> shoot> rice. Red amaranth accumulates higher concentration of metals than tomato and pumpkin. Cr concentration was 10.40 mg/kg in red amaranth whereas 4.13 mg/kg in tomato and 3.42 mg/kg in pumpkin. Moreover, Cd concentration was lower in vegetables compared to Cr, Pb and Ni concentration. Toxic metals also found in considerable amount in Taki, balm, Chingri, Kakila, Puti fishes. Toxic Cr concentration was the highest contamination in fishes is likely as river water and soil severly Cr polluted.

Trace amount of heavy metals can tolerate by human being. This study reveals that the toxic metals contamination has occur in water, vegetable, rice and fish. The **Table 4.2.12** shows the Tolerable Daily Intake (TDI) of Heavy metals (per kg of body weight) for a person. According to this table intake of metals per day should be lower than this recommended value. The high levels of these heavy metals take place the consumers of these vegetable/ crops grown within the study area at health risk with time unless an urgent step is taken by Government/ relevant agencies in address this issue. Therefore, consumers around Dhaka might intake toxic metal through their food including vegetables and crops which indicates they are facing severe toxic threat from their daily food intake.

The concentration of heavy metals in vegetables, crops and water and soil will provide baseline data and there is a need for intensive sampling of the same for quantification of the results. Crops/vegetables/fish/soil, and water quality monitoring, together with the prevention of metals enters, is a prerequisite in order to prevent potential health of metals with industry/ sewage -fed water. Otherwise, the situation in near future might be further worsened with the continuing development of industries with discharging untreated industry wastes/ municipalities/ sewage to the river.

6.2: Questionnaire survey

Questionnaire survey from river bank community reveals the socio-economic impact of river pollution. The survey study has showed that the people who live the vicinity of Buriganga and Bongshi are vulnerable. The Key findings of questionnaire surveys are given below:

- Questionnaire survey showed that river bank community seriously affected by river pollution.

- All respondents of Bongshi (out of 400) river bank community said they did not use river water in house hold works and all of them said river water was used in agriculture. However, all respondents of Buriganga (out of 400) said that they did not use river water neither in house hold works nor other works. All people around these rivers use groundwater/tap water for different purpose.

- The most of the Respondent (76.75%) from Bongshi river bank community believed that the untreated waste disposal from Factory/mill/industry is the main cause of pollution. On the other hand, 45% of Buriganga river bank community people believe that the main causes of river pollution is factory/mill/industry and 44% thought that pollution comes from municipal & urban waste and 11% think Motorized Boat may be responsible for pollution.

- All the respondents of Bongshi and Buriganga river bank community opined that no fish found in dry season especially March and April. Even though some fishes are available in the month of November, December and January (dry season), these fishes are very stinky after cooking probably contain toxicity.

- River pollution contributed an adverse effect in their social life. 31.82% respondent of Bongshi and 11.5% Buriganga river bank community believed that.

- 100% of respondents of Bongshi river bank community said that they don’t have any idea that soil or crops have contamination or not.

6.3: Implication of this research

- This research will provide a clear idea about the present water quality including toxic/heavy metals status of six rivers around Dhaka which will be a basis of future research and monitoring activities for preventing water pollution.
- The data generated in this study help to work out in effluent management strategy towards control over effective treatment in terms of toxic and heavy metal contents.
- The data from this study will be also usefull for policy approaches to improve food security in Bangladesh.
- The recommendation generated from this study will help to get better approaches strategies towards management of water resources.

7. Recommendations to alleviate pollution

It is essential to make provision for protection and improving water quality of the rivers to sustain the ecosystem in the rivers and overall environment of the Dhaka city. Current pollution threat will be minimized in Dhaka if necessary approaches are properly implemented. The Following recommedtions will help to get better approaches for alleviating pollution along with water resourses management of rivers around Dhaka.

- **Alleviating pollution through refining sources**

Every industry should have effluent treatment Plant (ETP). Industrial plants must be required to set up suitable treatment systems or existing industrial plant should be run during operation to reduce pollution and revive the river ecosystem in Dhaka.

The untreated effluents discharging into the Buriganga, Bongshi, Turag, Shitalakha, Balu and Karnatoli River by the tannery, textile, electronic, and food industries in the industrial areas of the watershed are important contributors to pollution of this important water source for the people in Dhaka. The Buriganga is subject to severe pollution and considered as one of the worst polluted rivers in Dhaka. Hazaribagh tannery city, consisting of 196 tanneries is discharging its hazardous effluents everyday directly to the Buriganga without any treatment. The good thing is that this tannery industry is being moving Hazaribagh to Hemayetpur, Saver on the bank of Bongshi. Even though Efluent treatment plant (ETP) exists in the new tannery industry, the question is that ETP will use in near future or it is only eye wash to Government/mass people. Moreover, hundreds of municipal wastes are directly discharging to the Buriganga without any treatment. Moreover, water vehicles on the Buriganga continuously spilling oils to river water. Results of this study showed that water quality decreased drastically. Questionnaire survey reveals that 45% river bank community people believe that the main causes of river pollution is factory/mill/industry and 44% thought that pollution comes from municipal & urban waste and 11% think Motorized Boat may be responsible for pollution.

Along the Bongshi, there are 224 industries including two major export processing zone (EPZ), for export oriented industrial product (Upzila statistics, Savar, 2012) are discharging industrial effluent to Bongshi. There are garments, chemical, ceramics, medicines & drugs, dying, leather, and other heavy and light industries. The location of many of these industries is either on river/other open water-bed and either way drainage it with rivers. Most of the industries tend to release hazardous wastes like acids, organic chemicals and solvent of organic wastes, without treatments. A 76.75% of the respondent from Bongshi river bank community believed that the untreated waste disposal from factory/mill/industry is the main cause of pollution. Moreover, Karnatali, Turag, Balu and Shitalakhya rivers are also severely polluted rivers like the Buriganga and Bongshi due to untreaded industries, municipalities and sewerage discheges. **Figure 7.1** showed that how contaminants/ wastes inter to the rivers in Dhaka.

