ASSESSMENT OF HEAVY METAL CONTAMINATION IN SEDIMENT OF BURIGANGA-TURAG RIVER SYSTEM

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DHAKA, BANGLADESH

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A thesis submitted by

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In partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering (Environmental)

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CERTIFICATE OF APPROVAL

We hereby recommend that the thesis titled **"ASSESSMENT OF HEAVY METAL CONTAMINATION IN SEDIMENT OF BURIGANGA-TURAG RIVER SYSTEM."** submitted by ZOYNAB BANU, Student Number-1009042109F be accepted as fulfilling this part of the requirements for the degree of Master of Science in Civil Engineering (Environmental) on 20th July, 2013.

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ABSTRACT

The Buriganga and the Turag rivers are situated on the Southern and Western sides of Dhaka City. This is a good example of site where human pressures and ecological values collide with each other. Buriganga and Turag are some polluted rivers around Dhaka city. Encroachment, disposal of untreated domestic and industrial wastewater and dumping of solid wastes have degraded the overall quality of the rivers. The present study investigated the extent of pollution of sediments of those rivers. One of the aims of this research was to assess the level of heavy metal contamination in the sediment using advanced statistical techniques and different pollution indices and finally to analyze the ecological risk due to sediment contamination in the Buriganga –Turag river system.

Under this study, sediment samples were collected from 15 (fifteen) locations of the Turag river and available data from previous studies on 05 (Five) locations of the Buriganga were used for sediment analysis. Samples were collected in April, 2011 in case of Turag river and in May, 2010 in case of Buriganga river and analyzed for the regional variability for the concentrations of Cr, Pb, Zn, Cu and Cd- all of concern because of their potential toxicity, using Atomic Absorption Spectrophotometer. Aqua regia digestion (USEPA method 3050) has been performed for the dissolution of the sediment samples prior to the determination of heavy metals. Metal concentrations found to be higher for the Buriganga river than the Turag river.

The sediments of the Buriganga river assessed in this study have been found to be highly polluted with respect to Cu, Pb and Zn; unpolluted to moderately polluted with respect to Cd and moderately polluted to highly polluted with respect to Cr on the basis of USEPA sediment quality guideline.

The sediments of the Turag river assessed in this study have been found to be moderately to highly polluted with respect to Cr, Cu, Zn; unpolluted with respect to Pb and Cd on the basis of USEPA sediment quality guideline.

In order to determine the similarities and differences among sampling sites, concentration data of the heavy metals analyzed statistically by using Principal Component Analysis (PCA) methods. Cd-Cu-Zn; Pb-Cr may have same or similar source input in the sediments of Buriganga river and Cr-Zn; Pb-Cu in the sediments of Turag river on the basis of Principal Component Analysis.

Significant correlation between the contaminants of Cd and Zn (r=0.99), Cd and Cu (r=0.98), Zn and Cu (r=0.97), Pb and Zn (r=0.89), Pb and Cr (r=0.85), Cd and Pb (r=0.82), Pb and Cu (r=0.80), Cr and Cu (r=0.75) in Pearson's correlation for the heavy metals of Buriganga river indicates that those contaminants have same or similar source input.

Significant correlations between the contaminants of Cr and Zn (r=0.45), Pb and Cd (r=0.45), Pb and Cr (r=0.49) in Pearson's correlation for the heavy metals of Turag river indicates that those contaminants have same or similar source input.

Different types of indices have been used to assess the current pollution status in river sediments of the Buriganga and the Turag rivers. The Buriganga and the Turag river have a low to appreciable potential ecological risk due to heavy metal contamination according to Ecological Risk Index. As per Sediment Quality Guideline Quotient (SQG-Q) the Buriganga river sediments are moderately to highly impacted and the Turag river sediments are moderately impacted to adverse biological effects.

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ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
BIWTA	Bangladesh Inland Water Transport Authority
BOD	Biochemical Oxygen Demand
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh water development board
Canadian EQG	Canadian Environmental Quality Guidelines
COD	Chemical Oxygen Demand
DCC	Dhaka City Corporation
DND	Dhaka Narayanganj Demra
DO	Dissolved Oxygen
DoE	Department of Environment
DWASA	Dhaka Water Supply and Sewerage Authority
EQG	Environmental Quality Guidelines
EQS	Environmental Quality Standard
HNEC	High No Effect Concentrations
IWM	Institute of Water Modeling
Japan EQL	Japan's Environmental Quality Standard
JICA	Japan International Co-operation Agency
LEL	Lowest Effect Levels
Ontario MOE	Ontario Ministry of Environment
SEL	Severe Effect Level
SQG-Q	Sediment Quality Guideline Quotient
TCLP	Toxicity Characteristics Leaching Procedure
TEC	Threshold Effect Concentration
TRV	Toxicity Reference Values
TSS	Total Suspended Solid
USEPA-	United States Environmental Protection Agency
WQ	Water Quality

CHAPTER ONE
INTRODUCTION

1.1 General

The five peripheral rivers Buriganga, Dhaleswari, Turag, Balu, Sitalakhya and Tongi Khal are receivers of storm water, municipal and industrial wastewater and sewage from Dhaka City (Paul and Haq, 2010). There are 300 outfalls of domestic and industrial effluents. Nine outfalls are the major polluters. Effluents are discharged into the rivers indiscriminately without any treatment. The rivers are further polluted by indiscriminate throwing of household, clinical, pathological and commercial wastes and discharge of spent fuel and human excreta. In fact, the river has become a dumping ground of all kinds of solid, liquid and chemical waste of bank-side population (Rahman and Hadiuzzaman, 2005). The industrial units such as chemicals, fertilizer, pesticides, textile, oil, power station, ship repairing dock, cement and tannery are located in and around the Dhaka City (DoE, 1993). In terms of quality, the river water around the Dhaka is vulnerable to pollution from untreated industrial effluents and municipal wastewater, runoff from chemical fertilizers and pesticides, and oil and lube spillage in and around the operation of river ports (Alam et al., 2006).

The worldwide systematic monitoring of environmental pollution by heavy metals began since the 1960s (Salomons, 1993). Pollution of the natural environment by heavy metals is a worldwide problem because these metals are indestructible and most of them have toxic effects on living organisms, when they exceed a certain concentration (Nuremberg, 1984). Heavy metals are one of the serious pollutants in natural environment due to their toxicity, persistence and bioaccumulation problems (Nouri et al., 2006). Heavy metals contamination in river is one of the major quality issues in many fast growing cities, because maintenance of water quality and sanitation infrastructure did not increased along with population and urbanization growth especially for the developing countries (Ahmed et al., 2010). Trace metals enter in river from variety of sources; it be can be either natural or anthropogenic (Bem et al., 2003). Main anthropogenic sources of heavy metal contamination are mining, disposal of untreated and partially treated effluents contain toxic metals, as well as metal chelates from different industries and indiscriminate use of heavy metal-containing fertilizer and pesticides in agricultural fields (Hatje et al., 1998). Heavy metals are non-biodegradable and can accumulate in the

human body system, causing damage to nervous system and internal organs (Lee et al. 2007). However, the rivers play a major role in assimilation or transporting municipal and industrial wastewater and runoff from agricultural and mining land (Singh et al., 2004).

Sediments are normally mixtures of several components including different mineral species as well as organic debris. Sediments represent one of the ultimate sinks for heavy metals discharged into the environment (Gibbs, 1977). Polluted sediments are a starting point for contamination throughout the food chain, potentially damaging marine life and affecting human health. Pollutants from industrial discharges, burning of fossil fuels, and runoff from farms and urban and suburban areas are carried to coastal waters by rivers, rainfall, and wind, where they accumulate on the bottom. Small organisms incorporate these contaminants into their bodies, and when they are eaten by other organisms, the contaminants may move up the food chain (bioaccumulation). Areas with contaminated sediments may also be unsafe for swimming and other recreation. In order to protect the aquatic life community, comprehensive methods for identifying and assessing the severity of sediment contamination have been introduced over the past 10 years (Chapman, 2000).

In addition, sediment-associated chemicals have the potential to adversely affect sediment-dwelling organisms (e.g., by causing direct toxicity or altering benthic invertebrate community structure). Therefore, sediment quality data (i.e., information on the concentrations of chemical substances) provide essential information for evaluating ambient environmental quality conditions in freshwater systems.

Bangladesh being a riverine country, the requirement of dredging, as a tool for developing and maintaining its navigation channels. Bangladesh Inland Water Transport Authority (BIWTA) has a future plan to remove garbage's from the rivers of Buriganga and Turag and to decontaminate the water. The sediments and garbage's will be dumped into a new location. So, if the sediments are highly contaminated that will again pollute the new environment. Ultimate success of cleaning the rivers depends on disposal of dredged materials in suitable place and control of industrial and other pollution.

1.2 Scope of the Study

The study is limited to finding only the heavy metal contamination of sediments of some polluted rivers. Although other parameters responsible for sediment contamination are not less important. The analysis of river sediment is a useful method of studying environmental pollution with heavy metals. There are basically three reservoirs of metals in the aquatic environment: water, sediment and biota. The study has designed to find the pollution level of river sediments in terms of heavy metal content, as heavy metal is one of the most concerning pollutants around the world.

The scope of the study is limited to the following:

a) Dhaka city is surrounded by Sitalakhya, Buriganga, Turag and Balu rivers and different Khals (Begunbari Khal, Norai Khal, Tongi Khal) carry wastewater from different parts of the city including the North-eastern flood plain. Only heavy metal contamination of sediments of the Buriganga and the Turag river were considered in this study.

b) Traveling along the Turag river, monitoring the physical condition of river water along the river. A GPS machine has been used to locate the points of interest in the river and corresponding data of special features has recorded.

c) Sediment sample collection from the Turag river using a sediment sampler from shallow depth of the river.

d) Study of available previous data of heavy metal contamination of sediments of the Buriganga river has been studied.

1.2 Objectives

The overall objective of the present study is to assess the heavy metal contamination in river sediments of some polluted rivers. Specific objectives of this study include:

- To assess the level of heavy metal concentrations in the sediment, its spatial distribution and compare it with the USEPA quality guideline.
- Application of advanced statistical techniques such as Principal Component Analysis and correlation matrix in order to investigate the complex dynamics of pollutants, source of heavy metal concentration in the sediments and relationships.
- To select different pollution indices to assess heavy metal contamination.
- To analyze the ecological risk due to sediment contamination.

1.3 Outline of Methodologies

Sediment Sampling and Chemical Analysis:

Sediments sample have been collected from fifteen sampling sites along the Turag river during the dredging of Turag bed sludge in April, 2011. After collection, some portion of sediment samples have been dried in a vacuum oven at 105°C until constant weight, lightly ground in an agate mortar for homogenization and have been prepared for analysis of heavy metal and some portion of samples have been prepared for sieve analysis. For heavy metal test, 5 gm of dried sample have been digested with acid and 500 ml solutions have been prepared. Finally, five heavy metals (Pb, Cd, Cr, Cu and Zn) concentration have been determined in the Environmental Engineering Laboratory, BUET by using Atomic Absorption Spectrophotometer (Shimadzu, AA6800). Heavy metal concentration along different sites for Buriganga and Turag river have been collected from secondary sources. Toxicity Characteristics Leaching Procedure (TCLP) test for sediment samples have been performed for five heavy metals (Pb, Cd, Cr, Cu and Zn) to determine the readily toxicity level of heavy metals.

Assessment of Metal Contamination:
a) Background Enrichments Indices
b) Contamination Indices
c) Ecological Risk Indices

Assessment of Metal Pollution Index:

In order to evaluate the overall degree of stream sediment metal contamination, the Metal Pollution Index (MPI) has been calculated.

Ecological evaluation on heavy metals:

The Potential Ecological Risk Index (PERI) is a diagnostic tool for contamination control of lakes and coastal systems. PERI is formed by three basic modules: Degree of contamination (C_D); toxic-response factor (T_f) and potential ecological risk factor (E_f).

Multivariate Statistical Assessment:

Univariate and multivariate statistical methods of analysis have been used in the study. The software SPSS 15.0 has been used for statistical analysis. The correlation matrix which is based on the Pearson's correlation coefficient has been utilized for displaying

relationships between variables. The obtained matrix of heavy metal concentration has been subjected to multivariate analytical technique. Factor analysis which aims to explain an observed relationship between numerous variables in terms of simple relations has been applied.

1.4 Organization of the Thesis

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

Literature review, covering background information on pollution problem in the Buriganga and the Turag river, identifying major sources of pollution and review of the available water quality data. This chapter also provides essential information on heavy metal contamination in surface sediments.

Methodology, covering brief description on metal analysis methods, pollution indices calculation methods, Toxicity Characteristic Leaching Procedure test and data treatment by statistical method.

Sediment quality data of two polluted rivers (Buriganga and Turag) has presented in Chapter 4 (results and discussion). Based on the analysis of test results, a discussion has conducted for the current state of sediment quality of the Buriganga and the Turag river.

Summarization of the major conclusions from the present study and recommendations for future study in the polluted rivers is presented in chapter 5.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter provides an overview of the pollution scenario in some polluted rivers, identifying major sources of pollution. It provides a review of the available data on the water quality of some polluted rivers. This chapter also provides essential information on heavy metal contamination in surface sediments.

2.2 River Pollution in Bangladesh

Bangladesh lies at the deltaic or lower region of the three mighty river systems, the Ganga-Padma, the Brahmaputra-Jamuna and the Barak-Meghna. Perennial streams, beals and estuaries cover about 8 percent of the land area (Paul and Haq, 2010).

Of a large number of rivers flowing through Bangladesh, 56 rivers originate outside Bangladesh, including the three major rivers: the Ganges, the Brahmaputra and the Meghna. The remaining are mainly tributaries of the major and medium rivers. The rivers of Bangladesh can be divided into the major rivers comprising of the Ganges–Padma, Brahmaputra–Jamuna and the Barak–Meghna, and medium and minor rivers (including border tributaries and distributaries) (Paul and Haq, 2010).

Dhaka, the capital city of Bangadesh is located between $23^o35'$ to $23^o54'$ North Latitude and $90^o20'$ to $90^o33'$ East Longitude and is encompassed by six water ways, five rivers and one canal (Karn and Harada, 2001). These waterways constituted the following routes:

i. Tongi Canal-Balu river

ii. Tongi Canal-Turag river-Buriganga river-Dhaleshwari river

iii. Shitalakhya river

Rivers surrounding Dhaka city receive water mainly from the spill channels of Jamuna river and Old Brahmaputra and from rainfall-runoff during monsoon. But during dry period most of the spill channels loose their connection with Jamuna at their off take. As a result the peripheral rivers of Dhaka receive very feeble from the major rivers. During the monsoon (November to May) most of the peripheral rivers are influenced by tides. As a result, flow reversal occurs in these rivers. The peripheral river system consist of mainly three distinct system as follows (IWM, 2006)-

- Dhaleswari-Kaliganga System

- Bangsi-Turag-Buriganga System

- Banar-Lakhya System
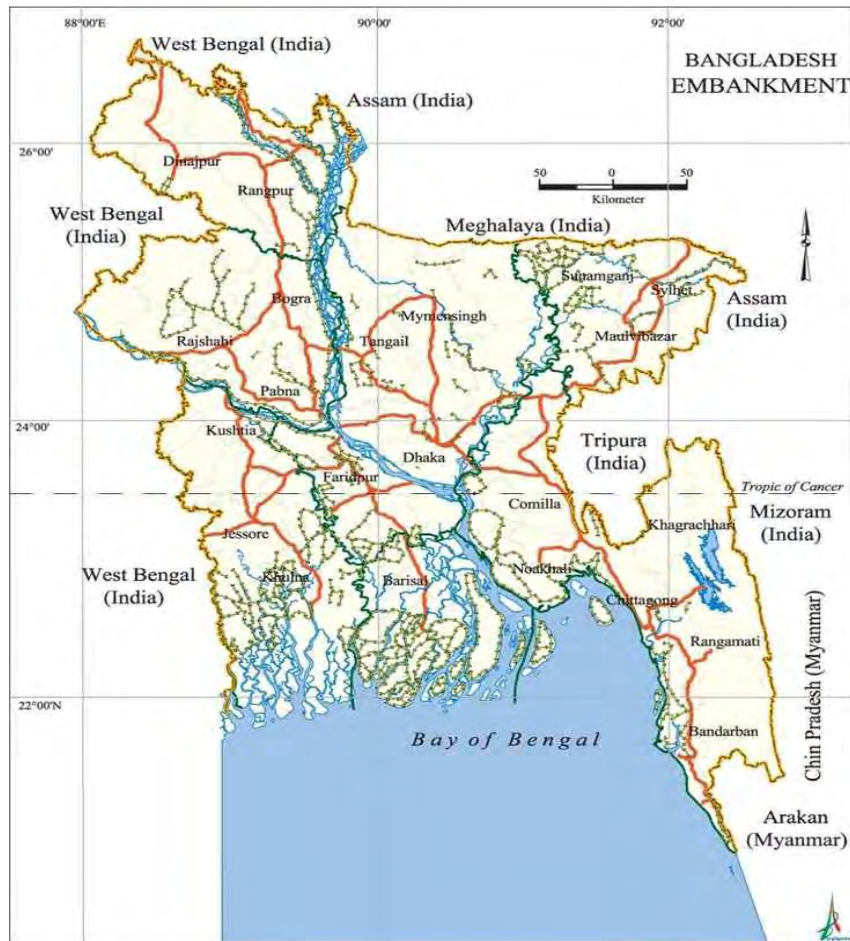
Fig. 2.1 Rivers in Bangladesh
(http://en.wikipedia.org/wiki/List_of_rivers_of_Bangladesh)

The river Buriganga takes name as Buriganga from the end of Turag at Kholamora of Keraniganj and flowing through the southern part of Dhaka city and meet Dhaleshwari river at Dharmaganj. Turag river generates from Banshi river at Kaliakoir and meets Buriganga at Kholamora of Keraniganj. Balu river generates from Voual-Garh and flowing south, which flowing through the eastern part of Dhaka city and meet Shitalakhya river at Demra. Another Branch of Turag is flowing side of Tongi and meets Balu river at Trimohoni. At present which locally known as Tongi khal. Shitalakhya river generate from old Brahmaputra at Tok of greater Mymensingh. This flows south touching the eastern part of Dhaka city and flowing through Narayanganj and meet Maghna river at Kolagachia of Munshiganj. Dhaleshwari river divides into two parts after running a short distance from its generation point of Jamuna. The part which flows south takes