This study result's reveals that water quality is quite better in post rainy seaon compared to the dry season. However, some parameters especially DO, toxic ammonia and some toxic heavy metals especially Cr, Cd and Pb are found considerable amount in post rainy season. Moreover, some fishes also contain significant amount of these toxic metals in post rainy season too. These findings confirm that the pollution is continuniuing during high water flow too. This indicates river is polluting even in rainy season and the level of pollution reach maximum in dry season. As toxic heavy metal is non-degradable which exist even with high water flow in post rainy season, indicating environmental degradation in post rainy season, too. Therefore, ETP must be required in both post rainy and dry seasons to set up suitable treatment systems in their facilities or existing industrial plant should be run during operation to reduce pollution and revive the river ecosystem in Dhaka.

Figure 7.1: Wastes enter into the rivers in Dhaka. These photoes has captured in March 2015

➢ **Alleviating pollution by strict enforcement of industrial and environmental rules and policies**

The primary institution for environmental management is the Department of Environment (DoE) under the Ministry of Environment and Forest (MoEF). The DoE is the authority with the mandate to regulate and enforce environmental management, including control of pollution of water resources and ensuring adequate EIAs. It is the primary institution for environmental management and setting and enforcement of environmental regulations. Its key duties related to the water sector include:

- Pollution control, including: monitoring effluent sources, ensuring mitigation of environmental pollution
- Setting Water Quality Standards (WQS) for particular uses of water and for discharges to water bodies

- Defining Environmental Impact Assessments (EIA) procedures and issuing environmental clearance permits - the latter being legal requirements before proposed projects can proceed to implementation
- Providing advice or taking direct action to prevent degradation of the environment
- Declaring Ecologically Critical Areas (ECAs) where the ecosystem has been degraded to a critical state. ECA status confers protection on land and water resources through a series of environmental regulations

Government through the Department of Environment (DoE) formulated several rules, regulations, policies and strategies to save the rivers from pollution. DoE has provided specific attention to the issue of river pollution through enacting a number of policies such as National Environmental Policy-1992, Industrial Policy-1999 and National Water Policy-1999. Moreover, the Government's interest in protecting the rivers from pollution has also been reflected in the ECA (Environmental Conservation Act)-1995 and the ECR (Environmental Conservation Rules)-1997. However, the implementation and enforcement of the policies and the regulations have so far been very ineffective. In many cases the policies and strategies are seemingly far from being practical in terms of implementation which has shown in **Figure 7.1**.

It is possible to control pollution by the policies through strict monitoring. The existing rules should be amended by strict enforcement. DoE personnel must speak up to engage surrounding peoples of rivers to stop polluting them. DoE should apply and monitor the ECR strictly in a regular basis to stop untreated industrial wastes falling directly to rivers. DoE must take necessary action to aware owner of the industries to stop polluting rivers and ground water. Under this policy, all tanneries have to clean their effluents before disposal and install environmentally friendly technologies. Those who are unable to obey the rules have to close their tanneries and Governments have to support them to switch in other sectors. As a large number of tanneries get collapsed under this policy, the existing tanneries will get some open space to build Central Effluent Treatment Plant (CETP) and the problems of inadequate waste management and insufficient open space can be solved. Other thousands of industries besides the rivers should be enforcement to clean their effluents before disposal to rivers and install environmentally friendly technologies with strick monitoring by DoE. High penalty will be imposed to industry owner who doesn't maintain laws.

- **Alleviating pollution by developing Phytoremediation technique**

Heavy metals are among the most important sorts of contaminant in the environment. Beside the natural activities, almost all human activities also have potential contribution to produce heavy metals as side effects. Heavy metals containing industry/ sewerage wastes water directly discharges to rivers in Dhaka which contributing towards contamination of the ecosystems.

Recent concerns regarding the environmental contamination have initiated the development of appropriate technologies to assess the presence and mobility of metals in soil, water, and wastewater. Presently, phytoremediation has become an effective and affordable technological solution used to extract or remove inactive metals and metal pollutants from contaminated soil. Phytoremediation is the use of plants to clean up a contamination from soils, sediments, and water. This technology is environmental friendly and potentially costeffective. Plants with exceptional metal-accumulating capacity are known as hyperaccumulator plants. Phytoremediation takes the advantage of the unique and selective uptake capabilities of plant root systems, together with the translocation, bioaccumulation, and contaminant degradation abilities of the entire plant body.

Many species of plants have been successful in absorbing contaminants such as lead, cadmium, chromium, arsenic, and various radionuclides from soils. One of phytoremediation categories, phytoextraction, can be used to remove heavy metals from soil using its ability to uptake metals. This study reveals that rice root absorbed significant amount of heavy metals from soil. Therefore, phytoremediation technique can be developed to reduce pollution. However, for development of this technique need comprehensive laboratory/ field experiment.

- **Create water flow at upstream for alleviating pollution in dry season**

Existing river navigation system should be improved with proper dredging management which can create water flow at upstream that reduces pollution. Gohailbari is a place of Shimuliya union of Savar Upazilla where Bongshi enters in Dhaka district. At this point, it is a very narrow canal in dry season and carries only the waste water of various industries situated near Nabinagar-Chandra highway. If water flow can create at Gohailbari in dry season, this water flows through Bongshi, Karnatoli, Buriganga and fall into the Meghna. As rivers in Dhaka are linked as a loop, flow from Gohailbari also continuining through Karnatoli, Turag, Balu and Shitalakhya and falls into the Meghna. Moreover, if water flow can increase through Ashulia lake at Turag, this water flow passes through the Balu Shitalakhya and fall into the Meghna. This Turag flow also can circulate through Buriganga and fall into the Meghna, and will be achieved the loop of flow.