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name as Kaliganga and other which flows east takes name as Barinda, than it flows as Banshi river (south) up to Savar.
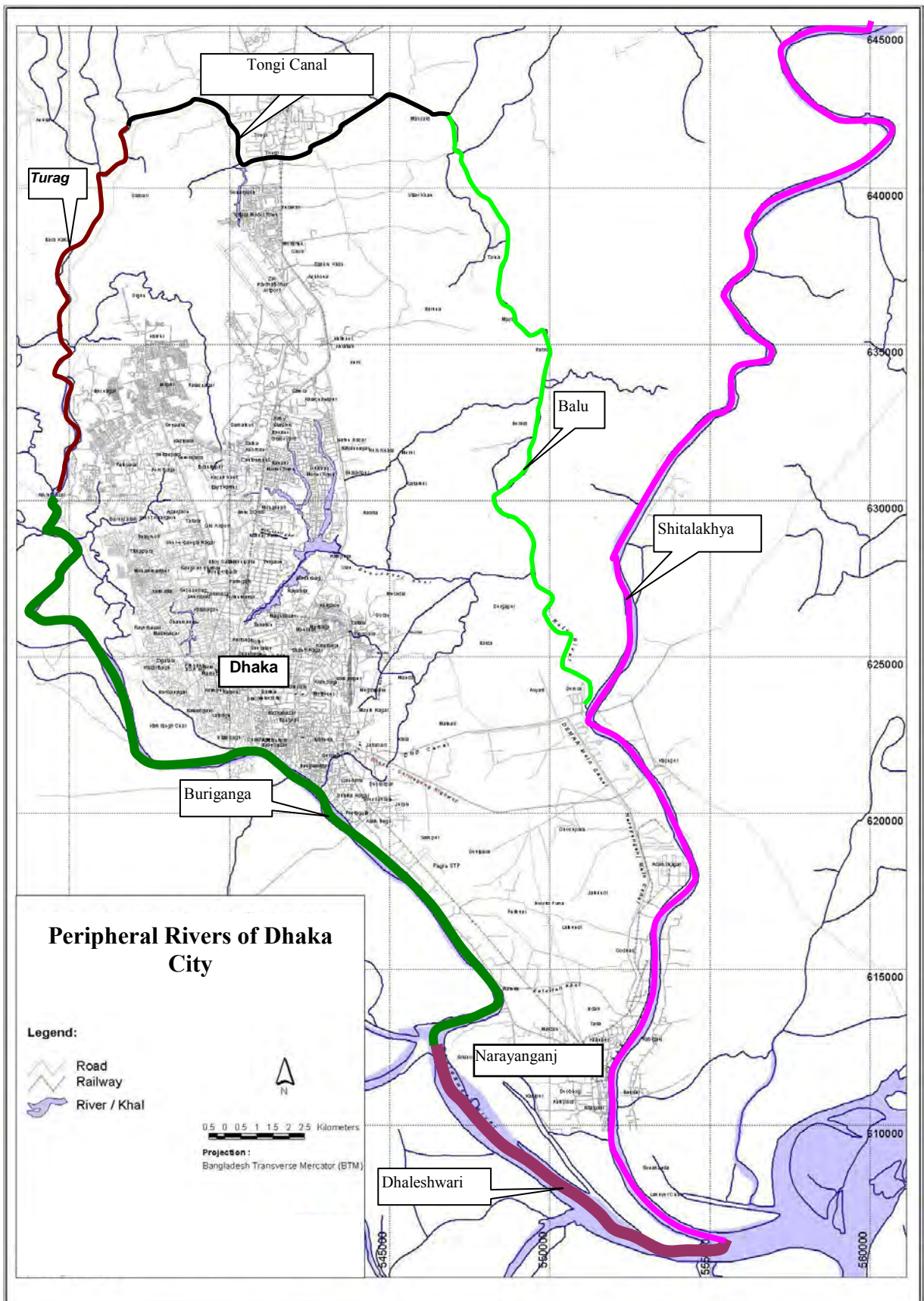
Fig. 2.2 Map of Peripheral Rivers around Dhaka city (Rahman and Hossain, 2007)
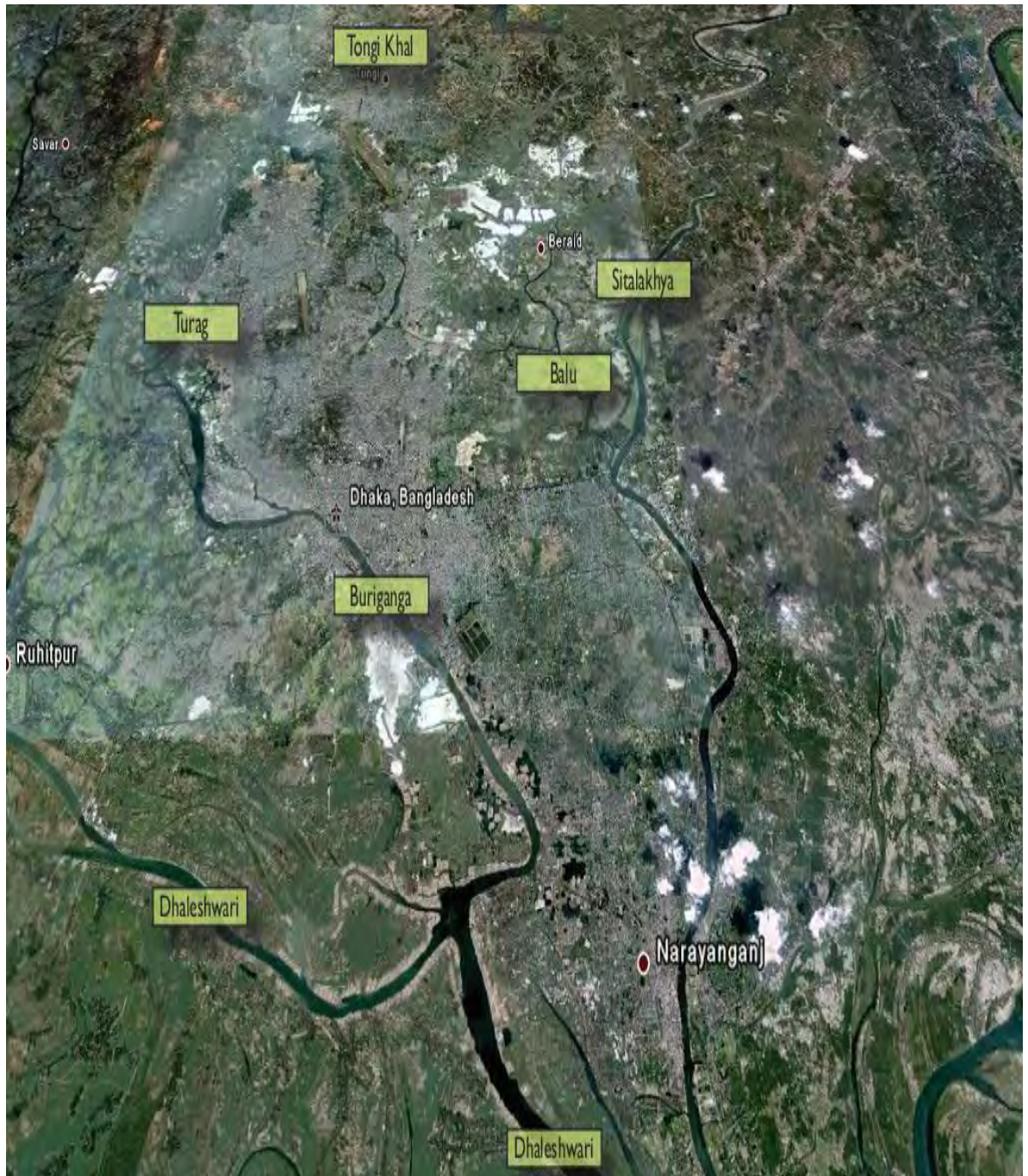
Fig 2.3: Satellite Image of Dhaka Watershed (Google Earth Pro, 2013)

2.2.1 Industrial units in Bangladesh

Industrial pollution is an area of growing environmental concern in Bangladesh. The country still has a relatively small industrial base contributing about 20% of GDP. The manufacturing sub-sector accounts for about half of this contribution and it grew at a rate of 5.04% between 1982 and 1992. The growth rates of some of the important sectors are shown in Figure 2.3 (Bhattacharya *et al.*, 1995). With the growth of the ready-made garments sector, the textile sector is also growing at a high rate in recent years.
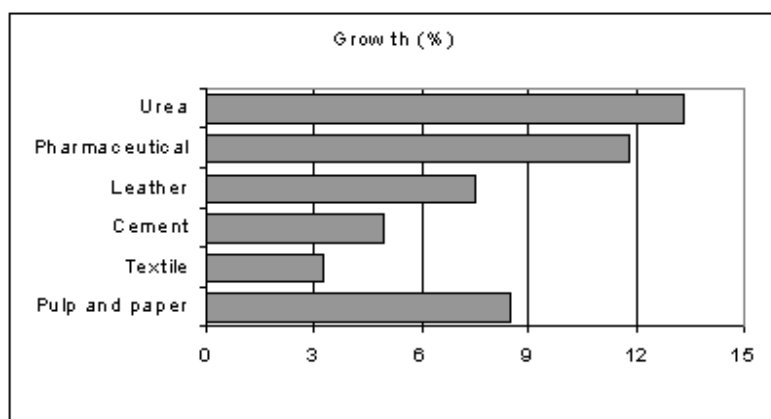
Fig. 2.4 Growth rates of important industrial sectors (Bhattacharya et al., 1995)

The major polluting industries such as tanneries, pulp and paper, sugar, fertilizer, pharmaceuticals, metal and chemical industries are mostly located in and around the major cities in Bangladesh. Some of these are also located on the banks of major rivers and lakes (World Bank, 1997).

In Bangladesh, industrial plants are mostly situated along the banks of the rivers in the vicinity of the cities of Dhaka, Chittagong, Khulna and Bogra districts. The Department of Environment has listed 1176 industries that cause pollution that have been categorized into 9 types:

- Chemical including pharmaceuticals
- Paper and pulp
- Sugar
- Food and tobacco
- Leather
- Industrial dyes
- Petroleum
- Metals
- Power generation

Most of the effluents produced by these industries are dumped directly or indirectly into the rivers. In case of industries located in Dhaka, they are discharged into Buriganga and Turag rivers badly polluting them. Some 300 mills and factories created in and around Khulna city currently discharge huge amounts of liquids waste into the Bhairab river causing a severe pollution. In Chittagong, the main polluters are the pulp and paper, fertilizer and petroleum industries located on the banks of the Karnafuli river and Kaptai lake. Operation of ships, mechanized boats and ports cause marine oil pollution.

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Tables 2.1 to 2.5 show length of the surrounding rivers in Dhaka city, the BOD load by industries, industrial areas in and around Dhaka city, industries by types in and around Dhaka city, industries by types in and around Greater Dhaka and concentration of heavy metals in surrounding rivers in Dhaka.

Table 2.1 Length of surrounding rivers in Dhaka city (Alam, 2003)

Name of the Rivers	Length (km)
Balu	13
Buriganga	17
Dhaleswari	58
Sitalakhya	23
Tongi Khal	14
Turag	75

Table 2.2 Estimated BOD load by Industries (JICA, 1999) in and around Dhaka city.

Type of Industry	Public enterprise [No.]	Private enterprise [No.]	Wastewater Discharge (m^3/s)	BOD Load (ton/day)
Leather	1	195	15,800	17.6
Textile	20	482	40,000	26.0
Pulp and Paper	4	1	228,000	40.0
Fertilizers	7	1	-	21.0
Chemical	1	99	1448	1.4
Pharmaceuticals	2	100	3500	0.7
Sugar	12	4	30000	4.0
Food and fish	0	193	5400	61.0
Rubber		25	-	17.7
Plastics		30	-	-
Pesticides	1	3	200	-
Distilleries		4	1600	5.7
Metal	17	67	13800	-
Cement	1	1	-	-

These Tables indicate that most of the rivers are highly populated by the effluents discharged into these rivers without treatment. The dissolved oxygen in these rivers is very low and some are already polluted beyond toxic point. The most problematic industries for the water sector are textiles, tanneries, pulp and paper mills, fertilizers, chemicals and refineries where a large volume of water is involved in their production process thus producing equal volume of effluents which when discharged into rivers, streams and other water bodies become a major source of pollution.

Table 2.3 Industrial Areas in and around Dhaka City (BKH, 1994)

Cluster Name	Type of Industry	Number of Industries	Total Wastewater discharge (m^3/day)	Total BOD load (kg/day)	Discharge recipient river
Hazaribagh	Leather	136	15800	17600	Turag
Tongi BSCIC	Textiles	13	4300	4400	Tongi Khal
Fatulla	Textiles	6	3400	3850	Buriganga
Kanchpur	Textiles	9	4300	3480	Lakhya

Tejgaon	Textiles, Chemical	16 27	3350 535	1960 475	Begunbari Khal
Tarabo	Textiles	14	1150	1475	Lakhya
Total		221	32835	33240	

Table 2.4 Industries by types in and around Dhaka (WSP, 1998)

Type of Industry	Number
Paper, Pulp, Wood, etc.	171
Dyeing, Painting, Printing, etc.	241
Electrical, Electronics, Computers, etc.	129
Metal, Iron, Aluminum, Steel, etc.	289
Plastic, Polythene, Glass, Cosmetics, Jewellery, etc.	142
Food, Confectionery, Hotels, etc.	140
Dairy, Poultry, Fishery, etc.	28
Tannery, Shoe, etc.	75
Pharmaceutical, Hospital, Soap, etc.	61
Chemicals, etc.	95
Ceramics, etc.	5
Building construction related, etc.	49
Handicrafts, etc.	16
Total	**2179**

According the zoning of Bangladesh by regions for industrial purpose, the North Central (NC) region comprises about 49% of the total industrial establishment. About 33% of industries in NC region are textile apparels and tanneries of which Dhaka district accounts for almost half of it while Narayanganj accounting for another 32%. About 65% of the total chemicals, plastics and petroleum industries are also located in the NC region concentrated in and around Dhaka, Narayanganj and Gazipur districts (WARPO, 2000). Region wise number of industrial establishments notorious for polluting the river water and water bodies are given in Table 2.6.

Table 2.5 Concentration (mg/L) of heavy metals in surrounding rivers of Dhaka city (Shamsuzzoha, 2002)

Sample source	Al	Cd	Cr	Pb	Hg	Se	Zn
Buriganga River at Hazaribagh	3.262	0.008	0.2320	0.4700	0.0033	0.0060	4.3
Buriganga River at Chandnighat	5.396	0.006	0.21	0.2500	0.0016	ND	4.6
Buriganga River at Friendship Bridge	3.270	0.014	0.27	ND	0.0021	0.0010	2.3
Turag River at Amin Bazar	11.884	0.018	0.1100	0.3940	0.0058	0.0002	2.0
Lakhya river at Saidabad WTP Intake	2.952	0.006	0.0280	0.0740	0.0032	0.0005	2.0
Balu River at Zirani Khal	2.166	0.006	0.01-0.13	ND	0.0010	ND	3.0

Sample source	Al	Cd	Cr	Pb	Hg	Se	Zn
Recommended value for drinking water*	0.2	0.005	0.05	0.05	0.001	0.01	5.0

Source: Measurements taken by IWM and DoE

ND= Not Detectable

* Environmental Quality Standards (EQS) for Bangladesh: Department of Environment: July, 1991

Table 2.6 Region-wise Numbers of Industrial Establishments and Polluting Industries (WARPO, 2000)

Region	No. of Establishments	Textiles, apparels and tanneries	Paper, paper products and printing	Chemicals, plastics and petroleum	Non-metallic minerals manufacture
North West	4403	545	113	181	360
North Central	12133	4093	707	1242	733
North East	1117	55	20	47	132
South East	2518	346	68	83	549
South West	849	72	39	42	199
South Central	1408	128	29	77	157
South East	2506	475	102	231	229
Total	24934	5714	1078	1903	2359

World Bank in 2003-2004 carried out a research project on water quality in the river and canal system around Dhaka city which is shown in Table 2.7

Table 2.7 Water quality in the river and canal system around Dhaka during 2003-2004 (World Bank, 2006)

Location	Season	Water Layer	Total Dissolved Solids (TDS) mg/l	Dissolved Oxygen (DO) mg/l	Biological Oxygen Demand (BOD) mg/l	Chemical Oxygen Demand (COD) mg/l	Ammonia (NH3) mg/l
Postogola (Buriganga River)	Dry	Surface	319	2.3	29.9	82.7	7.4
		Bottom	319	2.0	35.4	113.3	7.3
	Wet	Surface	69	8.3	0.9	67.3	0.4
		Bottom	66	8.5	0.9	76.0	0.4
Convergence of Sitalakhya and Dhaleswari Rivers	Dry	Surface	127	7.2	2.0	58.0	0.6
		Bottom	129	7.1	1.4	75.3	0.5
	Wet	Surface	63	8.9	1.3	70.7	0.7
		Bottom	63	9.1	1.3	67.3	0.5
Narayanganj Ghat (Sitalakhya River)	Dry	Surface	189	5.1	9.0	88.0	2.3
		Bottom	194	5.0	9.2	97.7	2.3
	Wet	Surface	63	8.6	1.0	73.3	0.4
		Bottom	63	8.5	0.9	66.0	0.5
Kanchon	Dry	Surface	193	7.2	2.0	72.3	0.6
		Bottom	208	7.3	2.0	56.3	0.6
	Wet	Surface	56	8.7	1.0	53.3	0.6
		Bottom	56	8.6	1.7	50.0	0.7
Demra (Sitalakhya	Dry	Surface	234	4.3	14.3	130.7	2.6

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Location	Season	Water Layer	Total Dissolved Solids (TDS) mg/l	Dissolved Oxygen (DO) mg/l	Biological Oxygen Demand (BOD) mg/l	Chemical Oxygen Demand (COD) mg/l	Ammonia (NH3) mg/l
River)		Bottom	236	4.1	15.4	114.7	3.0
	Wet	Surface	56	8.8	1.4	74.7	0.6
		Bottom	56	8.4	1.5	57.3	0.6
Balu River	Dry	Surface	257	2.1	28.0	151.7	6.7
		Bottom	258	1.6	30.5	215.3	6.7
	Wet	Surface	76	6.4	1.4	81.3	0.7
		Bottom	71	6.4	1.1	62.7	0.7
Singair	Dry	Surface	220	7.6	1.6	16.7	0.6
		Bottom	262	7.3	1.5	21.3	0.6
	Wet	Surface	66	8.5	0.7	31.3	0.4
		Bottom	65	8.3	0.8	33.3	0.4
Ashulia (Turag River)	Dry	Surface	326	6.4	5.1	98.7	2.2
		Bottom	344	6.6	4.5	85.3	1.6
	Wet	Surface	62	8.2	0.9	58.0	0.4
		Bottom	59	8.0	0.7	60.7	0.3
Uttar Khan	Dry	Surface	356	7.3	12.1	41.7	4.5
		Bottom	376	7.9	12.0	54.0	4.2
	Wet	Surface	53	8.0	0.8	52.7	0.4
		Bottom	62	8.1	0.7	44.0	0.3
Dholai Khal (Dhaka East)	Dry	Surface	396	2.4	77.7	167.8	20.8
		Bottom	388	2.3	94.9	199.0	19.5
	Wet	Surface	-	-	-	-	-
		Bottom	-	-	-	-	-
Begunbari Khal (Dhaka East)	Dry	Surface	386	2.1	75.9	187.5	22.4
		Bottom	385	2.4	71.2	163.3	21.8
	Wet	Surface	-	-	-	-	-
		Bottom	-	-	-	-	-
Norai Khal (Dhaka East)	Dry	Surface	343	2.6	54.8	137.9	21.5
		Bottom	316	2.9	53.9	135.1	22.0
	Wet	Surface	-	-	-	-	-
		Bottom	-	-	-	-	-
Saidabad Beel (Dhaka East)	Dry	Surface	179	5.3	11.0	64.8	2.2
		Bottom	181	5.8	10.2	65.8	2.3
	Wet	Surface	-	-	-	-	-
		Bottom	-	-	-	-	-
Hot spots (contaminated water) indicated as follows:			>100	<5	>5	>60	>1

The main industrial clusters and effluent "hotspots" include the tanneries at Hazaribagh which pollute the Buriganga River, the Tejgaon Industrial Area which drains to the Balu River, the Tongi Industrial Area which pollutes Tongi Khal, the Sayampur and Fatullah industrial clusters in Dhaka South and Narayanganj which discharge to the Buriganga River, and the developing heavy industrial strip along the Sitalakhya River.

Fig. 2.5 Industrial wastewater is discharged by a man in Turag River

Fig. 2.6 Dirty water of the Turag River
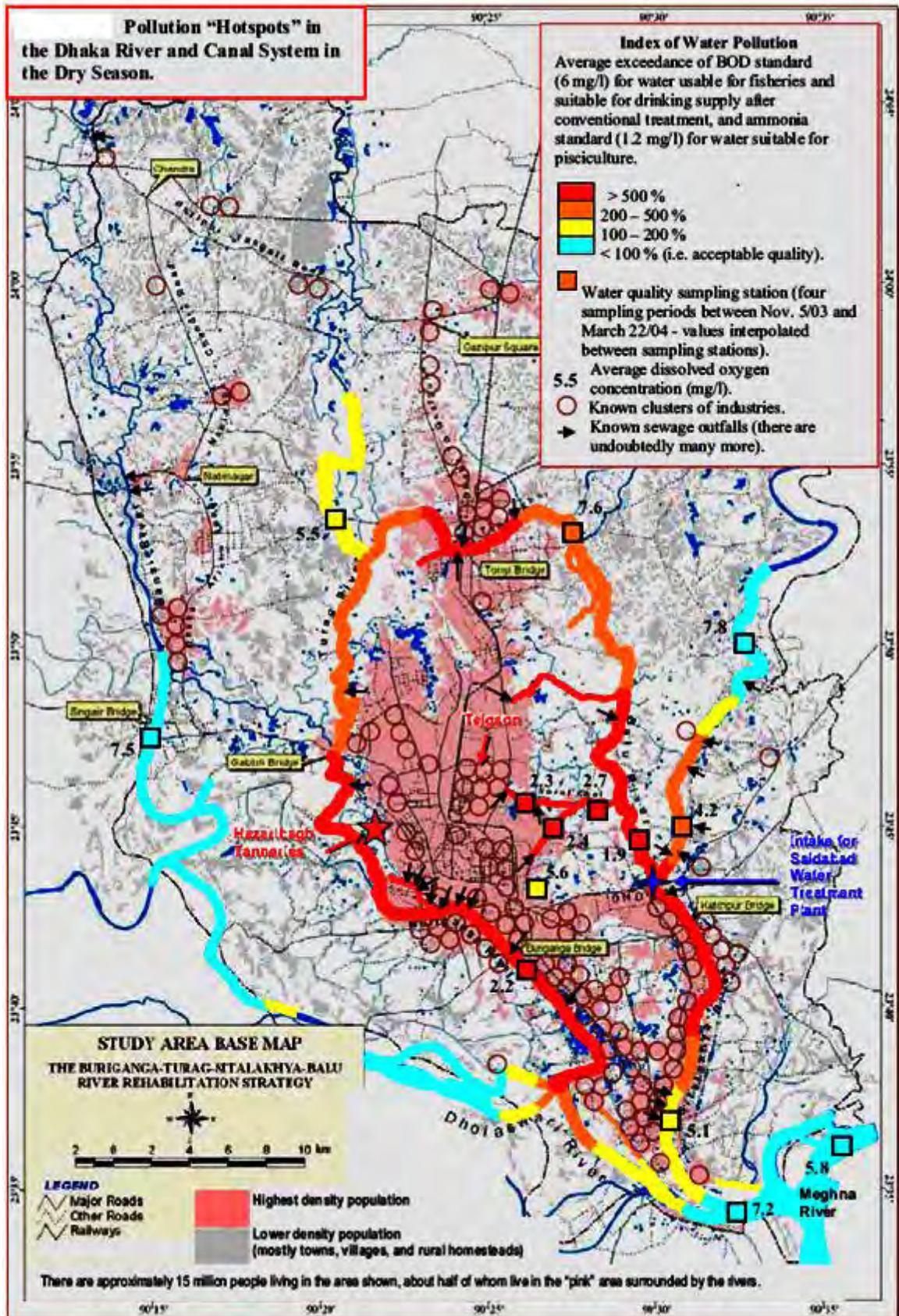
Fig. 2.7 Pollution "hotspots" in the Dhaka river and canal system in the dry season (World Bank, 2006)

2.2.2 Pollution in Buriganga river

The River Buriganga, which runs past Dhaka City, is at present one of the most polluted rivers in Bangladesh. Dhaka City is very densely populated and considered to be one of the ten 'Mega Cities' of the world. However, only a small fraction of the total wastewater being generated in the City is treated. Consequently, the amount of untreated wastes, both domestic and industrial, being released into the Buriganga is tremendous and is increasing day by day. The river is seriously polluted by discharge of industrial effluents into river water, indiscriminate throwing of household, clinical, pathological and commercial wastes, and discharge of fuel and human excreta. In fact, the river has become a dumping ground of all kinds of solid, liquid and chemical waste of bank-side population. These activities on the Buriganga have caused narrowing of the river and disruption of its normal flow of water. The water of the river has become so polluted that its aquatic life has almost been extinguished. People, living near the rivers, use the water because they are unaware of the health risks and also having no other alternative. This causes incidents of water borne and skin diseases. It was once the main source of drinking water for Dhaka's residents and an hour downstream from the capital city the river is still crystal clear. But as it flows through the capital, waste from sewers and factories especially tanneries pour into it. Up to 40,000 tones of tannery waste flows into the river daily along with sewage. About 12 sq. km area of Hazaribagh and adjacent area are full of offensive odors of various toxic Chemicals: hydrogen sulphide, ammonia, poisonous chlorine and several nitrogen based gases. An average of 19 cubic litre water containing more than 300 different chemical compounds is being discharged daily from these industries. Although treating the water for toxic chromium, sulphuric acid, and salt and chlorine compounds is seriously being considered the practice is yet to start. According to a recent estimate, about 70,000 tons of raw hides and skins are processed in these tanneries every year polluting the environment and the quantity of unbanned solid wastes namely raw trimming, pelt trimming generated in these tanneries is estimated to be 28,000 tons. Statistics provided by various sources suggest that a big tannery of the Hazaribagh area releases 2,500 gallons of chemicals wastes each day, polluting the city's air in addition to contaminating the water of the river Buriganga. Effluents and solid waste generated at different steps of leather processing trekking through the low-lying area of Hazaribagh contaminated by chromium, the old wounds take a longer time to heal. Long term chromium contamination may cause cancer. Laboratory tests carried out by DoE show that chromium, a carcinogenic agent, has seeped into the aquifer at some

places of Hazaribagh flow into the Buriganga river. Liquid waste is contaminating the waters of the Buriganga River on the surface as well as the groundwater resource base. During the lean season, the Buriganga river turns deadly for fish and other sub aquatic organisms. When solid waste and effluents run into the river, BOD in the water rises, creating oxygen is calamitous for the sub aqueous life. Among others, effluents of tannery factories lower DO content of the river water below the critical level of four milligrams per liter (Huq, 1999).

Fig 2.8-a: Man Through the Waste Water

Fig 2.8-b:Black pitch Water of Buriganga River

Fig 2.8-c:Childrens are playing on Waste Water

Fig 2.8-d:Waste Water Discharge on Buriganga River

Fig. 2.8 Waste materials dumping in Buriganga river

2.2.3 Pollution in Turag river

Due to rapid and unplanned urbanization and industrialization the Dhaka city's surrounding rivers, including the Turag have gradually experienced undue and unbearable pressure to their very existence.

Spatial pollution in Turag river

From the Buriganga Third Bridge to upper stream and from Tongi Bridge to downstream, pollution concentration appears to gradually decrease. The water color, odour and the DoE provided data prove this unique spatial pollution pattern. The water color becomes

pitch-black to almost normal both from the Buriganga Third Bridge and the Tongi Bridge to Goran Chatbari, near Mirpur Botanical Garden.

The main reason behind this spatial pollution pattern in the Turag within above mentioned area is that huge load of untreated toxic liquid chemical waste is directly dumped into the river from Hazaribagh tanneries through the Bashila Khal at the downstream and from the Tongi Industrial Area at Tongi Bridge and Iztema Field area. This very high pollution concentration literally diffuses to other parts of the river through upstream flow during the rainy season and some tidal activity during the dry season. Through lateral diffusion process, the pollution concentration decreases with increase in distance from the pollution source. Pollution concentration comparatively increases in the dry season when water level of the river recedes a lot.

There have been found, according to the field survey, about 28 minor waste disposal outlets to the Turag River. Of them, about 20 are solid (household, commercial, and industrial) waste dumping sites along the embankment which emit huge amount of waste (both bio-degradable and non-bio-degradable) into the river. Along the south-eastern bank of the river, there have been found four sluice gates which dispose huge load of sewerage waste of the DCC area into the river (Hossain, 2010). The river has also a vast non-point source of pollution. Along its north-western bank, there is a vast agricultural land particularly paddy field from Bagchotra, Savar to Tongi Pourosava area. The residue of the chemical fertilizers used in the cultivable land is also added to the pollution of the river through overland flow resulting from heavy downpour during the rainy season.

Temporal pollution in Turag river

The selected sample drawing points of the Turag River includes the points near Iztema Field, Tongi Bridge, Gabtali Bridge and Sinnir Tek BIWTA Landing Station. Analyzing the DoE provided water quality data of 5 years (2006-2010), the following temporal pattern of the Turag River Pollution has been found.

Table 2.9 Variation of water quality parameters in Turag river during 2006-2010 (Hossain, 2010)

Parameter	Unit	2006	2010
pH	mg/L	7.1	7.5
EC	,,	98	1800
Chloride	,,	2	34
Turbidity	,,	6.5	12.5
TS	,,	380	896
TDS	,,	342	812
DO	,,	6	0
BOD	,,	2.8	22
COD	,,	58	102
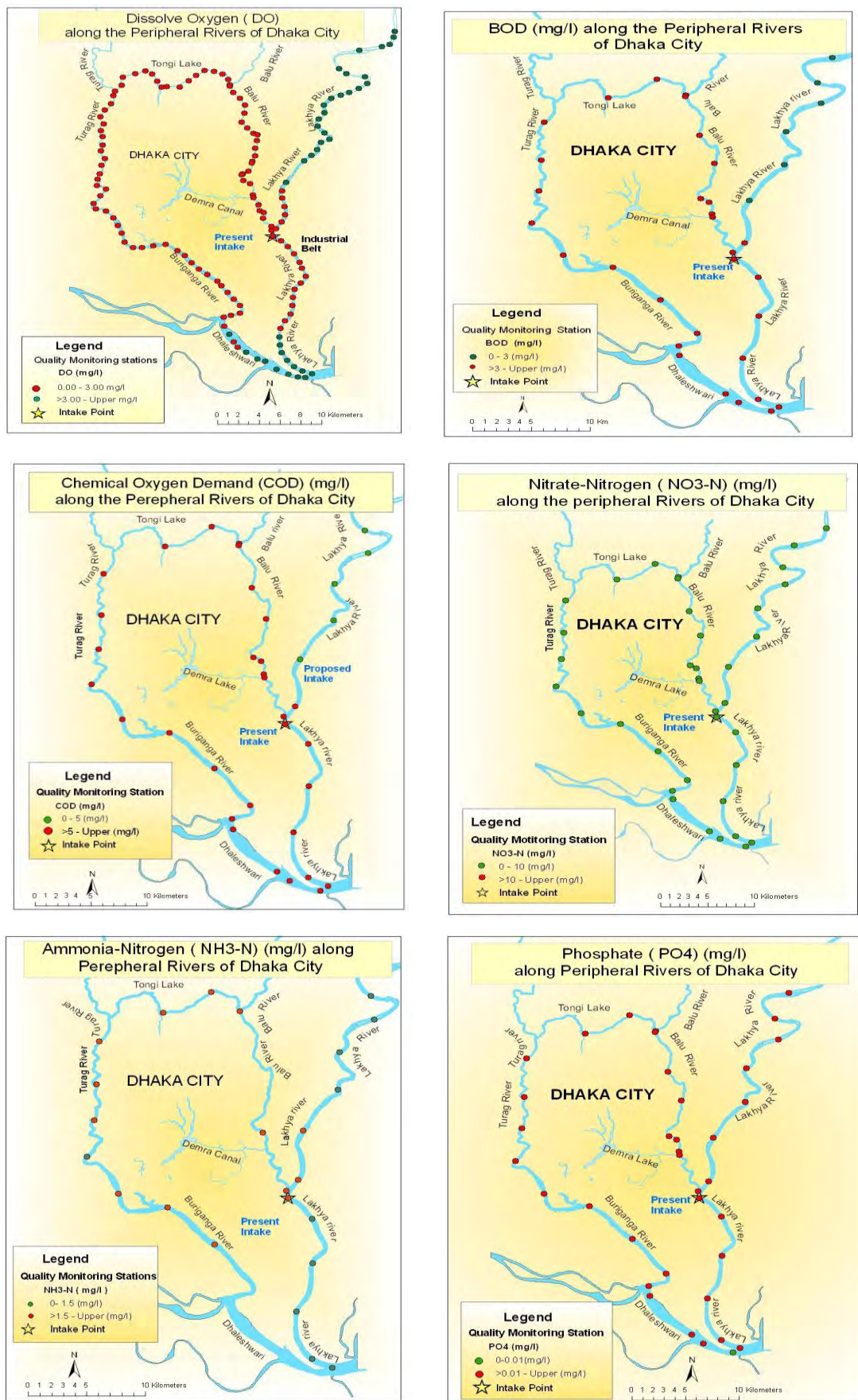
Fig. 2.9 Six maps of water quality parameters along peripheral rivers of Dhaka city (Rahman and Hossain, 2007)

Bari and Badruzzaman (2007) prepared a water quality map of peripheral rivers around Dhaka city. This map contains five water quality classes. Water class I indicates none to very slight organic pollution, water class II indicates Moderate pollution, water class III indicates Critical pollution, water class IV indicates heavy pollution and water class V indicates very heavy to extreme pollution.
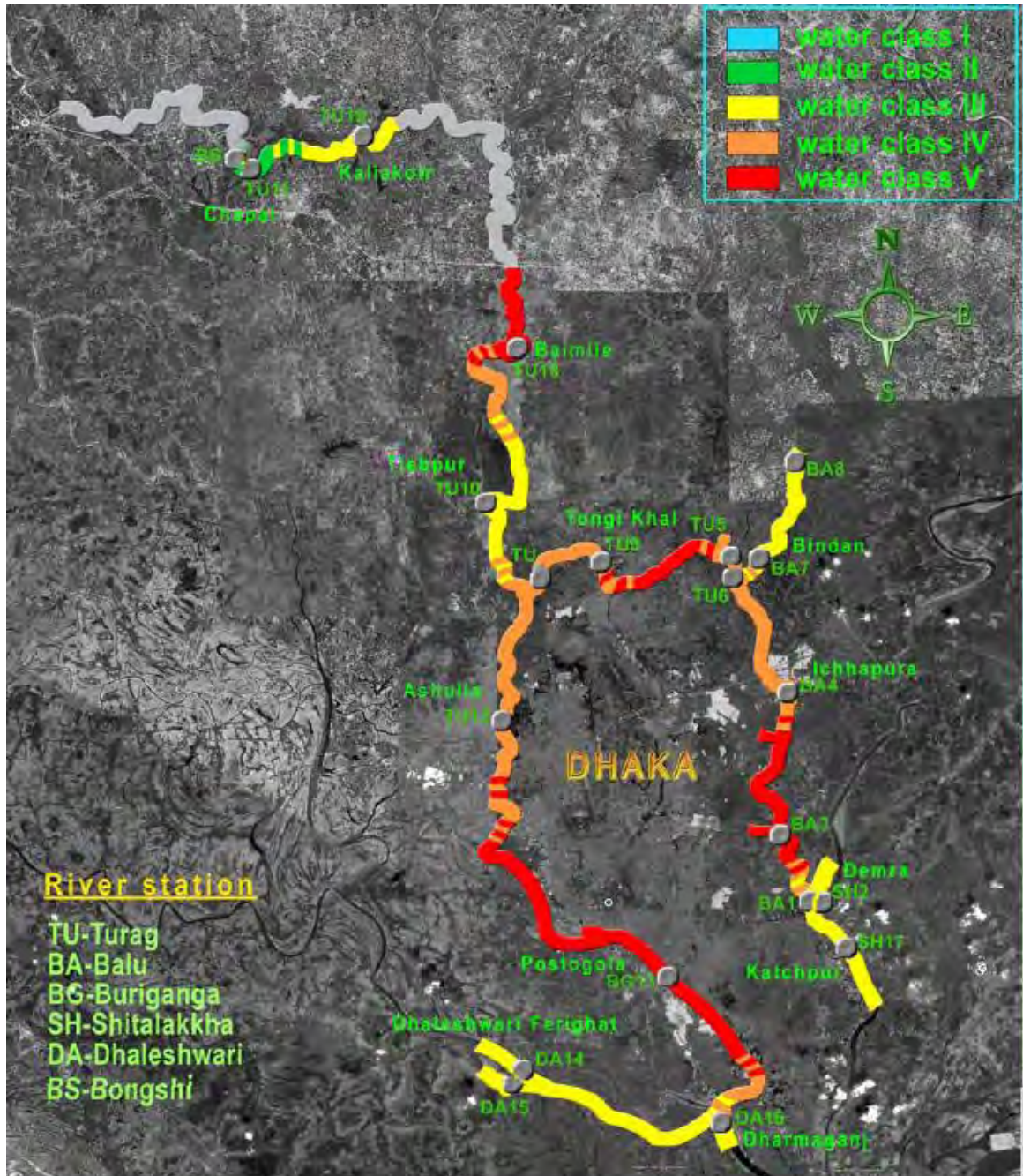
Fig. 2.10 River water quality map around Dhaka city (Bari and Badruzzaman, 2007)

Bari and Badruzzaman depicted in their research that the water quality may be a useful tool for water resources managers and decision makers involved in sustainable

management and utilization of river resources though physico-chemical parameters pH, BOD_5, etc. are not reflected in the water quality map.

Fig 2.11.a: Textile wastewater discharge in Turag River

Fig 2.11. b: Industrial wastewater discharge in Turag River

Fig 2.11.c: Pitch black water of Turag river, the west of Tongi Bridge, Dhaka, Bangladesh

Fig 2.11.d: Pitch black water discharges from textile dyeing units in low deep canal that link with Turag, Buriganga and Sitalakhya River

Fig. 2.11 Waste materials dumping in Turag river

2.3 Heavy Metals, Uses and Sources

Metals are natural constituents of rocks, soils, sediments and water. However, over the 200 years following the beginning of industrialization huge changes in the global budget of critical chemicals at the earth's surface have occurred, challenging those regulatory systems which took millions of years to evolve (Wood and Wang 1983).