Figure 7.2: Arrows (orange colour) indicate possible places where water flow should be increased in dry season for maintaining continuous water flow all round the year

In this regad, Government has taken initiative to create water flow at upstream of Dhaka rivers.

- **Stop land encroachment to alleviate pollution**

Encroachments with installations/establishments along the river are the major point source of pollution. Land encroachment especially in Buriganga, Bongshi, Turag, Shitalakhya and Balu are severe. The rivers in Dhaka has been steadily shrinking and slowly dying due to actions from a number of influential quarters engaged in encroaching and grabbing the river bit by bit. Dumping of garbage along the banks, apparently to reclaim land, has been practiced over the years. To consolidate their holdings, encroachers resort to large scale and indiscriminate dumping of wastes and garbage for landfill. Most of the installations were found to encroach upon land at the river and discharge all their wastes directly into the river. The major encroachments identified along the rivers included permanent buildings, markets, mosques, industrial units and educational institutions and Housing Estatae too.These installations along the bank of the river are one of the major causes of and concerns for detertioration of the environment in and around the rivers. Sedimentation in the river channel and encroachment of its banks causes river meandering, shrinking of river, river erosion etc. Encroachments by the land grabbers cause a serious threat in life of rivers.

Figure 7.3: Land encroachment at the Bank of Bongshi

All illegal houses along the riverside should be removed, demolition of illegal structures along the rivers following the rules and regulation, which were established by the ECR (1997). Effective urban planning and land use regulation is required to maintain the river. Though the adjacent area of the rivers is foreshore/ shore, assurance should be given from the ministry of land that the land would not be encroached further. When dredging is activated properly the slope of the bank will be stepper and the depth will increase which will discourage encroaching. To remove the encroachment, it is necessary to monitor the shoreline of the river regularly and apply the environmental & social rules and regulations strictly.

- **Alleviating pollution by developing chemical/biochemical/dilution technique in earthen canals**

Many earthen canals are directly connected from factories to the rivers especially in Bongshi and Turag rivers. Chemical/biochemical/dilution technique can be developed to reduce contamination. However, comprehensive laboratory study will be required to develop some techniques.

Figure7.4: Earthen canal containing industrial waste at of Bongshi

- **Increase awareness to reduce river pollution**

- **Through selective authority**

Department of Environment is the key authority to manage environmental issues. They must speak up to engage surrounding peoples of rivers to stop polluting them. The main source of pollution is industrial wastes. DoE should apply and monitor the ECR strictly in a regular basis to stop untreated industrial wastes falling directly to rivers. DoE must take necessary action to aware owner of the industries to stop polluting rivers and ground water. Dhaka wasa is another authority who deals with the river water. They should increase awareness to the people not to throw wastes to rivers. Dhaka and Narayangang City Corporations must treat the huge amount of human wastes produced daily which are a significant part of pollutants polluting the rivers. Beside this, these city corporations are responsible for the managing of house hold wastes. So, they have an important role to aware people against pollution. BIWTA is the authority to control the river vessels such as launch, ship, steamer, small and large carrier vessels etc. For to operation of these vessels, BIWTA must maintain navigability of the rivers. Land enchrochment and low upstream flow is the main reason for low navigability. They should aware people who are enchroching land and people who are victim of this enchrochment. RAJUK is developing new residency along with other private developer, who mainly develop low land to build houses. RAJUK should follow the DAP and take awareness program among the people and developers. Agricultural extension office may take awareness program among fermers not to use polluted river water for irrigation and teach them about the health risk of the crops, vegetables, etc. produced using polluted river water irrigation.

- **Through mass media**

Mass media is a very important tool to creat awareness among people now a day. Government may use Television, FM Radio, Newspaper, Official Billboard, etc. to increase awareness to the people, just like government did previously for sanitation, family planning and recently against religious extremism where found some excellent results. School students are the best group of people to teach anything. Government may include a chapter about environmental pollution and their bad effects in human health in the science or general science book. Social media is the newly introduced most handy platform to spread any thought. Government may use social media such as Facebook, Twitter, Youtube, etc. to increase the awareness of the people about the environmental pollution and their health risks. Extensive research should carry out to alleviate pollution and circulate the results by various talk shows, seminar, symposium, conferences, etc.

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Annexure

Table-1: Alkalinity values at different locations measured at different seasons in different rivers.