The term heavy metal may have various general or more specific meanings. According to one definition, the heavy metals are a group of elements between copper and lead on the periodic table of the elements; having atomic weights between 63.55 and 200.59 and specific gravities greater than 4.0. Living organisms require trace amounts of some heavy metals but excessive levels can be detrimental to the organism. However vanadium, chromium, manganese, iron and nickel are above copper on the periodic table and are all

very important due to their effects on organisms. Their accumulation over time in the bodies of mammals can cause serious illness.

A stricter definition restricts the term to those metals heavier than the rare earth metals, at the bottom of the periodic table. None of these are essential elements in biological systems; all of the more well-known elements with the exception of bismuth and gold are horribly toxic.

Trace metals, including those defined as "heavy", arising from industrial and mining activities are discharged into coastal waters and estuaries at many sites. The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic, highly toxic or poisonous at low concentrations. These anthropogenically derived inputs can accumulate in local sediments (up to five orders of magnitude above the overlying water and invertebrates living on or in food, and the rate of accumulation caries widely between species and heavy metal concentration found in "clean" conditions. Less is known of the uptake of these metals by ingestion with food or from close contact with contaminated sediments.

Heavy metals belong to the group of elements whose hydro-geochemistry cycles have been greatly accelerated by man. Anthropogenic metals emissions into the atmosphere such as Pb, Hg, Zn, Cd and Cu are 1:3 orders of magnitude higher than natural fluxes. As a consequence these elements are expected to become increasingly accumulated in natural reservoirs. An increase in trace metal concentrations in sea water is not obvious since earlier data on the trace metals concentrations in these systems suffer from inadequacy of sampling technique as well as from a lack of reliable analytical tools (Schindler, 1991).

The heavy metal content of sediments comes from natural sources (rock weathering, soil erosion, dissolution of water-soluble salts) as well as anthropogenic sources such as from municipal waste, manufacturing industries, and agricultural activities etc. The metals must be both abundant in nature and readily available as soluble species. Abundance generally restricts the available metals to those of atomic numbers below 40, some of which are virtually unavailable due to the low solubility of their hydroxides. Viewed from the standpoint of environmental pollution, metals may be classified according to three criteria (Wood, 1974);

(i) Non critical (Na, Mg, Fe, K, Ca, Al, Sr, Li, Rb),

(ii) Toxic but very insoluble or very rare (Ti, Hf, Zr, W, Ta, Ga, La, Os, Ir, Ru, Ba),

(iii) Very toxic and relatively accessible (Be, Co, Ni, Cu, Zn, Sn, Cr, As, Se, Te, Ag, Cd, Hg, Tl, Pb, Sb, Bi).

Environmental pollution with toxic metals is becoming a global phenomenon. As a result of the increasing concern with the potential effects of the metallic contaminants on human health and the environment, the research on fundamental, applied and health aspects of trace metals in the environment is increasing.

Advances in information of the distributions and concentrations of trace metals in the marine environment have occurred since the mid 1970s. This is mainly due to developments in procedures for contamination free sampling, the adoption of clean methodologies for handling and analysis of samples, and increased application of improved analytical methods such as inductively coupled plasma-mass spectrometry (ICP-MS).

Heavy metals occur naturally as they are components of the lithosphere and are released into the environment through volcanism and weathering of rocks. However, large-scale release of heavy metals to the aquatic environment is often a result of human intervention. Coastal regions are some of the most sensitive environments and yet they are subject to growing human pressures because of increasing urbanization, industrial development, and recreational activities. Therefore, pollution levels are often elevated in the coast because of nearby land based pollution sources. Industrial processes that release a variety of metals into waterways include mining, smelting and refining. Almost all industrial processes that produce waste discharges are potential sources of heavy metals to the aquatic environment. Domestic wastewater, sewage sludge, urban runoff, and leachate from solid waste disposal sites are also obvious sources of heavy metals into rivers, estuaries and coastal waters. A proportion of the total anthropogenic metal input in the sediments in near shore waters, adjacent to urban and industrial growth centers comes from the combustion of fossil fuels. Other potential sources include ports, harbors, marinas and mooring sites, also subjected to heavy metal inputs associated with recreational, commercial, and occasionally, military, boating, and shipping activities (Denton, et al. 1997).

Natural background levels of heavy metals exist in the majority of sediments due to mineral weathering and natural soil erosion. It is when man's activities accelerate or

antagonize these processes that the background levels are increased, by pollution, to levels that have detrimental effects on the environment. Sediments with low heavy metal concentrations are not necessarily "natural" just because the levels are indeed low. They may represent a mixture of small quantity of pollutants diluted by a large amount of natural sediment with low heavy metal content.

In the past sediments and particulate matter have been considered as purely abiotic material. This is obviously not the case and it is now well known that sediments contain large bacterial populations. Sediments are also complex mixtures of a number of solid phases that may include clays, silica, organic matter, carbonates and large bacterial populations. There are three possible mechanisms by which trace metals may be taken up by sediments and suspended matter

1) Physic chemical adsorption from the water column

2) Biological uptake by organic matter or organisms

3) Physical accumulation of metal enriched particulate matter by sedimentation or entrainment

Physicochemical adsorption direct from the water column happens in many different ways. Physical adsorption usually occurs when particulate matter directly adsorbs heavy metals straight from the water. Chemical and biological adsorptions are more complicated as they are controlled by many factors such as pH and oxidation. There is a lack of detailed knowledge about the specific nature of sediment surfaces. This is mainly due to the high concentrations used in most adsorption experiments which are unrealistic and would not occur naturally.

A number of studies have shown that metal ions are strongly adsorbed by solid organic matter. The structure and composition of humid matter can vary considerably depending upon its origin and can be expected to influence the results of sorption experiments. Natural organic matter has a very important influence on the distribution of trace metals in aquatic systems. In addition uptake may be actively completed by bacteria and algae. This results in sediment enrichment. Sedimentation of enriched particulate matter is the other potentially important mechanism by which sediments may concentrate trace metals (Hart 1982).

There is no evidence to suggest that trace metal binding to solid natural organic matter should be any different to that by soluble natural organic matter. The difference between

these surface types is not well understood particularly with respect to trace metal uptake. (Gardner, 1974) found that adsorption of cadmium by river mud samples was very rapid (in the order of minutes) and that some additional adsorption occurred over a further 24 hour period. Within the soil, trace metals can be either transformed to less soluble forms or they can move to living biota. There is also the possibility that they may be eluted into the watershed and contribute to diffuse pollution in that area.

Elevated levels are helped also by the oxidation of surface sediments due to periodic drying between tides. This, incorporated with some biological processes such as bioturbiation or O_2 release from mangrove roots, can enhance uptake rates. This exposure to O_2 results in the oxidation of sulphides in the sediment. A reduction in sediment pore water pH due to production of sulphuric acid, allows the mobilization of metals.

Many authors propose that the interface between water and sediment plays many important roles in the chemistry of trace metals. Firstly, the upper layer of sediment is usually oxidized and therefore, acts as a diffusion barrier for mobilized solutes travelling upward from reducing zones of sediment.

Secondly, the surface sediments on the bed of many estuaries exchange readily with suspended solids in the water column and therefore easily adsorb any passing material. Long (1992) suggests that the oxidation-reduction potential and the concentration of sulphides in the sediments can strongly influence the concentration of trace metals and their availability.

Additional loads of pollution, especially those gained from run-off, in surface waters, of nutrients and trace metals derived from soil erosion processes are largely influenced by the kind of crop grown on the surrounding land.

Depending upon the environment the sediment particle size distribution may range from very small colloidal particles (of $< 0.1\mu m$ in diameter) to large sand and gravel particles several millimetres in diameter. There is a small variation between the mobility of particulate in river waters and seawater. This is very supervising due to a wide expected variation in particle types. Therefore, metals and the subsequent pollution will progress equally in both rivers and the ocean. Harbison (1986) has reported that tidal mudflats and particularly mangrove substrates contain a much greater load of trace metals than other shoreline sediments. This is where the sediments are most vulnerable to the environmental parameters that might influence the migration of these metals. Cadmium

(Cd) and manganese (Mn) ions may also influence the sorption of other trace metals ions. This happens, on oxide surfaces, in either of three ways.

1) Firstly Cd and Mn are normally present at concentrations many orders of magnitude higher than the other trace metals. They may, therefore, occupy most of the surface binding sites and leave little opportunity for binding of other metals even though they form less stable surface complexes.

2) Tipping (1981) showed that twice as much natural fluvial (changeable) heavy metal material was sorbed to goethite (hydrated iron oxide sediments, common in areas of large ore deposits) when calcium and magnesium were present than when absent.

3) Recent work by Benjamin and Leckie (1980 and 1981), however, suggests that oxide surfaces may consist of many groups of binding sites. The strength of binding between a given metal ion and the surface may vary by an order of magnitude, from one site to another. At small sorption densities all types of sites are available in excess. (Hart, 1982) supports this statement by reporting that at higher adsorption densities the availability of the strongest binding sites decreases in the apparent adsorption equilibrium constant. This seems to occur only when a few percent of all surface sites are occupied.

Vertical sections of sediments can give detailed records of the historical level of contamination over time. Provided that the pollutants are persistent and the sediment stratum has not been seriously disturbed, a very accurate account can be obtained.

2.3.1 Cadmium (Cd)

Cadmium is a common impurity as complex oxides, sulfides, and carbonates in zinc, lead and copper ores, and it is most often isolated during the production of zinc. Some zinc ores concentrates from sulfidic zinc ores contain up to 1.4 % of cadmium. Cadmium is extremely toxic to most plants and animal species particularly in the form of free cadmium ions. The major sources of cadmium include metallurgical industries, municipal effluents, sewage sludge and mine wastes, fossil fuels and some phosphorus containing fertilizers.

In sediments, cadmium does not appear to be absorbed to colloidal material, but organic matter, appear to be the main sorption material for the metal. Cadmium levels tend to increase with decrease in size and increase in density in terms of partition of sediment samples by size and density. The sorption of cadmium to sediments, and to the clay content, increases with pH. The release of cadmium from the sediment is influenced by a

number of factors including acidity, redox conditions and complexing agents in the water. Cadmium is less mobile under alkaline conditions.

The average concentration of cadmium in the lithosphere is ~0.1μg/g and it is strongly chalcophilic. Concentrations in pristine areas are <0.2 μg/g with levels exceeding 100 μg/g at severely contaminated sites. The major effects of cadmium poisoning are experienced in the lungs, kidneys and bones. Acute effects of inhalation are bronchitis and toxemia in the liver. Chronic inhalation of cadmium compounds as fumes or dust produce pulmonary emphysema, where the small air sacs of the lungs become distended and eventually destroyed reducing lung capacity (Denton, et al. 1997).

2.3.2 Chromium (Cr)

Chromium is the 21st most abundant element in Earth's crust with an average concentration of 100 mg/kg. Chromium compounds are found in the environment, due to erosion of chromium containing rocks and can be distributed by volcanic eruptions. The concentrations range in soil is between 1 and 3000 mg/kg, in sea water 5 to 800 μg/L, and in rivers and lakes 26 μg/L to 5.2 mg/L. Chromium like zinc, is one of the most abundant heavy metals in the lithosphere with an average concentration of about 69 μg/g and mercury content in carbonate sediments is reported to be 0.03 μg/g. Chromium is moderately toxic to aquatic organisms. Major coastal marine contributors of chromium are dominated by input from rivers, urban runoff, domestic and industrial wastewaters and sewage sludge. Also other main sources in the aquatic environment include the waste stream from electroplating and metal finishing industry.

Cr (III) occurs naturally in the environment and is found in rocks, animals, plants, soil and in volcanic dust and gases. Cr is used in nuclear and high temperature research, refractories, drilling muds, metal-finishing textiles, fungicides, wood preservatives, odor agents, leather treatment, industrial water treatment, photo-mechanical processing, dyes and pigments, catalytic manufacture and in the production of chromic acid and specialty chemicals. Anthropogenic sources of chromium include chrome plating, the manufacture of pigments, leather tanning and treatment of wood products.

Once chromium enters the blood stream, chromium compounds can be distributed to all organs of the body. Cr (VI) is unstable in the body and is reduced ultimately to Cr (III) by many substances like ascorbate and glutathione. Once this reduction occurs, excretion

can occur through urine, hair and nails. However, hair and nails provide minor pathways of excretion. Studies suggest that toxicity effects of Cr (VI) compounds result from the destruction of cellular components. Destruction of cells is caused by generation of free radicals.

It is a well-known fact that chromium is essential for leather quality, such as strength, elasticity and thickness. Chromium is essential for animals, being involved in glucose metabolism.

Levels of chromium in marine sediments range from 2.4 μg/g at unpolluted sites to 749 μg/g at grossly contaminated sites. Chromium is carcinogenic to humans and long term exposure has been associated with lung cancer in workers exposed to levels in air that in the order of 100 to 1000 times higher than usually found in the environment.

2.3.3 Copper (Cu)

Copper is a moderately abundant heavy metal with mean concentration in the lithosphere of about 39 μg/g. It is an essential trace element for the growth of most aquatic organisms however it becomes toxic to aquatic organisms at levels as low as 10 μg/g. Heavily polluted sediments have been reported to exceed 200 μg/g. Inputs of copper into the natural waters come from various sources including mining, smelting, domestic and industrial wastewaters, steam electrical production, incinerator emissions, and the dumping of sewage sludge. Algaecides and antifouling paints are identified as major contributors of copper to harbor areas whereas coastal waters are generally receiving inputs from rivers and atmospheric sources (Denton, et al. 1997).

Copper has a high affinity for clay mineral fractions, especially those rich in coatings containing organic carbon and manganese oxides and as a result, residues are often elevated in sediments near localized sources of inputs (Denton, et al. 1997). Copper is essential for good health. However, exposure to higher doses can be fatal. Long term exposure to copper results in nose irritation, mouth, and eyes, and cause headache, and diarrhea.

2.3.4 Lead (Pb)

Lead is a soft, malleable metal, also considered one of the heavy metal. Metallic lead does occur in nature, but it is rare. Lead is usually found in ore with zinc, silver and copper, and is extracted together with these metals. The main lead mineral is galena

(PbS), which contains 86.6% lead. Inorganic lead is moderately toxic to aquatic flora and ranks behind mercury, cadmium, copper and zinc in the order of toxicity to invertebrates. On the other hand, organolead compounds, particularly the alkyl-lead compounds are considered toxic to any forms of life (Denton, et al. 1997).

The major sources of Pb in natural waters include manufacturing processes, atmospheric deposition. Other sources include domestic wastewaters, sewage and sewage sludge (Denton, et al. 1997).

Lead species are strongly sorbed to Fe/Mn oxides, which are reported to be more important than association with clays and organic materials (Fergusson, 1990). The sorption of lead onto Fe/Mn oxides is not affected by aging. The sorption process is pH dependent. As a result, lead is immobile in the aquatic environment and tends to accumulate in sediments close to its point of entry.

Lead is reported to be in the 15 - 50 μg/g range for coastal and estuarine sediments around the world (Denton, et al. 1997) with < 25 μg/g in clean coastal sediments.
Lead is toxic and a major hazard to human and animals. Lead has two quite distinct toxic effects on human beings, physiological and neurological. The relatively immediate effects of acute lead poisoning are ill defined symptoms, which include nausea, vomiting, abdominal pains, anorexia, constipation, insomnia, anemia, irritability, mood disturbances and coordination loss. In more severe situations neurological effects such as restlessness, hyperactivity, confusion and impairment of memory can result as well as coma and death.

2.3.5 Zinc (Zn)

Zinc is a very common environmental contaminant and usually outranks all other metals considered in this study in terms of abundance and it is commonly found in association with lead and cadmium. Major sources of Zinc to the aquatic environment include the discharge of domestic wastewaters; coal-burning power plants; manufacturing processes involving metals; and atmospheric fallout. Approximately one third of all atmospheric zinc emissions are from natural sources, the rest come from nonferrous metals, burning of fossil fuels and municipal wastes, and from fertilizer and cement production (Denton, et al. 2001).

Sediments are known as major sinks for zinc in the aquatic environment, and residues in excess of 3000 μg/g have been reported close to mines and smelters. The highest sedimentary zinc levels are found to be from enclosed harbors reaching as high as 5700 μg/g. This is mainly due to restricted water circulation and also particularly prone to zinc contamination from a variety of localized sources including brass and galvanized fittings on boats, wharves and piers; zinc-based anti-corrosion and anti-fouling paints.

The average zinc content of the lithosphere is approximately 80 μg/g, sediments from uncontaminated waters typically contain zinc concentration in the order of 5-50 μg/g. Ingesting high levels of zinc for several months may cause anemia, damage to pancreas, and decrease levels of high-density lipoprotein (HDL) cholesterol.

Table 2.10 Probable sources of heavy metals in river bed sediments of Kabini river (Taghinia *et. al.,* 2010)

Provenance (source)	Source Category		Pollutant types					Matrices Involved	Mechanism of pollution
	Point	Non point	Cu	Cd	Cr	Pb	Zn		
A. Natural (Lithogenic) Amphibolites, Granites, gneisses, Ultra basic rocks and carbonates			√	√	√	√	√	River water, suspended load bed sediment soil ground water biomass	Dissolution Suspension Deposition Reprecipitation
B. Anthropogenic 1- industrial a) textile b)tannery c)distillery d)miscellaneous	√ √ √ √		√ √ √ √	√ √ √ √	√ √ √ √	√	√ √ √ √	Soil Suspended load Bed sediment Biomass	Flows Land spreading Soaking Sorption Seepage Plumes CEC Suspension
2- municipal a)sewage effluent b) sewage sludge c) garbage dumps	√ √ √	√	√ √ √	√ √ √	√ √ √	√ √	√ √ √	Soil Ground water Suspended load Bed sediment	Mixing, Dispersion, Soaking, Seepage, Sorption
3- agricultural a) return flows b) stockpiles	√	√		√	√		√		

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2.4 Heavy Metal Pollution in Sediments

Major indicators of pollution in aquatic environments are contaminated sediments that can be defined as soils, sand, organic matter, or minerals accumulated at the bottom of a water body (US EPA, 1998). Under certain conditions, contaminants found in sediments can be released to waters and thus, sediments can be important sources of the contaminants in waters.

Metals have the potential to be toxic to living organisms if present at availability above a threshold level. This threshold varies between taxa and metal speciation.

Most urban and industrial runoff contains a component of trace and heavy metals in the dissolved or particulate form.

Contamination caused by trace metals affects the ocean waters, the contential shelf and the coastal zone, where besides having a longer residence time; metal concentrations are higher due to the input and transport by river runoff and the proximity of industrial and urban zones. The impact of anthropogenic perturbation is most strongly felt by estuarine and coastal environments adjacent to urban areas.

Heavy metals from incoming tidal water and fresh water sources are rapidly removed from the water body and are deposited onto the sediments. Since heavy metals cannot be degraded biologically, they are transferred and concentrated into plant tissues from soils and pose long-term damaging effects on plants. Nevertheless, different plants react differently to wastewater irrigation; some are more resistant to heavy metals. The ability of mangrove plants to tolerate heavy metals in wastewater is not clear and the impact of wastewater on plant growth must be understood before the system can be employed for removing heavy metal from wastewater. Heavy metals that accumulate in soils not only exert deleterious effects on plant growth, but also affect the soil microbial communities and soil fertility.