	Dry Season				Wet Season			
River	Location	Avg.	Mean ± SD	Mean ± SE	Specific point	Avg.	Mean ± SD	Mean ± SE
Bongshi	Gohailbari	417.67	385.06 ± 137.65	385.06 ± 56.19	Goalbari	100.5	104.5 ± 4.92	104.5 ± 2.02
	Dhamsona	520.00			Dhamsona	108.5		
	DEPZ Canal	498.33			DEPZ Canal	109		
	Nama Bazar	446.33			-	-		
	Rafiq Setu	227.33			-	-		
	New Tannery	200.67			New Tennery,	100		
Buriganga	Amin Bazar Bridge	263	317.28 ± 43.34	317.28 ± 12.02	Amin Bazar	78.67	90.50 ± 12.45	90.50 ± 6.23
	Bosila	254			-	-		
	Hazaribagh Canal	269			Hazaribagh Canal	90.67		
	Gazir Ghat	278			-	-		
	Kholamora Boat Ghat	305			-	-		
	Soari Ghat	342			Soari Ghat	107.67		
	Babubazar	369			-	-		
	Sadar Ghat	368			-	-		
	Mirerbagh (Opposite Forasganj)	343			-	-		
	Postagola	375			-	-		
	Munshi Khola	324			-	-		
	Pagla	347			-	-		
	Fatulla	289			Fatulla	85.00		
Turag	Pal Para	276.333	303.89 ± 81.28	303.89 ± 33.18	Pal Para	83.67	104.89 ± 30.72	104.89 ± 12.54
	Sluice Gate (Beri Bhad)	315.667			Sluice Gate	154.7		
	Birulia near Cement Factory	266.333			Birulia	105.0		
	Ashulia Lake	238			Ashulia Lake	73.66		
	Tongi Bridge	265.333			Tongi Bridge	86.0		
	Termukh	461.667			Termukh	126.3		
Balu	Ichapur	381.33	349.92 ± 22.60	349.92 ± 11.3	-	-	-	-
	Beraid	347.33			-	-	-	-
	Dakshinpara	327.67			-	-	-	-
	Chanpara (Demra College)	343.33			-	-	-	-
Karnatali	Begun Bari	352.5	365.83 ± 11.55	365.83 ± 6.67	-	-	-	-
	Alfalah Char Khet	372.5			-	-	-	-
	Karna Para Bridge (Bank Town)	372.5			-	-	-	-
Shitalakhya	Nowpara	422.00	364.89 ± 93.09	364.89 ± 38.00	-	-	-	-
	Demra Bridge, Tarabo	420.67			-	-	-	-
	Kanchpur Bridge	303.00			-	-	-	-
	Adamzi EPZ	425.67			-	-	-	-
	Narayangonj, Launch Ghat	416.67			-	-	-	-
	Shah Cement Factory, Muktarpur	201.33			-	-	-	-

Table-2: Chloride values at different points measured at different seasons in different rivers.

	Dry Season				Wet Season			
River	Location	Avg. (N=6)	Mean ± SD	Mean ± SE	Specific point	Avg. (N=4)	Mean ± SD	Mean ± SE
Bongshi	Gohailbari	303.33	163.17 ± 98.41	163.17 ± 40.18	Goalbari	7.5	5.18 ± 4.03	5.18 ± 2.02
	Dhamsona	175.00			Dhamsona	-		
	DEPZ Canal	249.00			DEPZ Canal	13.2		
	Nama Bazar	123.00			-			
	Rafiq Setu	72.00			-	-		
	New Tannery	56.67			New Tennery,	-		
Buriganga	Amin Bazar Bridge	134.67	138.26 ± 19.93	138.26 ± 5.53	Amin Bazar	13.77	13.77 ± 4.59	13.77 ± 2.30
	Bosila	93.00			-	-		
	Hazaribagh Canal	126.67			Hazaribagh Canal	11.33		
	Gazir Ghat	155.00			-	-		
	Kholamora Boat Ghat	107.67			-	-		
	Soari Ghat	155.00			Soari Ghat	9.77		
	Babubazar	164.33			-	-		
	Sadar Ghat	151.67			-	-		
	Mirerbagh (Opposite Forasganj)	136.67			-	-		
	Postagola	150.00			-	-		
	Munshi Khola	135.00			-	-		
	Pagla	143.00			-	-		
	Fatulla	144.67			Fatulla	20.20		
Turag	Pal Para	144.33	148.69 ± 12.12	148.69 ± 4.95	Pal Para	-	104.89 ± 30.72	104.89 ± 12.54
	Sluice Gate (Beri Bhad)	138.67			Sluice Gate	-		
	Birulia near Cement Factory	140.00			Birulia	-		
	Ashulia Lake	140.95			Ashulia Lake	-		
	Tongi Bridge	162.51			Tongi Bridge	-		
	Termukh	165.67			Termukh	-		
Balu	Ichapur	189.33	195.92 ± 38.13	195.92 ± 19.07	-	-	-	-
	Beraid	172.33			-	-	-	-
	Dakshinpara	251.67			-	-	-	-
	Chanpara (Demra College)	170.33			-	-	-	-
Karnatali	Begun Bari	204.00	196.89 ± 13.19	196.89 ± 7.62	-	-	-	-
	Alfalah Char Khet	205.00			-	-	-	-
	Karna Para Bridge (Bank Town)	181.67			-	-	-	-
Shitalakhya	Nowpara	208.67	139.81 ± 88.87	139.81 ± 36.28	-	-	-	-
	Demra Bridge, Tarabo	158.00			-	-	-	-
	Kanchpur Bridge	215.00			-	-	-	-
	Adamzi EPZ	200.33			-	-	-	-
	Narayangonj, Launch Ghat	40.33			-	-	-	-
	Shah Cement Factory, Muktarpur	16.50			-	-	-	-

Table-3: Carbon-di-Oxide values at different points measured at different seasons in different rivers.