The potential hazard to the marine environment of pollutants depends mostly on their concentration and persistence. Persistence pollutants, such as heavy metals, can remain in the environment unchanged for years and thus may pose a threat to man and other organisms. The pollution levels and wide distribution reported here suggest that heavy metals must be considered a serious regional threat. Inadequate or no sewage treatment, increasing waste from industrial and particularly agricultural activities, oil spill and soil

erosion are just a few of the chronic problems that Central American countries have faced over the last two decades.

All the problems associated with heavy metal pollution will increase considerably in the years to come if measures for control and management are not created. Metal accumulation in agricultural soils together with associated natural metal erosion will remain a chronic pollution problem in the future. A major regional problem is associated with deforestation, increasing soil erosion from agricultural activities, consequent run-off of both natural and anthropogenic metals and long-distance transport of pollutants from industrial areas. Therefore, the problem extends beyond any local or national borders and must be managed at regional levels.

Marine sediments constitute part of the contaminants in aquatic environments. The bottom sediment serves as a reservoir for heavy metals, and therefore, deserves special consideration in the planning and design of aquatic pollution research studies. Heavy metals such as cadmium, mercury, lead, copper, and zinc, are regarded as serious marine pollutants because of their toxicity, tendency to be incorporated into food chains, and ability to remain in an environment for a long time.

Sediments are known to act as the main sink for heavy metals in coastal ecosystems that are impacted by anthropogenic activities. The concentration of heavy metals in sediments can be influenced by variation in their texture, composition, reduction/oxidation reactions, adsorption/desorption, and physical transport or sorting in addition to anthropogenic input. Potentially, toxic compounds, especially heavy metals, are adsorbed on mineral or organic particles either in their organic or inorganic forms. Studies on the distribution of trace metals in sediments and other media are of great importance in the context of environmental pollution.

Sediments of rivers, lakes and estuaries in a large number of locations have been contaminated by inorganic and organic materials. Among the inorganic materials metals are frequent and important contaminants in aquatic sediments. They are involved in a number of reactions in the system including sorption and precipitation, and they are greatly influenced by redox conditions in the sediments. Heavy metals are transported as either dissolved species in water or an integral part of suspended solids. They may be volatilized to the atmosphere or stored in riverbed sediments. They can remain in solution or suspension and precipitate on the bottom or can be taken up by organisms.

The heavy metal content of sediments comes from natural sources (rock weathering, soil erosion, dissolution of water-soluble salts) as well as anthropogenic sources such as municipal wastewater-treatment plants, manufacturing industries, and agricultural activities.

2.5 Effects of Heavy Metal Contamination in Sediments

Heavy metals are preferentially transferred from the dissolved to the particulate phase and these results in the elevation of metal concentrations in estuaries and marine sediments. Therefore, concentrations often exceed those in overlying water by several orders of magnitude. Since sediments can accumulate heavy metals, concentrations can be high and become potentially toxic. Exposure and uptake of even a small fraction of sediment-bound metal by organisms could have significant toxicological significance, in particular where conditions favor bioavailability. In addition, increased metal concentrations in pore water may contribute significantly to sediment toxicity.

Evidence of fatal effects of metal-polluted sediments can be determined by the absence of sensitive species or by the development of resistance mechanisms and adaptation in tolerant forms such like efficient excretory features in organisms. Binning and Baird (2001) reported that many of the metals have no known biological function in the marine environment, but can act together with other chemical species to increase toxicity. The potential effects of accumulating levels of heavy metals can be estimated by comparing the concentrations of contaminants of interest present in sediments with sediment quality guidelines (SQGs). The Sediment Quality Guidelines (SQGs) have been derived from large databases, which correlate the incidence of adverse biological effects with the concentrations of contaminants in sediments. They are used in the evaluation of sediment contamination and potential ecotoxicological effects.

Table 2.11 Sediment quality guidelines by USEPA, Consensus Based, New York and Interim

(mg/kg dry weights)	Zn	Pb	Cu	Cd	Cr
US EPA Sediment quality proposed					
Not Polluted	<90	<40	<25	-	<25
Moderately polluted	90-200	40-60	25-50		25-75
Heavily polluted	>200	>60	>50	>6	>76
Consensus Based SQG (2003)					
Not Polluted	<90	<40	<25	<0.99	<43
Moderately polluted	90-200	40-70	25-75	0.99-3	43-76
Heavily polluted	>200	>70	>75	>3	>76
New York Sediment Criteria					
Lowest effects range	120	32	16	0.6	26
Severe effects range	270	110	110	9	110

(mg/kg dry weights)	Zn	Pb	Cu	Cd	Cr
Interim Sediment Quality Criteria Guideline (1992)					
Lowest effects range (ISQG-low)	120	31	16	0.6	26
High effects range (ISQG-high)	220	250	110	10	110

There are two levels of risks considered under this SQG – effects low range (ERL) and effects range-moderate (ERM) (Guerra-Garcia and Garcia-Gomez 2005). Concentrations below the ERL value are rarely associated with biological effects while concentrations above the ERL but below the ERM indicate a possible range in which effects would occur occasionally. Concentrations above ERM are associated with frequent adverse ecological effects on the benthic communities.

Table 2.12 Sediment quality guidelines proposed by Long et al. (1998) to characterize the toxicity of a metal (µg/g) in estuarine sediment towards benthic organisms

Toxicity	Scarce	Occasional	Frequent
Cd	<1.2	1.2-9.6	>9.6
Cr	<81	81-370	>370
Cu	<34	34-270	>270
Hg	<0.15	0.15-0.71	>0.71
Ni	<21	21-52	>52
Pb	<47	47-218	>218
Zn	<150	150-410	>410

The effect of heavy metal contaminants in the sediment on benthic organisms can be either acute or chronic. No matter whether metals are essential or not, all heavy metals form an important group of enzyme inhibitors when natural concentrations are exceeded. Therefore, organisms living in or adjacent to metal contaminated sediments may suffer toxic effects that can be fatal in highly contaminated situations (Denton, et al. 2001). In addition, metal enrichment in estuaries and coastal environments is a major concern as heavy metals have the ability to bio-accumulate in the tissues of various biota's. At last, it can affect the distribution and density of benthic organisms, as well as the composition and diversity of in faunal communities.   A wide range of criteria to find the impact of metals on marine organisms have been developed during the last few years. Growth, reproduction, and recruitment are usually the processes most susceptible to metal stress. Heavy metal contamination has become a subject of public interest because humans have been harmed by metal contamination.

The toxicity of a trace element to an organism depends on the metal chemical species, its concentration and the organism being affected. As for the organism, toxic effects occur when excretory, metabolic, storage, and detoxicification mechanisms no longer have the capacity to match uptake rates. This capacity may vary between species, populations, even individuals and can also depend on the stage in the life history of the organism. The consumption of marine food is the principal path to human exposure to heavy metals. Effects on humans can be observed after either a one-off exposure to a large non-lethal dose (acute) or after repeated exposure to lower dose (chronic).

2.6 Assessment of Contaminated Sediments

The environmental fate of contaminants must be understood in order to predict potential impacts on human health and ecosystems. Extensive experience is required for understanding how contaminants enter water bodies, the geochemical processes that govern their bioavailability, and how they are transformed by biological, geological, and chemical processes over time Scientists design and oversee sampling and analysis programs to identify whether and to what extent various key effects may be occurring and the source of environmental risks. These data are used in a risk management setting in concert with industry and regulators to determine whether remediation is appropriate and identify the optimal courses of action.

Field studies may also include an important environmental forensics component, which can help allocate liability among various sources. Risk posed by sediment-associated chemicals to aquatic organisms is best understood through an evaluation of sediment quality, known as the Sediment Quality Triad: sediment chemistry, toxicity, and benthic community. Measurements of these three areas are integrated to reach conclusions based on the degree of risk indicated by each measurement and the confidence in each measurement. Exponent ecologists and toxicologists have extensive experience in applying the Sediment Quality Triad approach to sediments containing metals, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and pesticides. Scientists working in this field should have specific expertise in cost-effective study design, including selecting appropriate test methods, interpreting results of Sediment Quality Triad studies, and developing technically defensible cleanup goals to support remedial decisions. Assessing the toxicity of the complex mixture of contaminants that can be present in sediment can be a challenging undertaking. For example, individual compounds in oil vary in potency and modes of toxic action, and the

influence of weathering changes the composition and toxicity of the mixture. Technical approaches to understand and predict the toxicity of individual sediment contaminants are required and it should be developed site-specific sediment quality guidelines and cleanup levels.

2.7 Studies in the Field of Contaminated Sediments

Heavy metal is one of the most serious environmental pollutants because of its high toxicity, abundance and ease of accumulation by various plant and animal organisms. Industrial activities, vehicle emissions, agricultural activities and domestic waste; in addition to shipping traffic especially in and close to harbors can all act as sources of heavy metal pollution. With the rapid industrialization and economic development in coastal regions, heavy metals are continuing to be introduced to estuarine and coastal environment through rivers, runoff and land-based point sources where metals are produced as a result of metal refinishing by products. Therefore, heavy metal contamination is still an environmental problem today in both developing and developed countries throughout the world.

Sediments can act as a scavenger agent for heavy metal and an adsorptive sink in aquatic environment. It is therefore, considered to be an appropriate indicator of heavy metal pollution. Metals accumulate in sediment from both natural and anthropogenic sources occur in the same manner, and this makes it difficult to identify and determine the origin of heavy metal present in sediment.

Sediment analyses play an important role in assessments of pollution status of marine environment. They are used as environmental indicators to reflect the quality of marine or lake systems (Zhang, *et al.* 2007).

Two major uses of sediment analyses - especially on heavy metals, can be defined as:

- The identification, monitoring, and control of pollution sources,

- The evaluation of the environmental impact of polluted sediments.

Several sediment contamination analyses were performed by many workers. Much attention has been paid to the monitoring and risk assessment of industrialized coastal areas exposed to contaminants from very different sources and many protocols have been developed. Hence, there is a clear need to adopt assessment techniques specifically for marine environments.

Measurement of heavy metal concentrations in sediments is the first step in evaluating their potential health or ecological hazard. Sample digestion is often a necessary step before determination. A standard and relatively safe dissolution method that provides a high analytical recovery of sediment bound metals is required. Various digestion methods are used to determine the concentration of heavy metals in sediment, including different combinations of concentrated acids. Open beakers heated on hot plates, digestion tubes in a block digester, and digestion bombs placed in microwave ovens are the most commonly used equipment to digest solid sample matrices. In particular, since the 1980s, the microwave-assisted sample digestion technique has become popular and presently it is widely used due to its safe, efficient and rapid performance.

The introduction of microwaves, with both open and closed pressurized systems, has allowed a considerable reduction in the total time of analyses as well as in the risk of sample contamination. Considering the matrix of most environmental samples (soils, sediments, sludges), a total digestion scheme must include the use of hydrofluoric acid (HF) to completely release the trace elements included in the aluminosilicate phase . However, the use of HF leads to long, dangerous, and cumbersome schemes and its use is not recommended for routine analyses.

Falciani, *et al.* (2000) described a method for the multi-element analysis of V, As, Co, Hg, Cd, Mo, Sn, Ba, Be, Cr, Ni, Pb, Cu and Zn in soils and sediments by inductively coupled plasma-mass spectrometry. They performed a microwave digestion procedure in order to obtain complete sample dissolution.

Scientists in the Netherlands have recently found that mixed farming, combining arable with dairy farming, leads to less heavy metal contamination than farming based exclusively on one or the other of these. The team calculated contamination levels by examining the difference between the input and output of heavy. They developed indicators for which metal exceeded the quality norms for soil, crops or ground water at any given moment. This makes it possible, for example, to predict that in a country like the Netherlands, given current input and output levels, conventional arable farming will exceed the quality norm for cadmium contamination within 70 years. Saha and Hossain (2010) investigated the pollution of Buriganga River by measuring the trace elements of the surface sediments. They collected sediment samples from 5 locations in the river. The collected samples were acid digested and analyzed by Flame Atomic Absorption Spectrometry (FAAS).

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This research work aims at finding sediment quality of the Buriganga and the Turag river by assessing heavy metal contamination. To achieve the goals study on the surface sediments is important. Methodology is very important to put finding forward the findings from the thesis work. The sediment quality of Buriganga and Turag river is deteriorating rapidly due to pollution from industrial and municipal sources. Among the sediment quality parameters, heavy metal contents would be analyzed.

Turag river drawn into the Jamuna system by the invasion of the Lohajang river (in Tangail district). The Turag remains active, although it has only a small flow in the dry season. Jamuna sediments have invaded its valley almost as far south as Tongi Khal perhaps since the Assam earthquake in 1950. It joins the buriganga near Mirpur (Dhaka) and is tidal in its lower reaches. It is navigable by country boats throughout the year. The whole of the Turag valley south of the Mymensingh Trunk road is notable for boro rice cultivation.

3.2 Selection of Site for Sample Collection

The study area consists of Turag river, one of the most prominent rivers in the flood plain region of Bangladesh which generates from Banshi river at Kaliakoir and meets Buriganga at Kholamora of Keraniganj. Turag River drawn into the Jamuna system by the invasion of the Lohajang river (in Tangail district). The Turag remains active, although it has only a small flow in the dry season. Jamuna sediments have invaded its valley almost as far south as Tongi Khal perhaps since the Assam earthquake in 1950. It joins the Buriganga near Mirpur (Dhaka) and is tidal in its lower reaches. It is navigable by country boats throughout the year. The GPS co-ordinate of selected fifteen points along Turag river is shown in Table 3.1.

Table 3.1: Global positioning system (GPS) data of sample collection in Turag river

Station No.	Name of Location	Longitude	Latitude
1	Near Tongi Railway Bridge	90°24'20.35"E	23°52'54.69"N
2	Tongi Bridge	90°24'2.15"E	23°52'53.86"N
3	World Estema Field	90°23'38.11"E	23°52'47.76"N
4	Near IUBAT Campus	90°23'31.94"E	23°53'17.73"N
5	Kamarpara Bridge	90°23'22.94"E	23°53'29.03"N
6	Near Beximco Pharma	90°23'15.87"E	23°53'54.49"N

Station No.	Name of Location	Longitude	Latitude
7	Near Bailey Bridge Connecting Road	90°22.57'86"E	23°53.54'86"N
8	Taltola Bridge	90°22'40.60"E	23°53'54.31"N
9	Near Kamarpara Petrol Pump	90°22'28.17"E	23°53'45.93"N
10	Near Cargo Container	90°22'7.75"E	23°53'43.64"N
11	Ashulia Toll Plaza	90°21'48.60"E	23°53'38.35"N
12	Ashulia Beri Bandh	90°21'37.29"E	23°53'33.74"N
13	Near Ashulia - Savar	90°21'30.10"E	23°53'23.25"N
14	Near Ashulia Mirpur Road	90°21'20.73"E	23°52'49.15"N
15	Ashulia Brick Field	90°21'6.60"E	23°52'37.20"N

3.3 Data Collection from Secondary Sources

Heavy metal concentration of sediment samples for Buriganga river has been collected from previous studies. Saha and Hossain (2010) investigated the pollution of Buriganga river by measuring the trace elements of the surface sediments. They collected sediment samples from 5(five) locations in the river during May, 2010. The collected samples were acid digested and analyzed by flame atomic absorption spectrometry (FAAS). The river Buriganga takes name as Buriganga from the end of Turag at Kholamora of Keraniganj and flowing through the southern part of Dhaka city and meet Dhaleshwari river at Dharmaganj. The study area of Buriganga river is located between 23^0 42' N to 23^0 45' N latitudes and 90^0 20' E to 90^0 25' E longitudes. The GPS co-ordinate of selected five points along Buriganga river is shown in Table 3.2.

Table 3.2: Global positioning system (GPS) data of sample collection in Buriganga river (Source : Saha and Hossain, 2010)

Designation	Location	Latitude	Longitude
B-1	Wachpur Ghat	23°44'41.6"N	90°20'35"E
B-2	Kolatiya Para	23°44'17.2"N	90°21'1.8"E
B-3	Kamrangirchar (End)	23°42'37.4"N	90°23'20.9"E
B-4	Kamrangirchar (North)	23°44'1.4" N	90°21'21.1"E
B-5	Badamtoli Ghat	23°42'37" N	90°24'1.3"E
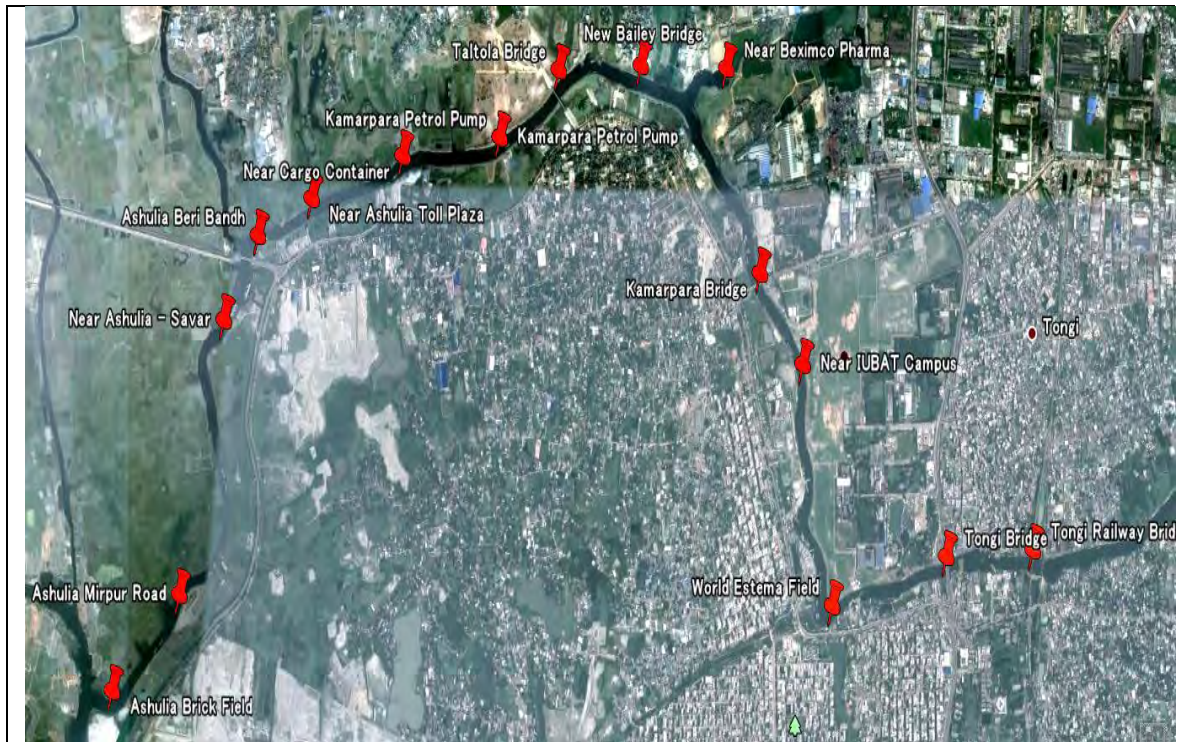
Fig. 3.1 Sediment Sampling Points in Turag river
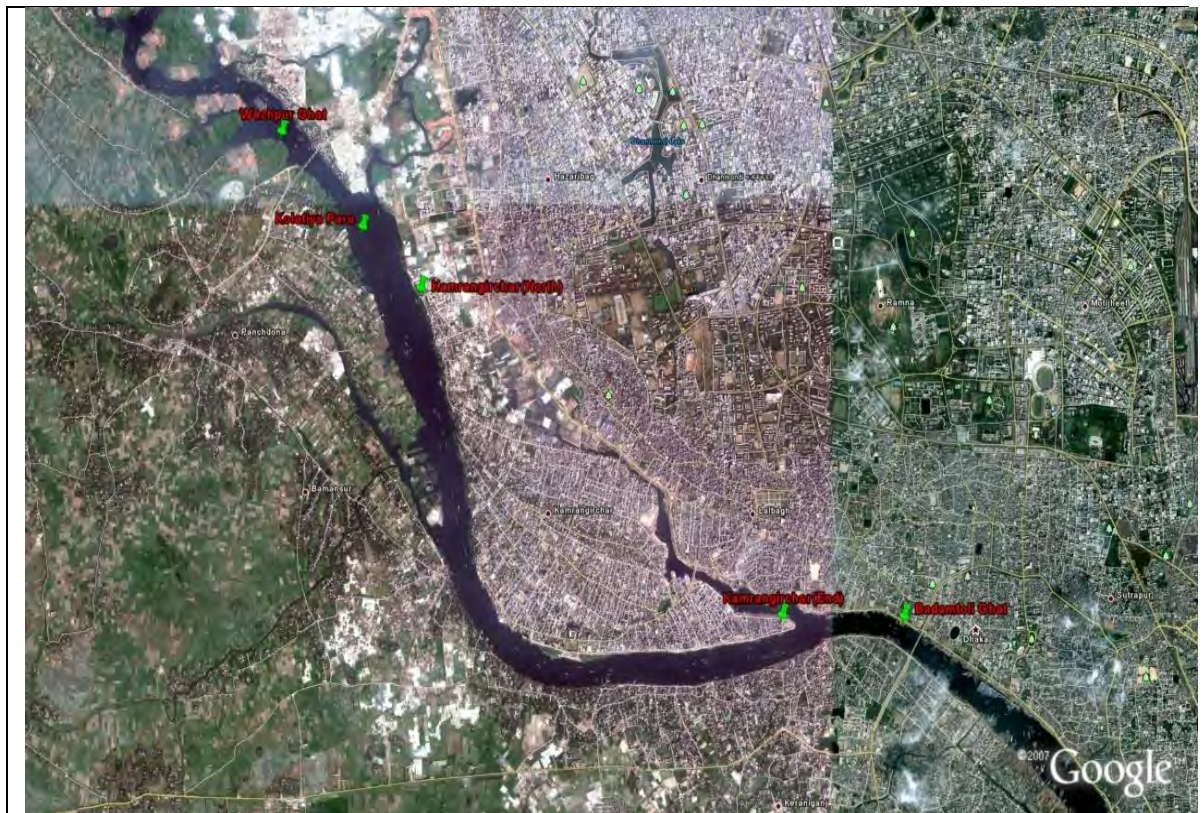
Fig. 3.2 Sediment Sampling Points in Buriganga river