	Dry Season				Wet Season			
River	Location	Avg. (N=6)	Mean ± SD	Mean ± SE	Specific point	Avg.)	Mean ± SD	Mean ± SE
Bongshi	Gohailbari	7.850	8.21 ± 0.44	8.21 ± 0.18	Goalbari	16.53	20.37 ± 3.25	20.37 ± 1.63
	Dhamsona	8.770			Dhamsona	18.93		
	DEPZ Canal	8.697			DEPZ Canal	22.27		
	Nama Bazar	7.690			-	-		
	Rafiq Setu	8.210			-	-		
	New Tannery	8.070			New Tennery,	23.73		
Buriganga	Amin Bazar Bridge	107.9	113.7 ± 11.85	113.7 ± 5.93	Amin Bazar	17	22.95 ± 7.03	22.95 ± 3.51
	Bosila	127.9			-	-		
	Hazaribagh Canal	100.8			Hazaribagh Canal	18		
	Gazir Ghat	118.2			-	-		
	Kholamora Boat Ghat	-			-	-		
	Soari Ghat	-			Soari Ghat	24.6		
	Babubazar	-			-	-		
	Sadar Ghat	-			-	-		
	Mirerbagh (Opposite Forasganj)	-			-	-		
	Postagola	-			-	-		
	Munshi Khola	-			-	-		
	Pagla	-			-	-		
	Fatulla	-			Fatulla	32.2		
Turag	Pal Para	36.95	46.54 ± 10.74	46.54 ± 4.38	Pal Para	22.9	27.13 ± 5.93	27.13 ± 2.42
	Sluice Gate (Beri Bhad)	45.00			Sluice Gate	28		
	Birulia near Cement Factory	40.20			Birulia	30.2		
	Ashulia Lake	43.40			Ashulia Lake	27.3		
	Tongi Bridge	46.33			Tongi Bridge	18.6		
	Termukh	67.33			Termukh	35.8		
Balu	Ichapur	-	-	-	-	-	-	-
	Beraid	-			-	-		
	Dakshinpara	-			-	-		
	Chanpara (Demra College)	-			-	-		
Karnatali	Begun Bari	-	-	-	-	-	-	-
	Alfalah Char Khet	-			-	-		
	Karna Para Bridge (Bank Town)	-			-	-		
Shitalakhya	Nowpara	-	-	-	-	-	-	-
	Demra Bridge, Tarabo	-			-	-		
	Kanchpur Bridge	-			-	-		
	Adamzi EPZ	-			-	-		
	Narayangonj, Launch Ghat	-			-	-		
	Shah Cement Factory, Muktarpur	-			-	-		

Table-4: Dissolved Oxygen (DO) values at different points measured at different seasons in different rivers.

	Dry Season				Wet Season			
River	Location	Avg. (N=6)	Mean ± SD	Mean ± SE	Specific point	Avg. (N=4)	Mean ± SD	Mean ± SE
Bongshi	Gohailbari	0.14	1.67 ± 2.34	1.67 ± 0.96	Goalbari	5.50	5.31 ± 0.43	5.31 ± 0.21
	Dhamsona	0.17			Dhamsona	5.21		
	DEPZ Canal	0.20			DEPZ Canal	4.76		
	Nama Bazar	0.19			-	-		
	Rafiq Setu	4.57			-	-		
	New Tannery	4.84			New Tennery,	5.76		
Buriganga	Amin Bazar Bridge	0.24	0.18 ± 0.05	0.18 ± 0.01	Amin Bazar	2.82	1.21 ± 1.15	1.21 ± 0.57
	Bosila	0.20			-	-		
	Hazaribagh Canal	0.24			Hazaribagh Canal	1.21		
	Gazir Ghat	0.20			-	-		
	Kholamora Boat Ghat	0.27			-	-		
	Soari Ghat	0.21			Soari Ghat	0.20		
	Babubazar	0.16			-	-		
	Sadar Ghat	0.16			-	-		
	Mirerbagh (Opposite Forasganj)	0.18			-	-		
	Postagola	0.15			-	-		
	Munshi Khola	0.10			-	-		
	Pagla	0.17			-	-		
	Fatulla	0.14			Fatulla	0.62		
Turag	Pal Para	0.14	0.18 ± 0.03	0.18 ± 0.01	Pal Para		2.72 ± 1.62	2.72 ± 0.66
	Sluice Gate (Beri Bhad)	0.18			Sluice Gate	2.60		
	Birulia near Cement Factory	0.21			Birulia	4.00		
	Ashulia Lake	0.18			Ashulia Lake	4.14		
	Tongi Bridge	0.22			Tongi Bridge	3.90		
	Termukh	0.17			Termukh	1.55		
Balu	Ichapur	0.13	0.26 ± 0.13	0.26 ± 0.07	-	-	-	-
	Beraid	0.15			-	-		
	Dakshinpara	0.25			-	-		
	Chanpara (Demra College)	0.45			-	-		
Karnatali	Begun Bari	0.20	0.35 ± 0.14	0.35 ± 0.08	-	-	-	-
	Alfalah Char Khet	0.36			-	-		
	Karna Para Bridge (Bank Town)	0.49			-	-		
Shitalakhya	Nowpara	0.21	0.18 ± 0.02	0.18 ± 0.01	-	-	-	-
	Demra Bridge, Tarabo	0.19			-	-		
	Kanchpur Bridge	0.18			-	-		
	Adamzi EPZ	0.19			-	-		
	Narayangonj, Launch Ghat	0.17			-	-		
	Shah Cement Factory, Muktarpur	0.15			-	-		

Table-5: Electrical Conductivity (EC) values at different points measured at different seasons in different rivers.

River	Dry Season				Wet Season			
	Location	Avg.	Mean ± SD	Mean ± SE	Specific point	Avg.	Mean ± SD	Mean ± SE
Bongshi	Gohailbari	1840	1393.57 ± 622.13	1393.57 ± 253.98	Goalbari	281.33	263.75 ± 24.59	263.75 ± 12.29
	Dhamsona	1804			Dhamsona	230.00		
	DEPZ Canal	2120			DEPZ Canal	261.00		
	Nama Bazar	1234			-	-		
	Rafiq Setu	707			-	-		
	New Tannery	656			New Tennery,	282.67		
Buriganga	Amin Bazar Bridge	990.67	1032.23 ± 62.89	1032.23 ± 17.44	Amin Bazar	272	293.5 ± 15.61	293.50 ± 7.80
	Bosila	1094.00			-	-		
	Hazaribagh Canal	1082.00			Hazaribagh Canal	304		
	Gazir Ghat	1059.67			-	-		
	Kholamora Boat Ghat	1079.00			-	-		
	Soari Ghat	1043.67			Soari Ghat	292		
	Babubazar	1052.00			-	-		
	Sadar Ghat	1044.67			-	-		
	Mirerbagh (Opposite Forasganj)	1041.00			-	-		
	Postagola	1091.00			-	-		
	Munshi Khola	1022.33			-	-		
	Pagla	941.67			-	-		
	Fatulla	877.33			Fatulla	306		
Turag	Pal Para	994.67	1120.33 ± 267.85	1120.33 ± 109.35	Pal Para	286.0	349.22 ± 98.74	349.22 ± 40.31
	Sluice Gate (Beri Bhad)	872.67			Sluice Gate	497.0		
	Birulia near Cement Factory	1020.67			Birulia	281.0		
	Ashulia Lake	1157.33			Ashulia Lake	277.3		
	Tongi Bridge	1042.33			Tongi Bridge	301.0		
	Termukh	1634.33			Termukh	453.0		
Balu	Ichapur	1042.00	984.84 ± 57.90	984.84 ± 28.95	-	-	-	-
	Beraid	984.00			-	-		
	Dakshinpara	1007.67			-	-		
	Chanpara (Demra College)	905.67			-	-		
Karnatali	Begun Bari	1159	1129.00 ± 26.46	1129.00 ± 15.28	-	-	-	-
	Alfalah Char Khet	1109			-	-		
	Karna Para Bridge (Bank Town)	1119			-	-		
Shitalakhya	Nowpara	916.67	888.78 ± 146.08	888.78 ± 59.64	-	-	-	-
	Demra Bridge, Tarabo	932.67			-	-		
	Kanchpur Bridge	975.67			-	-		
	Adamzi EPZ	983.33			-	-		
	Narayangonj, Launch Ghat	928.67			-	-		
	Shah Cement Factory, Muktarpur	595.67			-	-		

Table-6: Hardness values at different points measured at different seasons in different rivers.

	Dry Season				Wet Season			
River	Location	Avg.	Mean ± SD	Mean ± SE	Specific point	Avg.	Mean ± SD	Mean ± SE
Bongshi	Gohailbari	310.67	213.2 ± 52.37	213.2 ± 21.38	Goalbari	85.00	87.67 ± 5.01	87.67 ± 2.51
	Dhamsona	166.67			Dhamsona	82.00		
	DEPZ Canal	177.67			DEPZ Canal	91.00		
	Nama Bazar	199.67			-	-		
	Rafiq Setu	229.67			-	-		
	New Tannery	195.00			New Tennery,	92.67		
Buriganga	Amin Bazar Bridge	167.67	185.45 ± 3.47	185.45 ± 0.93	Amin Bazar	67.00	74.09 ± 5.73	74.09 ± 2.87
	Bosila	126.00			-	-		
	Hazaribagh Canal	193.67			Hazaribagh Canal	73.67		
	Gazir Ghat	161.33			-	-		
	Kholamora Boat Ghat	211.33			-	-		
	Soari Ghat	203.00			Soari Ghat	81.00		
	Babubazar	182.33			-	-		
	Sadar Ghat	191.67			-	-		
	Mirerbagh (Opposite Forasganj)	182.33			-	-		
	Postagola	193.33			-	-		
	Munshi Khola	205.33			-	-		
	Pagla	193.33			-	-		
	Fatulla	197.00			Fatulla	74.67		
Turag	Pal Para	188.00	168.17 ± 5.92	168.17 ± 2.42	Pal Para		75.89 ± 17.25	75.89 ± 7.04
	Sluice Gate (Beri Bhad)	171.33			Sluice Gate	64.33		
	Birulia near Cement Factory	161.67			Birulia	84.33		
	Ashulia Lake	167.67			Ashulia Lake	55.00		
	Tongi Bridge	169.00			Tongi Bridge	67.00		
	Termukh	162.00			Termukh	103.0		
Balu	Ichapur	177.33	186.00 ± 18.18	186.0 ± 9.09	-	-	-	-
	Beraid	163.33			-	-		
	Dakshinpara	205.33			-	-		
	Chanpara (Demra College)	180.67			-	-		
Karnatali	Begun Bari	194.67	214.56 ± 18.59	214.56 ± 10.73	-	-	-	-
	Alfalah Char Khet	236.00			-	-		
	Karna Para Bridge (Bank Town)	203.00			-	-		
Shitalakhya	Nowpara	204.67	192.11 ± 69.80	192.11 ± 28.50	-	-	-	-
	Demra Bridge, Tarabo	186.00			-	-		
	Kanchpur Bridge	204.33			-	-		
	Adamzi EPZ	313.00			-	-		
	Narayangonj, Launch Ghat	177.67			-	-		
	Shah Cement Factory, Muktarpur	174.67			-	-		

Table-7: pH values at different points measured at different seasons in different rivers.