Fig 3.3: The Turag River and it`s Surrounding Environment

3.4 Time for Sediment Collection

Sediments sample were collected from fifteen sites along the Turag River as showing in Figure 3.1 Latitude and Longitude for each site were illustrated in Table 3.1. The sediment samples were directly collected from the Turag River during the dredging of Turag bed sludge in April 2011. The samples were carried by polythene bag from 15 (fifteen) locations (Near Tongi Railway Bridge, Tongi Bridge, World Estema Field, Near IUBAT Campus, Kamarpara Bridge, Near Beximco Pharma, Near Bailey Bridge Connecting Road, Taltola Bridge, Near Kamarpara Petrol Pump, Near Cargo Container, Near Ashulia Toll Plaza, Ashulia Beri Bandh, Near Ashulia – Savar, Near Ashulia Mirpur Road, Ashulia Brick Field) along Turag river.

3.5 Grain Size and Its Effects in Metal Analysis

In recent years there has been a significant debate within the science community as to the effect of grain size on the adsorption of heavy metals in sediments. Particle dimension is one of the most significant parameters influencing trace metal levels in sediments. Bio-available sediment –bound metals depend, to a significant extent, on the particle size fraction with which a metal is associated. Traditionally, the fine grained (silt and clay) fraction of the sediment has been used to examine metal contamination in the whole sediment sample (Tam and Wong, 2000).

Tam and Wong (2000) designed their study to compare the concentrations of heavy metals bound in the fine-grained fraction (<63um) and the sand-sized fraction (2mm-63um) of the sediments. They found that the highest percentage of sediment in the fine-grained fraction (43%). They suggested that the concentrations of organic matter in the fine-grained fraction of the sediment were often higher than that in the sand sized fraction. Chakrapani and Subramanian (1993 quoted in Tam and Wong, 2000) reported that Cu, Zn, Mn and Fe increased in concentration with finer size and there was no significant variation in Pb with changes in grain size. The results of Tam and Wong's (2000) study found that the metal concentrations in the swamps represented the natural values and could be considered as the background. Although more metals were retained in the fine-grained sediments in most samples, metals would be accumulated in the sand-sized fraction if the swamp received heavy metals from anthropogenic inputs.

A very considerable amount of work has been reported on the sorption of trace metals by clays. The metals in this fine-grained fraction are more likely to be biologically available

than those in bulk sediments. Previous workers stated that the clay fraction is more important substrate for metal attachment and metal concentrations tended to increase from sand to silt (up to a 2 fold increase), whereas, the increase from silt to clay averages a 4-5.

Physical properties include texture (proportion of sand, silt and clay) and to some extent the type of clay minerals. It is infrequent that predominately coarser-textured soils and sediments become contaminated with problem levels of trace and toxic metals because such minerals have a low affinity for these elements.

Haque and Subramanian, 1982 recorded that metal absorption capacity was in the order of sand<silt<clay, due to increases in surface area, minerals and organic matter as particle size decreased from sand to clay.

However, this trend of more metal being accumulated in the fine-grained of the sediment may not be universal for all metals and may be varied between metal species.

3.6 Sediment Digestion Techniques

The choice of a particular analytical method is most often dictated by the available equipment and facilities. In any trace metal analysis method the first consideration should be the sensitivity of the method. One definition for sensitivity in atomic absorption spectrometry is the concentration of an element that will produce absorption of 1% generally expressed as µg/ml/1%. The detection limits are usually defined as twice the background. The analyst must realize that the stated values for sensitivity and detection limits can be largely instrument and operator dependant and in all cases should be determined experimentally and carefully defined.

The selectivity of analytical methods is the degree to which the method analyses one element with no interference or cross contamination from other elements in the matrix. Ideally, a method that is specific and measures each element individually with little or no interferences would be preferable. Accuracy and precision of the trace metal procedures are important but data will be less accurate as the concentrations analyzed reach the µg/l region.

1. After the sediments were fully thawed they were separated using a large sieve to remove any large stones, pebbles and organic matter.

2. They were then placed in acid-washed containers and placed in an oven at 105°C for 24 hours. Any samples not fully dried after these intervals were given some extra time in the oven until the required amount of drying was achieved.

3. The samples were then fully crushed to the finest possible fraction using an acid-washed pestle and mortar.

4. 5g of this crushed sediment was then transferred to a sample, acid-washed beaker into which 2.5 ml 65% concentrated nitric acid and 7.5 ml 37% concentrated hydrochloric acid was added and the beaker covered with a watch glass. The samples were left overnight to digest completely at room temperature.

5. 500 ml of distilled water was added to each beaker when they were adequately cooled and placed into a temperature controlled water bath @ 150°C for three hours. Water bath is more desirable in this situation instead of a hot plate as it regulates the temperature better and distributed the temperature evenly.

6. After the samples had all cooled to room temperature; they were all filtered through a glass funnel containing Whatttman No.1 filter paper. The expected concentration of the sample dictated the size of the volumetric flasks used. The reaction vessels and watch glasses were rinsed with distilled water to recover any residual metals. 500 ml sample were prepared for metal analysis.

7. Analysis was performed by Atomic Absorption Spectroscopy with the use of standards to allow determination of metal concentrations within each sample.

3.7 Metal Analysis Methods

In choosing the most appropriate analytical method to determine metals, each laboratory must consider the sample type and concentration levels, the number of elements to be determined and the costs the choice implies. As a result flame and graphite furnace Atomic Absorption Spectrometry (AAS) and inductively coupled plasma (ICP and ICP-MS) emission spectrometry are the most widely used analytical methods for determining trace elements.

Atomic Absorption Spectrometry (AAS)

Atomic Absorption Spectrometry is a spectro-analytical procedure for the qualitative and quantitative determination of chemical elements employing the absorption of optical

radiation (light) by free atoms in the gaseous state. In analytical chemistry the technique is used for determining the concentration of a particular element (the analyte) in a sample to be analyzed. AAS can be used to determine over 70 different elements in solution or directly in solid samples. Atomic Absorption Spectrometry was first used as an analytical technique, and the underlying principles were established in the second half of the 19th century by Robert Wilhelm Bunsen and Gustav Robert Kirchhoff, both professors at the University of Heidelberg, Germany. The modern form of AAS was largely developed during the 1950s by a team of Australian Chemists. They were led by Sir Alan Walsh at the CSIRO (Commonwealth Scientific and Industrial Research Organization), Division of Chemical Physics, in Melbourne, Australia.

Principles

The technique makes use of absorption spectrometry to assess the concentration of an analyte in a sample. It requires standards with known analyte content to establish the relation between the measured absorbance and the analyte concentration and relies therefore on Beer-Lambert Law. In short, the electrons of the atoms in the atomizer can be promoted to higher orbital's (excited state) for a short period of time (nanoseconds) by absorbing a defined quantity of energy (radiation of a given wave length). This amount of energy, i.e., wavelength, is specific to a particular electron transition in a particular element. In general, each wavelength corresponds to only one element, and the width of an absorption line is only of the order of a few picometers (pm), which gives the technique its elemental selectivity. The radiation flux without a sample and with a sample in the atomizer is measured using a detector, and the ratio between the two values (the absorbance) is converted to analyte concentration or mass using Beer-Lambert Law.
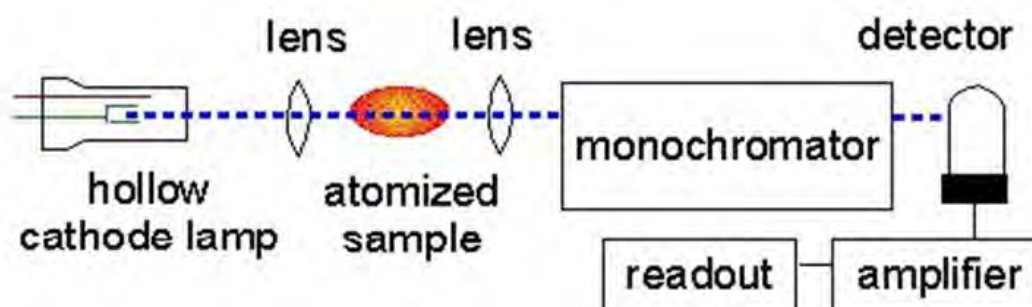
Fig. 3.4 Schematic of an atomic-absorption experiment (Tissue, 1996)

3.8 Assessment of Pollution Indices

In recent decades different metal assessment indices applied to estuarine environments have been developed. Each one of them aggregates the concentration of metal

contaminants and can be classified in three types—(i) contamination indices: which compare the contaminants with clean and/or polluted stations measured in the study area or simply aggregate the metal concentrations; (ii) background enrichment indices: which compare the results for the contaminants with different baseline or background levels, available in literature, that can be used for any study area; and (iii) ecological risk indices: which compare the results for the contaminants with Sediment Quality Guidelines or Values—SQG.

3.8.1 Background Enrichment Indices

Sediment Pollution According to Toxic Unit

Potential acute toxicity of contaminants in sediment sample can be estimated as the sum of the toxic unit (TU) defined as the ratio of the determined concentration to probable effect level (PEL) value (Pederson *et al.* 1998). Where, n is the number of heavy metal tested at a particular site.

$$\text{TU} = \sum_{i=1}^{i=n} \frac{C_{metal}}{PEL} \qquad (3.1)$$

3.8.2 Contamination Indices
a) Metal Pollution Index

In order to evaluate the overall degree of stream sediment metal contamination, the Metal Pollution Index (MPI) is calculated according Usero *et al.* (1996).

$$\text{MPI} = (M_1 \times M_2 \times M_3 \times ....\times M_n)^{(1/n)} \qquad (3.2)$$

Where, M_n is the concentration of metal n expressed in mg/kg of dry weight.

This method is simple but does not compare the contaminant concentration with any baseline or guidelines. No threshold classification from unpolluted to highly polluted sediment. Geometric average has advantages when compared with other aggregations methods, since it highlights concentration differences.

Table 3.3: Indices calculated in this study and guidelines used (S. Caeiro et al. / Ecological Indicators 5, 2005)

Index	Classification	Guidelines (mg/kg)				
		Cd	Pb	Zn	Cu	Cr
New pollution index (PIN)	Clean sediments (DR, 1995)	1	50	100	35	50
Degree of contamination (DC)	Pre-industrial reference level (Hakanson, 1980)	1	70	175	50	90
Pollution load index (PLI)	Baseline (Wilson and Jeffrey, 1987)	0.5	10	20	5	5
	Threshold (Wilson and Jeffrey, 1987)	1.5	100	100	50	50
Sediment quality guideline-quotient (SQG-Q)	Canadian PEL (MacDonald et al., 1996)	4.21	112	271	108	160
	Canadian TEL	0.7	30.2	124	18.7	52.3
	Wisconsin Consensus based PEL	5	130	460	150	110
	Wisconsin Consensus based TEL	0.99	36	120	32	43
Flemish SQG	Target value	2.5	70	160	20	60
	Limit value	7	350	500	100	220
	TEL: Threshold effect level	0.6	35	123	36	
Marine sediment pollution index (MSPI)	Percentile 0–20	0.6	3.3	15.4	3.0	2.0
	Percentile 21–40	1.0	5.0	34.0	6.0	5.0
	Percentile 41–60	1.5	8.0	57.0	12.0	9.2
	Percentile 61–80	2.9	18.2	101.6	30.6	19.6
	Percentile 81–100	8.0	69.0	507.0	191.0	63.0
	World avg. concentration for shale (Turekian and Wedepohl, 1961)	0.3	20	95	45	90
	TET: Toxic effect threshold MacDonald *et al.* (2000)	3.0	170	540	86	
EPA Region V	avg. conc. in the earth crust Engler (1980)	0.2	16	80	70	200
Average conc. in reference material Vinogradov (1966)	Sedimentary rock (clay and claystone)	0.3	20	80	57	100
Taylor and McLennan (1985 and 1995)	Upper continental crust	0.098	17	71	25	85
	Average continental crust	0.1	8	80	75	185
US DOE	TEC	0.59	34.2	159	28	56
	PEC	11.7	396	1532	77.7	159
	HNEC	41.1	68.7	541	54.8	312
Canadian EQG	ISQG	0.6	35	123	35.7	37.3
	PEL	3.5	91.3	315	197	90
US EPA	TRV	0.6	31	110	16	26
Ontario MOE	LEL	0.6	31	120	16	26
	SEL	10	250	820	110	110
Japan	EQS	1	0.01	-	125	-
	World Surface Rock Average (Martin and Meybeck, 1979)	0.2	20	129	32	97

3.8.3 Ecological Risk Indices

Ecological risk assessment is defined as a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors. A risk does not exist unless (1) the stressor has an inherent ability to cause one or more adverse effects and (2) it co-occurs with or contacts an ecological component (i.e., organisms, population, communities or ecosystem) long enough and at a sufficient intensity to elicit the identified adverse effect. Ecological risk assessment may evaluate one or more stressors and ecological component (USEPA, 1992a).

a) Theory Base of Evaluation on Potential Ecological Risk

In 1980, Lars Hakanson reported an ecological risk index for aquatic pollution control; therefore, Hakanson's method has been often used in ecological risk assessment as a diagnostic tool to penetrate one of many possible avenues towards a potential ecological risk index, i.e., to sort out which drainage area, reservoir, and substances should be given special attention. The method is based on the hypothesis that a sediment ecological risk index for toxic substances in limnic systems should account for the following requirements: (1) the potential ecological risk index (RI) increases with the metal pollution increase in sediments; (2) the ecological harms of different heavy metals in sediments have co-operativity, and the potential ecological risk of the cooperative harm is more serious, especially for Cu, Zn, Pb, Cd, and Cr and (3) toxicity response of each heavy metal element is different, and those metals whose biologic toxicity are strong have larger proportion in RI. On the premise mentioned above, the index is calculated as the following equations:

$$C_f^i = \frac{C_D^i}{C_R^i} \tag{3.3}$$

$$C_H = \sum_{i=1}^{m} C_f^i \tag{3.4}$$

$$E_f^i = T_f^i \times C_f^i \tag{3.5}$$

$$RI = \sum_{i=1}^{m} E_f^i \tag{3.6}$$

$$E_f^i = T_f^i \times C_f^i \tag{3.7}$$

Table 3.4 Evaluated parameters for ecological risk index calculation

Parameter	Cd	Cr	Cu	Pb	Zn
Pre-industrial background values (Hakanson, 1980), C_R^i	1	90	50	70	175
Toxic Response Factor, T_f^i	30	2	5	5	1

In which, C_f^i is the pollution coefficient of single metal; C_D^i is the measured concentration of sample; C_R^i is the background concentration of sediments; C_H is the polluted coefficient of many metals; E_f^i is the potential ecological risk factor of single metal; T_f^i is the biological toxicity factor of different metals; and RI is the potential ecological risk index of many metals.

According to Hakanson's ecological risk index method, the heavy metal polluted elements in sediment samples are analyzed and evaluated. In this study, only five polluted elements (Cu, Pb, Zn, Cd, and Cr) are investigated, which are less than eight elements required for Hakanson's method. Therefore, the integrated pollution degree (C_H) is defined as following: $C_H<5$, low pollution; $5 \leq C_H<10$, middle-pollution; $10 \leq C_H<20$, high-pollution; $C_H \geq 20$, higher-pollution. Biological toxicity factors of heavy metals (T_f^i), which are shown in Table 3.5. The background value of local soil as the reference value.

The standard parameter of toxic response made by Hakanson is:

Zn(1)<Cr(2)<Cu(5)=Ni(5)=Pb(5)<As(10)<Cd(30)<Hg(40) (Lars Hakanson, 1980).

Table 3.5 Relation between ecological risk index and grade

Potential ecological risk factor E_f^i		Potential ecological risk index RI	
Threshold range of single metal risk factor grade		Threshold range of five metals RI grade	
<30	I low	<110	A low
30~60	II middle	110~220	B middle
60~120	III appreciable	220~440	C appreciable
120~240	IV high	>440	D high
>240	V much high		

b) Pollution load index (PLI): Ecological Risk Index

For each contaminant the PLI is calculated using the formula proposed by Wilson and Jeffrey (1987):

$$PLI = anti \log_{10} (1 - \frac{C - B}{T - B}) \qquad (3.8)$$

B is the baseline value—not contaminated; T the threshold, minimum concentrations associated with degradation or changes in the quality of the estuarine system. Wilson and

Jeffrey (1987) define B and T for the different contaminants; C the concentration of the pollutant. For each place the PLI calculation takes into account all the n contaminants:

$$\text{PLI} = (PLI_1 \times PLI_2 \times PLI_3 \times .... \times PLI_n)^{(1/n)} \qquad (3.9)$$

PLI varies from 10 (unpolluted) to 0 (highly polluted).