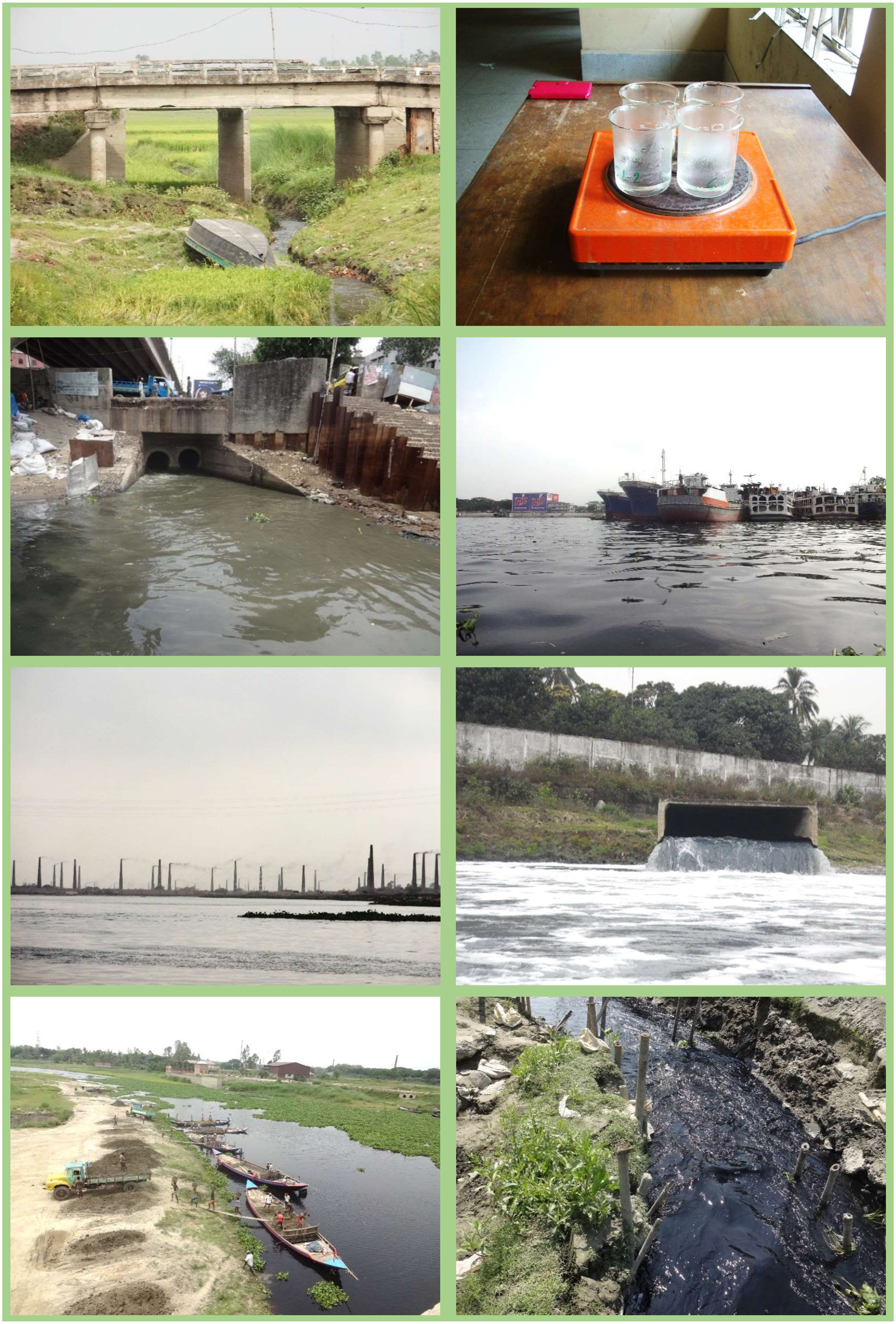
	Dry Season				Wet Season			
River	Location	Avg.	Mean ± SD	Mean ± SE	Specific point	Avg.	Mean ± SD	Mean ± SE
Bongshi	Gohailbari	7.85	8.21 ± 0.44	8.21 ± 0.18	Goalbari	7.43	7.36 ± 0.09	7.36 ± 0.04
	Dhamsona	8.77			Dhamsona	7.37		
	DEPZ Canal	8.69			DEPZ Canal	7.41		
	Nama Bazar	7.69			-	-		
	Rafiq Setu	8.21			-	-		
	New Tannery	8.07			New Tennery,	7.24		
Buriganga	Amin Bazar Bridge	7.55	7.54 ± 0.27	7.54 ± .075	Amin Bazar	7.3	7.23 ± 0.07	7.23 ± 0.03
	Bosila	6.77			-	-		
	Hazaribagh Canal	7.70			Hazaribagh Canal	7.27		
	Gazir Ghat	7.54			-	-		
	Kholamora Boat Ghat	7.52			-	-		
	Soari Ghat	7.49			Soari Ghat	7.15		
	Babubazar	7.44			-	-		
	Sadar Ghat	7.42			-	-		
	Mirerbagh (Opposite Forasganj)	7.54			-	-		
	Postagola	7.61			-	-		
	Munshi Khola	7.79			-	-		
	Pagla	7.77			-	-		
	Fatulla	7.85			Fatulla	7.19		
Turag	Pal Para	7.50	7.58 ± 0.33	7.58 ± 0.13	Pal Para	7.29	7.39 ± 0.12	7.39 ± 0.05
	Sluice Gate (Beri Bhad)	7.28			Sluice Gate	7.51		
	Birulia near Cement Factory	7.53			Birulia	7.32		
	Ashulia Lake	7.60			Ashulia Lake	7.35		
	Tongi Bridge	7.36			Tongi Bridge	7.28		
	Termukh	8.20			Termukh	7.58		
Balu	Ichapur	7.64	7.52 ± 0.19	7.52 ± 0.09	-	-	-	-
	Beraid	7.64			-	-		
	Dakshinpara	7.24			-	-		
	Chanpara (Demra College)	7.55			-	-		
Karnatali	Begun Bari	7.84	7.83 ± 0.30	7.83 ± 0.17	-	-	-	-
	Alfalah Char Khet	7.53			-	-		
	Karna Para Bridge (Bank Town)	8.12			-	-		
Shitalakhya	Nowpara	8.24	7.78 ± 0.26	7.78 ± 0.11	-	-	-	-
	Demra Bridge, Tarabo	7.54			-	-		
	Kanchpur Bridge	7.54			-	-		
	Adamzi EPZ	7.69			-	-		
	Narayangonj, Launch Ghat	7.79			-	-		
	Shah Cement Factory, Muktarpur	7.87			-	-		

Table-8: Total Dissolved Solid (TDS) values at different points measured at different seasons in different rivers.

	Dry Season				Wet Season			
River	Location	Avg.	Mean ± SD	Mean ± SE	Specific point	Avg.	Mean ± SD	Mean ± SE
Bongshi	Gohailbari	922.00	694.5 ± 317.93	694.5 ± 129.79	Goalbari	134.90	126.35 ± 12.69	126.35 ± 6.35
	Dhamsona	884.67			Dhamsona	109.23		
	DEPZ Canal	1082.00			DEPZ Canal	124.30		
	Nama Bazar	610.33			-	-		
	Rafiq Setu	346.33			-	-		
	New Tannery	321.67			New Tennery,	136.97		
Buriganga	Amin Bazar Bridge	491.00	509.46 ± 33.48	509.46 ± 9.28	Amin Bazar	130.5	140.63 ± 7.35	140.63 ± 3.67
	Bosila	543.67			-			
	Hazaribagh Canal	536.00			Hazaribagh Canal	145.8		
	Gazir Ghat	534.00			-			
	Kholamora Boat Ghat	528.00			-	-		
	Soari Ghat	515.00			Soari Ghat	139.9		
	Babubazar	529.00			-	-		
	Sadar Ghat	516.67			-	-		
	Mirerbagh (Opposite Forasganj)	513.00			-	-		
	Postagola	538.67			-	-		
	Munshi Khola	482.00			-	-		
	Pagla	466.00			-	-		
	Fatulla	430.00			Fatulla	146.3		
Turag	Pal Para	516.33	560.22 ± 136.37	560.22 ± 55.67	Pal Para	137.2	171.1 ± 54.67	171.11 ± 22.32
	Sluice Gate (Beri Bhad)	429.00			Sluice Gate	260.3		
	Birulia near Cement Factory	504.00			Birulia	134.2		
	Ashulia Lake	574.00			Ashulia Lake	132.3		
	Tongi Bridge	516.00			Tongi Bridge	144.267		
	Termukh	822.00			Termukh	218.4		
Balu	Ichapur	513.00	485.00 ± 28.44	485.00 ± 14.22	-	-	-	-
	Beraid	485.00			-	-		
	Dakshinpara	496.00			-	-		
	Chanpara (Demra College)	446.00			-	-		
Karnatali	Begun Bari	577.00	562.67 ± 14.50	562.67 ± 8.37	-	-	-	-
	Alfalah Char Khet	548.00			-	-		
	Karna Para Bridge (Bank Town)	563.00			-	-		
Shitalakhya	Nowpara	463.00	438.83 ± 1.02	438.83 ± 0.58	-	-	-	-
	Demra Bridge, Tarabo	459.00			-	-		
	Kanchpur Bridge	477.67			-	-		
	Adamzi EPZ	482.33			-	-		
	Narayangonj, Launch Ghat	461.33			-	-		
	Shah Cement Factory, Muktarpur	289.67			-	-		

Table-9: Temperature values at different points measured at different seasons in different rivers.

	Dry Season				Wet Season			
River	Location	Avg.	Mean ± SD	Mean ± SE	Specific point	Avg.	Mean ± SD	Mean ± SE
Bongshi	Gohailbari	30.00	23.74 ± 2.95	23.74 ± 1.11	Goalbari	29.50	29.68 ± 0.35	29.68 ± 0.18
	Dhamsona	31.80			Dhamsona	29.53		
	DEPZ Canal	28.60			DEPZ Canal	30.20		
	Nama Bazar	25.50			-	-		
	Rafiq Setu	26.30			-	-		
	New Tannery	24.00			New Tennery,	29.47		
Buriganga	Amin Bazar Bridge	23.04	22.77 ± 0.41	22.77 ± 0.11	Amin Bazar	29.20	30.10 ± 0.64	30.10 ± 0.32
	Bosila	22.70			-			
	Hazaribagh Canal	23.70			Hazaribagh Canal	30.70		
	Gazir Ghat	23.20			-	-		
	Kholamora Boat Ghat	22.80			-	-		
	Soari Ghat	22.30			Soari Ghat	30.30		
	Babubazar	22.40			-	-		
	Sadar Ghat	22.70			-	-		
	Mirerbagh (Opposite Forasganj)	22.70			-	-		
	Postagola	22.80			-	-		
	Munshi Khola	22.80			-	-		
	Pagla	22.30			-	-		
	Fatulla	23.10			Fatulla	30.20		
Turag	Pal Para	23	23.33 ± 0.80	23.33 ± 0.33	Pal Para	28.8	29.62 ± 0.41	29.62 ± 0.17
	Sluice Gate (Beri Bhad)	22.5			Sluice Gate	29.8		
	Birulia near Cement Factory	22.9			Birulia	29.6		
	Ashulia Lake	23.5			Ashulia Lake	29.8		
	Tongi Bridge	23.3			Tongi Bridge	29.9		
	Termukh	24.8			Termukh	29.8		
Balu	Ichapur	24.20	25.18 ± 0.78	25.18 ± 0.39	-	-	-	-
	Beraid	24.90			-	-		
	Dakshinpara	25.70			-	-		
	Chanpara (Demra College)	25.90			-	-		
Karnatali	Begun Bari	27.70	26.43 ± 1.17	26.43 ± 0.67	-	-	-	-
	Alfalah Char Khet	26.20			-	-		
	Karna Para Bridge (Bank Town)	25.40			-	-		
Shitalakhya	Nowpara	25.30	25.05 ± 0.68	25.05 ± 0.28	-	-	-	-
	Demra Bridge, Tarabo	24.60			-	-		
	Kanchpur Bridge	24.60			-	-		
	Adamzi EPZ	25.90			-	-		
	Narayangonj, Launch Ghat	25.70			-	-		
	Shah Cement Factory, Muktarpur	24.20			-	-		



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