This index allows the comparison between several estuarine systems. It has been applied successfully in European estuaries.

Values of baseline and threshold not defined locally for each coastal zone analyzed and not recently revised.

c) Mean Sediment Quality Guideline Quotient (SQG-Q)

In order to predict adverse biological effects in contaminated sediments, numerous sediment quality guidelines (SQGs) have been developed over the past decade. In this investigation, we compared our total concentration with SQG of probable effect concentrations (PEC) as described by MacDonald et al. (2000) to assess the possible biological consequences of the metal concentrations in the surface sediments.

Table 3.6 Definitions used in mean sediment quality guideline quotient (SQG-Q)

Sediment Guideline	Description
Effect range low (ERL)/ Effect range medium (ERM)	Adverse effect infrequent
Threshold effect level (TEL)/ Probable effect level (PEL)	Adverse effect likely to occur

Mean sediment quality guideline quotient is an ecological risk index proposed by Long and MacDonald (1998). Sediment quality guideline quotient takes into account a complex mixture of contaminants in each location. Sediment quality guideline quotient for a river is calculated using the following formula:

$$\text{PEL-Q} = \frac{C_{metal}}{PEL} \qquad (3.10)$$

$$\text{SQG-Q} = \frac{\sum_{i=1}^{n} \text{PEL-Q}_i}{n} \qquad (3.11)$$

Where, PEL-Q is the probable effect level quotient, PEL is the probable effect level for each metal (concentration above which adverse effects frequently occur).

3.9 Toxicity Characteristics Leaching Procedure Test

Toxicity Characteristic Leaching Procedure is designed to determine the mobility of both organic and inorganic analytes present in liquid, solid and multiphase wastes. This is usually used to determine if a waste may meet the definition of EP Toxicity, that is, carrying a hazardous waste code under RCRA (40 CFR Part 261) of D004 through D052. Sometimes in cleanup actions, businesses are often asked to perform an analysis on their waste using the TCLP, The Code of Federal Regulations (CFR).

The TCLP test is the assay prescribed by the EPA to determine whether a solid waste is hazardous by toxicity characteristic. The TCLP test involves the extraction of contaminants from a 100-g size-reduced sample of waste material with an appropriate extraction fluid. A 20:1 liquid to solid (L/S) ratio (mass/mass, m/m) is employed, and the mixture is rotated for 18 ± 2 hr at 30 rpm using a rotary agitation apparatus. Where volatile constituents must be evaluated, a smaller sample mass is used (25 g) and a specialized zero-headspace extraction (ZHE) vessel is employed. The extraction fluid used for the extraction depends on the alkalinity of the waste material. Very alkaline waste materials are leached with a fixed amount of acetic acid without buffering the system (pH 2.88 ± 0.05), while other waste materials are leached with acetic acid buffered at pH 4.93 ± 0.05 with 1-N sodium hydroxide. After rotation, the final pH is measured, and the mixture is filtered using a glass fiber filter. The filtrate is collected in an appropriate container, and preservative may be added if needed. The filtrate is analyzed for a number of constituents.

Table 3.7—Maximum Concentration of Contaminants for Toxicity Characteristic (the D List) (Method USEPA 1311)

EPA Hazardous Waste code	Contaminant	Regulated Level (mg/l) (or ppm)
D004	Arsenic (As)	5.0
D005	Barium (Ba)	100.0
D006	Cadmium (Cd)	1.0
D007	Chromium (Cr)	5.0
D008	Lead (Pb)	5.0
D009	Mercury (Hg)	0.2
D010	Selenium (Se)	1.0
D011	Silver (Ag)	5.0

Technical Basis of Test

In developing the original toxicity characteristic, EPA designed the EP based upon a "mismanagement scenario" in which potentially hazardous wastes would be co-disposed with municipal solid waste (MSW) in a landfill with actively decomposing material overlying an aquifer. Consistent with this mismanagement scenario, the EP required that a liquid extract be obtained from solid waste (following particle size reduction, if necessary) by exposing the waste to organic acids (the acids likely to be found in a landfill containing decomposing municipal wastes). In conjunction with the co-disposal scenario, EPA assumed that the most likely pathway for human exposure to toxic constituents would be through drinking water contaminated by leachate from the landfill. Analyses of the EP extract were to be compared to the National Interim Primary Drinking Water Standards (NIPDWS). To account for the likely dilution and attenuation of the toxic constituents that would occur as they traveled from the landfill to a drinking water source, regulatory limits were established by multiplying the NIPDWS by a "dilution and attenuation factor" (DAF) of 100. The DAF of 100 was not derived from any model or empirical data, but rather was an estimated factor that EPA believed would indicate substantial hazard.

The TCLP was developed using the same mismanagement assumptions that formed the basis for the development of the EP -- that wastes would be co-disposed with actively decomposing MSW in a landfill. Under this co-disposal scenario, infiltrating precipitation combined with water-soluble products of MSW biodegration act as the leaching fluid.

The TCLP analysis simulates landfill conditions. Over time, water and other liquids percolate through landfills. The percolating liquid often reacts with the solid waste in the landfill, and may pose public and environmental health risks because of the contaminants it absorbs. The TCLP analysis determines which of the contaminants identified by the United States Environmental Protection Agency (EPA) are present in the leachate and their concentrations.

Although the TCLP test is primarily used to determine hazardous characteristics, it is sometimes used to determine the impact of a waste on groundwater even when the waste is stored or disposed in non landfill conditions.

3.10 Statistical Methods

Statistics is the study of the collection, organization, analysis, and interpretation of data. It deals with all aspects of this, including the planning of data collection in terms of the design of surveys and experiments. Common goal for a statistical research project is to investigate causality and in particular to draw a conclusion on the effect of changes in the values of predictors or independent variables on dependent variables or response (Wikipedia).

3.10.1 Overview of Principal Component Analysis (PCA)

Principal Component Analysis (PCA) can be considered as the mother of all methods in multivariate data analysis. The aim of PCA is dimension reduction and PCA is the most frequently applied method for computing linear latent variables (components). PCA can be seen as a method to compute a new coordinate system formed by the latent variables, which is orthogonal, and where only the most informative dimensions are used. Latent variables from PCA optimally represent the distances between the objects in the high-dimensional variable space. Here the distance of objects is considered as an inverse similarity of the objects. PCA considers all variables and accommodates the total data structure; it is a method for exploratory data analysis (unsupervised learning) and can be applied to practical any X-matrix; no y-data (properties) are considered and therefore not necessary (Varmuza and Filzmoser 2008).

Dimension reduction by PCA is mainly used for;

- Visualization of multivariate data by scatter plots

- Transformation of highly correlating x-variables into a smaller set of uncorrelated latent variables that can be used by other methods

- Separation of relevant information (described by a few latent variables) from noise

- Combination of several variables that characterize a chemical-technological process into a single or a few ''characteristic'' variables.

PCA is successful for data sets with correlating variables. Constant variables or highly correlating variables cause no problems for PCA; however, outliers may have a severe influence on the result, and also scaling is important. The direction in a variable space that best preserves the relative distances between the objects is a latent variable which has maximum variance of the scores. This direction is called by definition the first principal component (PC1). It is defined by a loading vector

$$p_l = (p_1, p_2, \ldots\ldots p_m)$$ (3.12)

In chemometrics, the letter p is widely used for loadings in PCA. It is common in chemometrics to normalize the lengths of loading vectors to 1; that means; m is the number of variables. The corresponding scores are linear combinations of the loadings and the variables. For instance, for object i, defined by a vector x_i with elements x_{i1} to x_{im}, the score t_{i1} of PC1 is

$$t_{i1} = x_{i1}p_1 + x_{i2}p_2 + \ldots\ldots\ldots\ldots + x_{im}p_m = x_i^T \cdot p_i$$ (3.13)

The last part of this equation expresses this orthogonal projection of the data on the latent variable. For all n objects arranged as rows in the matrix X the score vector, t_1, of PC1 is obtained by

$$t_1 = X \cdot p_1$$ (3.14)

The second principal component (PC2) is defined as an orthogonal direction to PC1 and again possessing the maximum possible variance of the scores. For two-dimensional data, only one direction, orthogonal to PC1, is possible for PC2. In general further PCs can be computed up to the number of variables. Subsequent PCs are orthogonal to all previous PCs, and their direction has to cover the maximum possible variance of the data projected on this direction. Because the loading vectors of all PCs are orthogonal to each other - as the axes in the original x-coordinate system - this data transformation is a rotation of the coordinate system. For orthogonal vectors, the scalar product is zero, so for all pairs of PCA loading vectors we have

$$p_j^T p_k = 0 \quad j,k=1,\ldots\ldots\ldots\ldots,m$$ (3.15)

Number of PCA Components

The principal aim of PCA is dimension reduction; that means to explain as much variability as possible with as few PCs as possible.

If in a score plot, using the first two PCs more than about 70% of the total variance is preserved, the scatter plot gives a good picture of the high-dimensional data structure. If more than 90% of the total variance is preserved, the two-dimensional representation is excellent, and most distances between object points will reflect well the distances in the high-dimensional variable space.

CHAPTER FOUR

RESULTS ANALYSIS AND DISCUSSION

4.1 General

Heavy metal pollution in river sediments is one of the serious threats to humans. Determination of heavy metal concentration is the first step to evaluate the extent of pollution in the surface sediment. This chapter will enhance the concept of evaluation of heavy metal pollution, similarities among the metals, their sources in Buriganga and Turag river sediments.

4.2 Grain Size Analysis of Sediment Samples

Grain size has a great influence over the adsorption capacity of heavy metals. So, it is utmost important to analyze the grain size of sediment samples collected from Fifteen selected locations along Turag river. Sediment composition was determined for all samples by sieve analysis and it is found that on an average, 32.70% materials passing through #200 sieve (fine particle) whereas 54.39 % materials retain on #8 to #200 sieve (medium size particle), that indicate the sediment size of the Turag river ranges over medium to fine and it also contains a significant amount of fine particles. It also observed that medium particles range from 46.68% to 63.45% and fine particle range from 24.14% to 44.41%.

Grain size analysis of sediment samples from Buriganga river shows that on an average 25.34% materials passing through #200 sieve (fine particle) whereas 72.90% materials retain on #8 to #200 sieve (medium size particle), that indicate the sediment size of the Buriganga river ranges over medium to fine and it also contains a significant amount of fine particles. It is also observed that medium particles range from 68.89% to 77.82% and fine particle range from 20.95% to 30.74%.

Sediment samples of Wachpur Ghat contain 76.40% medium particle and 22.86% fine particle. Sediment sample collected from Kolatiya Para contains 73.84% medium particles and 23.71% fine particle. Sediment samples of Kamrangirchar (end) contain 68.94% medium particles and 28.44% fine particle. Sediment sample of Kamrangirchar (north) contain 77.82% medium particles and 20.95% fine particle. Sediment samples from Badamtoli Ghat contains 68.89% medium particles and 30.74% fine particle. The locations can be arranged with respect to amount of fine particle as, Badamtoli Ghat >

Kamrangirchar (end) > Kolatiya Para > Wachpur Ghat > Kamrangirchar (north). Gradation curve shows that sediment samples are well graded.

4.3 Heavy Metal Contamination of River Sediments

In this section metal ion concentration, Toxicity Characteristics Leaching Procedure test and comparison of metal ion concentration with USEPA sediment quality guideline will be discussed.

4.3.1 Metal ion Concentration

Concentrations of metals in sediment samples from Turag river are presented in Table 4.1. The concentration of metals in surface sediments has the trend: Zinc (Zn)> Copper (Cu)>Lead (Pb)>Chromium (Cr)>Cadmium (Cd).

Concentrations of metals in sediment samples from Turag River are presented in Table 4.3. The concentration of metals in surface sediments has the trend: Zinc (Zn)>Copper (Cu)>Chromium (Cr)>Lead (Pb)>Cadmium (Cd).

Lead concentrations ranges from 28- 36.4 mg/kg and the average value is 33.51 mg/kg. Among the five locations along Turag river, Pb concentration in Near Tongi Bridge is maximum and in Near Ashulia Mirpur Road, it is minimum. Lead concentration along Turag river is almost uniform as the standard deviation is 2.66 mg/kg.

Cadmium concentrations ranges from 0 – 0.8 mg/kg and the average value is 0.29 mg/kg. Among the Fifteen locations along Turag river, Cadmium concentration in Near Cargo Container and Ashulia Beri Badh is maximum and in Kamarpara Bridge, it is minimum.

Table 4.1: Concentration of heavy metals (mg/kg dry weight) of sediments of Turag river

Location	Lead (Pb)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Zinc (Zn)
T-1	36.2	0.1	35.5	59.4	178
T- 2	36.4	0.1	36	60	179.3
T-3	34.4	0.1	33.5	46.3	113.8
T-4	35.5	0.4	35	58	172.5
T-5	30.4	0	75.5	46.4	190.1
T-6	34.4	0.3	34	46.1	112.5
T-7	34	0.3	33.5	46	110.4
T-8	28.3	0.4	32	50	94.6
T-9	33.28	0.2	32.5	45.8	190.1
T-10	32.4	0.8	32	46.4	120.5
T-11	32	0.4	75.5	46	118

Location	Lead (Pb)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Zinc (Zn)
T-12	34.4	0.8	38.1	49.3	119.6
T-13	30.4	0.2	31.5	45.1	94.6
T-14	28	0.2	32	49.5	93.5
T-15	34.4	0.1	29	49.2	119.6
Mean	32.96	0.29	39.04	49.56	133.80
Max	36.4	0.8	75.5	60	190.1
Min	28	0	29	45.1	93.5
SD	2.66	0.24	14.96	5.20	36.64

Chromium concentrations ranges from 29- 75.5 mg/kg and the average value is 39.04 mg/kg. Among the Fifteen locations along Turag river, Chromium concentration in Near Kamarpara Bridge is maximum and in Near Ashulia Brick Field, it is minimum.

Copper concentrations ranges from 45.1- 60 mg/kg and the average value is 49.56 mg/kg. Among the Fifteen locations along Turag river, Cu concentration in Tongi Bridge is maximum and near Ashulia- Savar, it is minimum. Copper concentration along the Turag river is almost uniform as the standard deviation is 5.20 mg/kg.

Zinc concentrations ranges from 93.5- 190.1 mg/kg and the average value is 133.80 mg/kg. Among the Fifteen locations along Turag river, Zn concentration in Near Kamarpara Bridge is maximum and in Near Ashulia Mirpur Road, it is minimum. It is also shown in this study, the standard deviation (SD) between the concentrations of metals at different sites along Turag river are not significant that may indicate the spatial distribution of metal contamination is almost uniform.

Concentrations of metals in sediment samples from Buriganga river are presented in Table 4.2. The concentration of metals in surface sediments has the trend: Zinc (Zn)> Copper (Cu)>Chromium (Cr)>Lead (Pb)>Cadmium (Cd). Cadmium concentration ranges from 0.4 - 1.6 mg/kg and the average value is 0.82 mg/kg.

Table 4.2: Concentration of heavy metals (mg/kg dry weight) of sediments of Buriganga river

Location	Lead (Pb)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Zinc (Zn)
B-1	82.30	0.40	129.90	107.70	329.60
B-2	70.40	0.50	57.90	85.00	276.00
B-3	60.30	0.40	52.80	70.00	245.00
B-4	80.60	1.20	125.80	313.40	675.80
B-5	105.60	1.60	139.60	346.00	984.90

Location	Lead (Pb)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Zinc (Zn)
Mean	79.84	0.82	101.20	184.42	502.26
Max	105.60	1.60	139.60	346.00	984.90
Min	60.30	0.40	52.80	70.00	245.00
SD	16.89	0.55	42.19	133.80	320.25

Chromium concentration ranges 52.80 – 139.60 mg/kg, respectively and the average value is 101.20 mg/kg. Among the five locations along Buriganga river, Chromium concentration in Badamtoli Ghat is maximum and in Kamrangirchar (End), it is minimum. Lead concentrations ranges from 60.3 - 105.6 mg/kg, respectively and the average value is 79.8 mg/kg. Among the five locations along Buriganga river, Pb concentration in Badamtoli Ghat is maximum and in Kamrangirchar (End), it is minimum.

Copper concentration ranges from 70.0 - 346.0 mg/kg, respectively and the average value is 184.4 mg/kg. Among the five locations along Buriganga river, Cu concentration in Badamtoli Ghat is maximum and in Kamrangirchar (End), it is minimum.

Zinc concentration ranges from 245.0 - 984.9 mg/kg, respectively and the average value was 502.3 mg/kg. Among the selected locations along Buriganga river, Zn concentration in Badamtoli Ghat is maximum and in Kamrangirchar (End), it is minimum. It is also found from this study that standard deviation (SD) between the concentrations of metals at different sites along Buriganga river are very high that may indicate the spatial distribution of metal contamination is not uniform.

4.3.2 Heavy Metal Contamination and USEPA Quality Guideline

In absence of any local standards for pollutants, the metal levels in sediment sample were compared with the sediment quality guideline proposed by United States EPA. These criteria are shown in Table 4.3.

Cu, Pb and Zn in all locations of Buriganga river belongs to highly polluted sediments. Cd in location B-4 and B-5 belongs to moderately polluted sediments while location B-1, B-2 and B-3 are not polluted by Cd. Cr in location B-1, B-4 and B-5 belongs to highly polluted while station B-2 and B-3 are moderately polluted sediment.
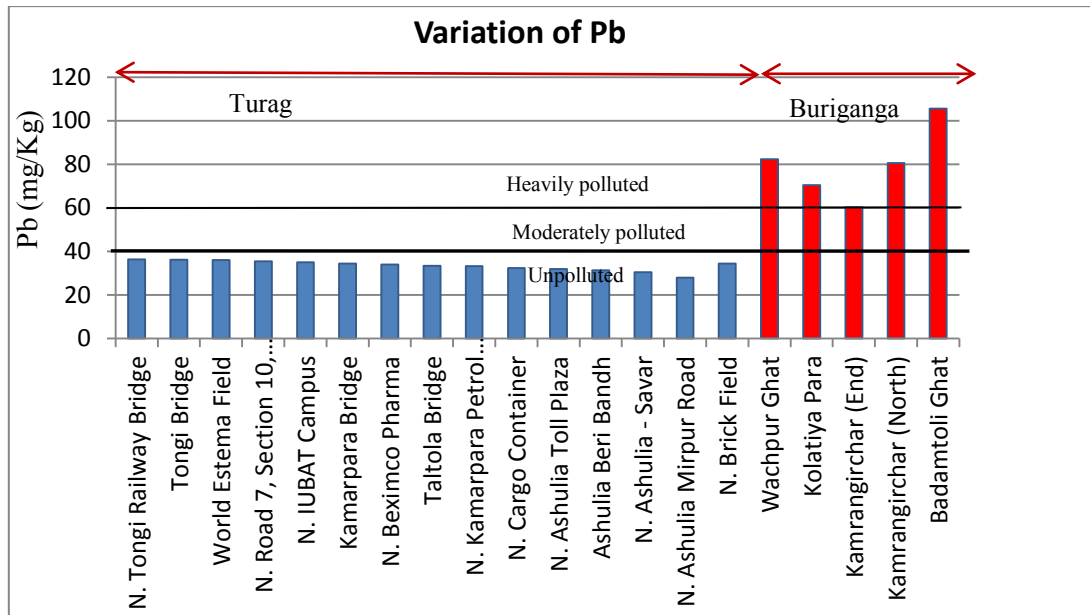
Fig. 4.1 Variation of Lead along Turag and Buriganga river in comparison to USEPA

Cr, Cu, Zn in all locations of Turag river belongs to moderately polluted sediments except location T-1, T-2, T-3, T-4 for Cu is highly polluted and location T-11 is heavily polluted in case of Cr. Pb and Cd in all locations belongs to not polluted.

Table 4.3 Comparison between USEPA sediment quality guideline and present study

(mg/kg dry weights)	Zn	Pb	Cu	Cd	Cr
US EPA Sediment quality guideline					
Not Polluted	<90	<40	<25	-	<25
Moderately polluted	90-200	40-60	25-50	-	25-75
Heavily polluted	>200	>60	>50	>6	>75
Present study					
Buriganga river	245-984.9	60.3-105.6	70-346	0.40-1.60	52.80-139.60
Turag river	94.6-190.1	28.30-36.40	46.3-60	0.00-0.80	32.00-75.50

Spatial variation of lead, copper, chromium, zinc and cadmium in three different rivers are shown in Fig. 4.1, 4.2, 4.3, 4.4 and 4.5, respectively. Fig. 4.1 shows that all locations along Turag river are unpolluted while Buriganga river are highly polluted with lead.
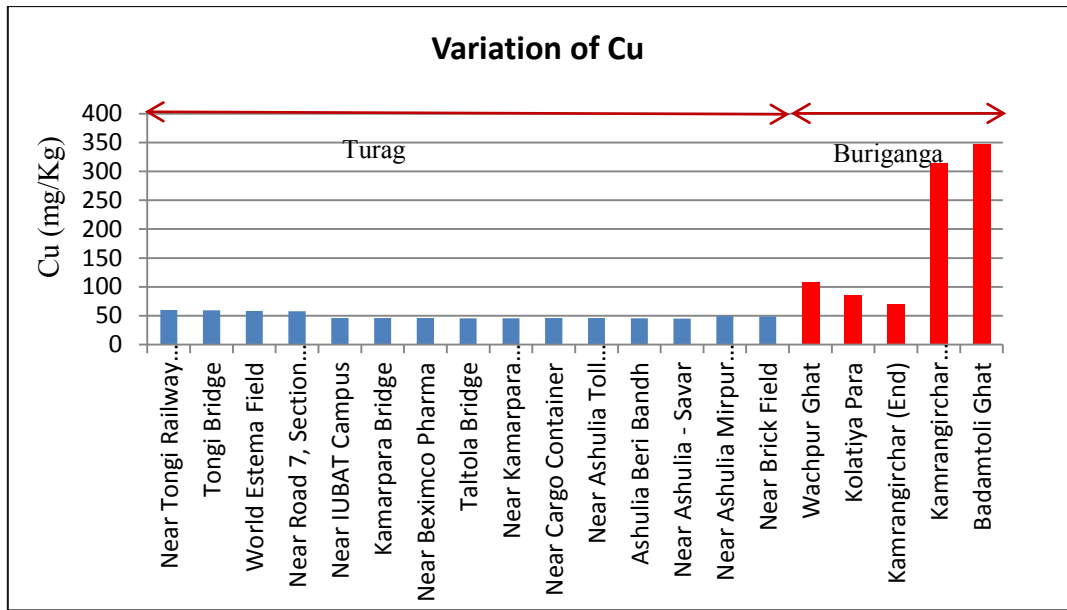
Fig. 4.2 Variation of Copper along Turag and Buriganga River in comparison to USEPA

Fig. 4.2 shows that All locations along Turag river are moderately polluted and Near Tongi Railway Bridge, Tongi Bridge, World Estema Field, Near IUBAT Campus are highly polluted with copper. This concludes that copper concentration along Turag river is almost uniform. While Buriganga river are highly polluted with Cu

Fig. 4.3 shows Turag river is moderately polluted with chromium. While Buriganga River is moderately to highly polluted with Cr as per USEPA.
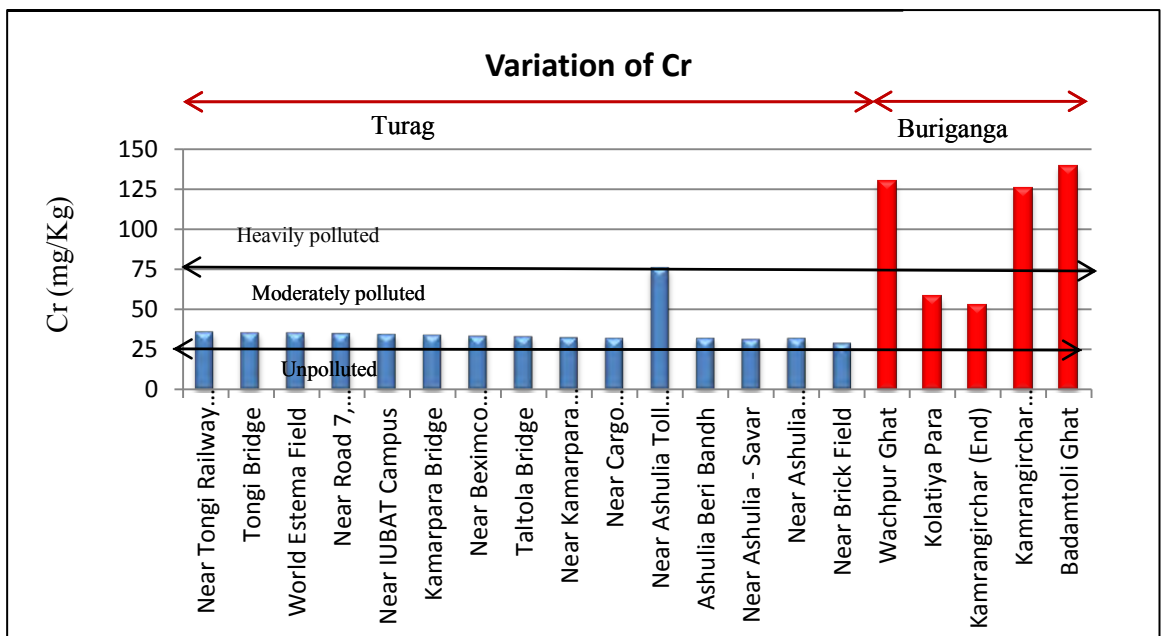
Fig. 4.3 Variation of Chromium along Turag and Buriganga River in comparison to USEPA

Fig. 4.4 shows that Turag River is moderately polluted with zinc. While Buriganga River is highly polluted with Zn.
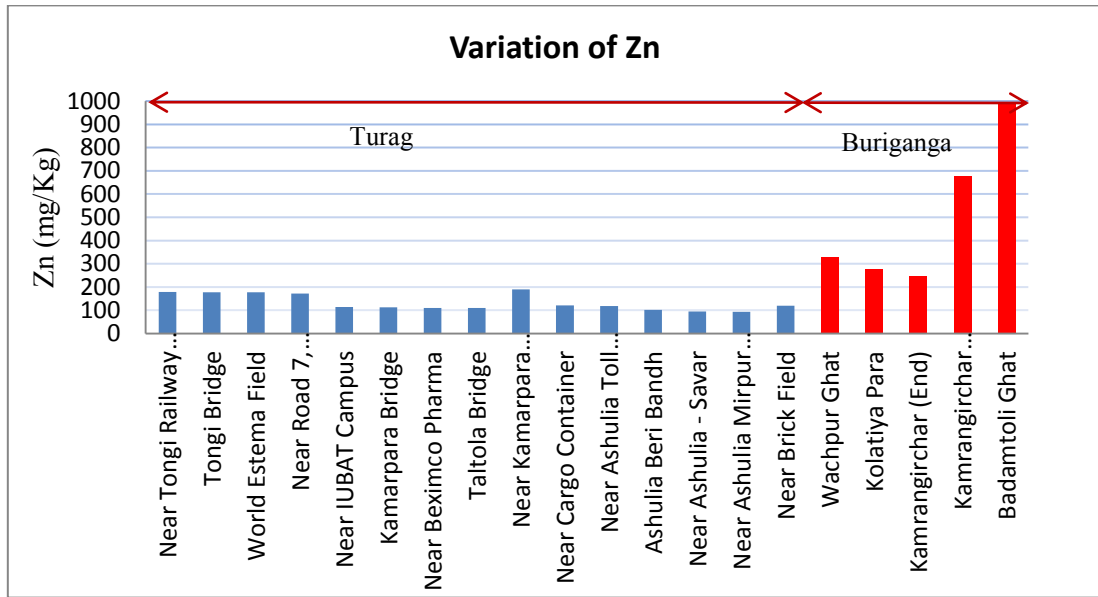
Fig. 4.4 Variation of Zinc along Turag and Buriganga river in comparison to USEPA

There is no limit of USEPA sediment quality guideline for unpolluted and moderately polluted with cadmium. Fig. 4.5 shows that all locations along the rivers are below the limit of heavily polluted sediments with cadmium.
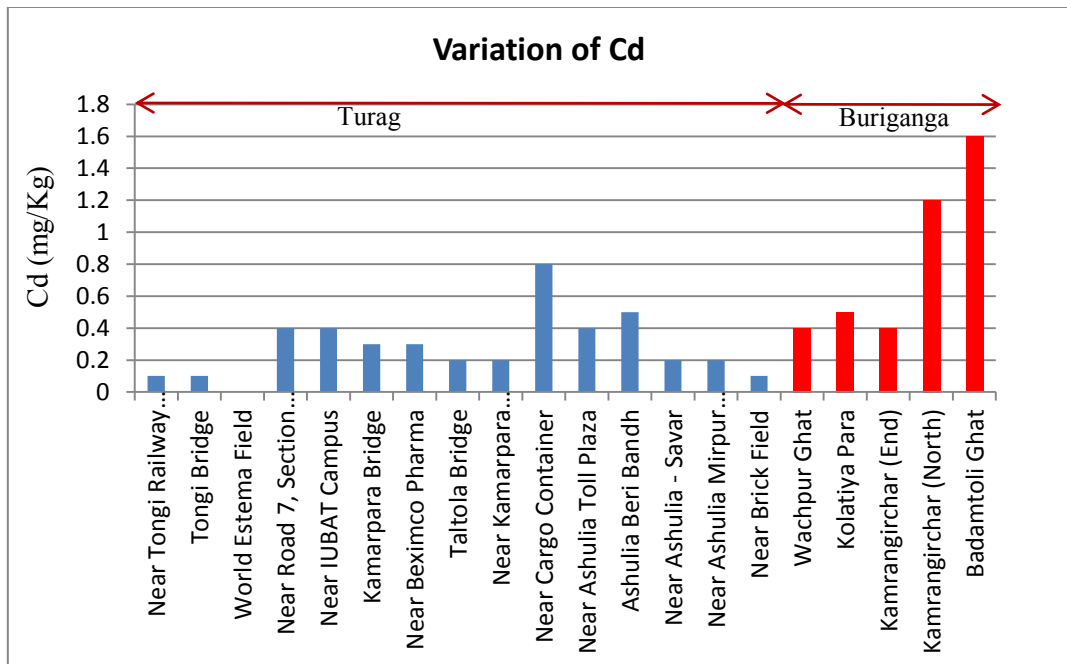
Fig. 4.5 Variation of cadmium along Turag and Buriganga river in comparison to USEPA

4.3.3 Toxicity Characteristics Leaching Procedure Test

Toxicity characteristics leaching procedure (TCLP) is a very important tool for assessing readily contaminated heavy metal for sediment samples. In this study, heavy metal concentrations from leachate of Turag river sediments were tested in the laboratory and pollution levels of leachate were assessed with comparison of USEPA standard. Results of the TCLP test are presented in the Table 4.4.

Table 4.4: TCLP test result (mg/L) for the sediment sample of the Turag river

Location	Pb	Cd	Cr	Cu	Zn
T-1	0.01	0.00	0.01	0.12	1.95
T-2	0.09	0.02	0.00	0.12	3.10
T-3	0.08	0.01	0.02	0.18	2.33
T-4	0.01	0.00	0.00	0.13	0.61
T- 5	0.04	0.00	0.00	0.18	3.77
T-6	0.01	0.00	0.00	0.12	0.61
T-7	0.01	0.00	0.00	0.12	0.61
T-8	0.01	0.01	0.00	0.13	0.61
T-9	0.02	0.01	0.00	0.12	0.61
T-10	0.02	0.01	0.00	0.12	1.95
T-11	0.02	0.00	0.01	0.12	1.95
T-12	0.02	0.00	0.01	0.12	1.95
T-13	0.02	0.00	0.00	0.13	0.60
T-14	0.01	0.00	0.00	0.13	0.60
T-15	0.01	0.00	0.00	0.13	0.60
Mean	0.04	0.01	0.01	0.15	2.35
Max	0.09	0.02	0.02	0.18	3.77
Min	0.01	0.00	0.00	0.12	0.61
SD	0.04	0.01	0.01	0.03	1.20
Regulated Level (USEPA)	5	1	5	-	-

Results of the TCLP test for Buriganga river sediments are presented in the Table 4.5. For all the sites, concentrations of heavy metal in the leachate are not exceeded the permissible EPA standard. That indicate regarding the readily toxicity pollution by heavy metal, Buriganga river sediment condition is not in the severe state.

Table 4.5: TCLP test result (mg/L) for the sediment sample of the Buriganga river

Location	Pb	Cd	Cr	Cu	Zn
B-1	0.10	0.02	0.05	0.34	9.43
B-2	0.13	0.01	0.02	0.20	6.25
B-3	0.19	0.01	0.03	0.12	4.19
B-4	0.13	0.02	0.04	0.27	18.96
B-5	0.17	0.02	0.05	0.25	26.09
Mean	0.14	0.02	0.04	0.24	12.98
Max	0.19	0.02	0.05	0.34	26.09

Location	Pb	Cd	Cr	Cu	Zn
Min	0.10	0.01	0.02	0.12	4.19
SD	0.03	0.01	0.01	0.08	9.26
Regulated Level (USEPA)	5	1	5	-	-

4.4 Methodologies for Assessment of Sediment Contamination

In this part of the chapter, different methods for assessment of sediment contamination have been discussed. The aim of this evaluation is to determine the best method for the assessment of contamination status of polluted rivers.

4.4.1 Introduction

In order to assess pollution status in the river sediments, it is important to verify different methods available for calculation of sediments pollution. In this part of the chapter pollution indices, Pearson's correlation and Principal Component Analysis have been discussed.

4.4.2 Pollution indices

In this section heavy metal pollution indices that can be applied to the sediments of Buriganga and Turag rivers have been discussed. In this study contamination indices, background enrichment indices and ecological risk indices have been calculated.

4.4.2.1 Contamination Indices Calculation

In this study metal pollution index by Usero *et al.* (1996) has been calculated.

a) Metal Pollution Index

In order to evaluate the overall degree of stream sediment metal contamination, the metal pollution index (MPI) is calculated according Usero *et al.* (1996). Metal pollution index of Buriganga and Turag river is shown in Table 4.6. MPI ranges from 0(zero) to 95.72 in the selected rivers. As metal concentration is comparatively high, Buriganga river sediments have a higher index than other two rivers.

Table 4.6: Metal Pollution Index in rivers

Location	Buriganga	Location	Turag
B-1	43.27	T-1	16.97
B-2	34.34	T-2	16.85
B-3	29.36	T-3	0
B-4	76.24	T-4	21.84
B-5	95.72	T-5	19.10
		T-6	17.86
		T-7	17.69

Location	Buriganga	Location	Turag
		T-8	16.15
		T-9	17.98
		T-10	21.54
		T-11	22.08
		T-12	18.74
		T-13	15.22
		T-14	15.26
		T-15	14.25

Figure 4.6 shows, the variation of Metal Pollution Index along Buriganga and Turag river Sediments
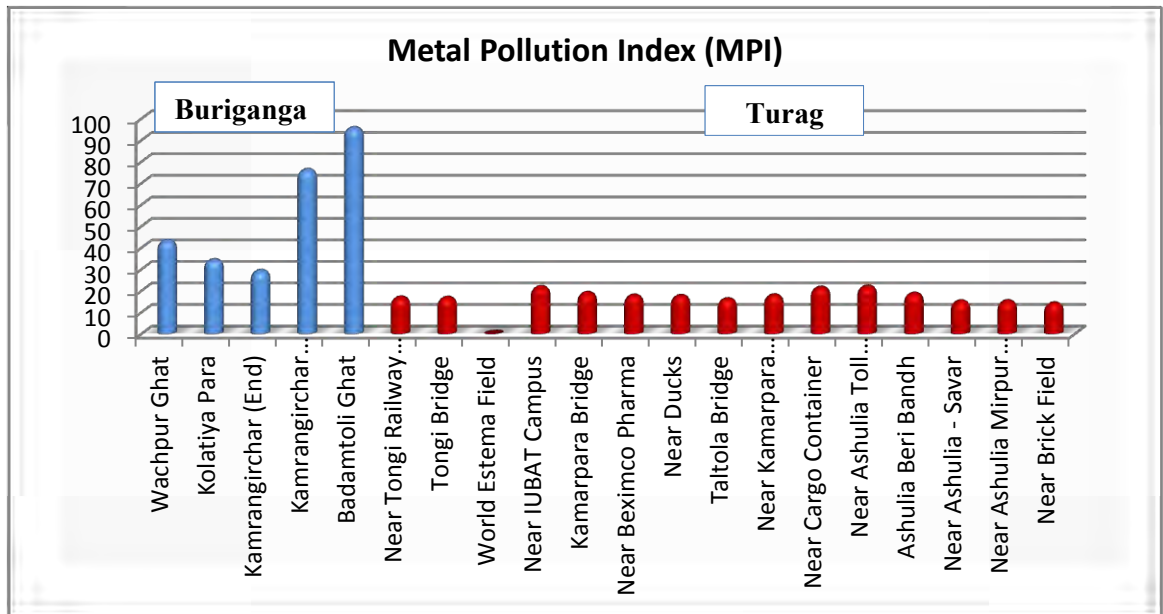
Fig. 4.6 Variation of Metal Pollution Index along Turag and Buriganga river

Metal pollution index without considering cadmium is shown in Table 4.7. It is found that range of MPI ranges for Buriganga river 85.96-266.23 and Turag river 45.49-67.08. This index suggests that metal pollution in Buriganga river sediments are more than Turag river sediments. All selected locations along Turag river have almost uniform metal pollution index.

Table 4.7: Metal Pollution Index in rivers excluding Cadmium

Location	Buriganga	Location	Turag
B-1	43.27	T-1	26.90
B-2	34.34	T-2	26.70
B-3	29.36	T-3	26.55
B-4	76.24	T-4	26.23
B-5	95.72	T-5	22.95
		T-6	22.72
		T-7	22.51
		T-8	22.29
		T-9	24.81

Location	Buriganga	Location	Turag
		T-10	22.52
		T-11	26.51
		T-12	21.53
		T-13	21.00
		T-14	21.06
		T-15	22.58
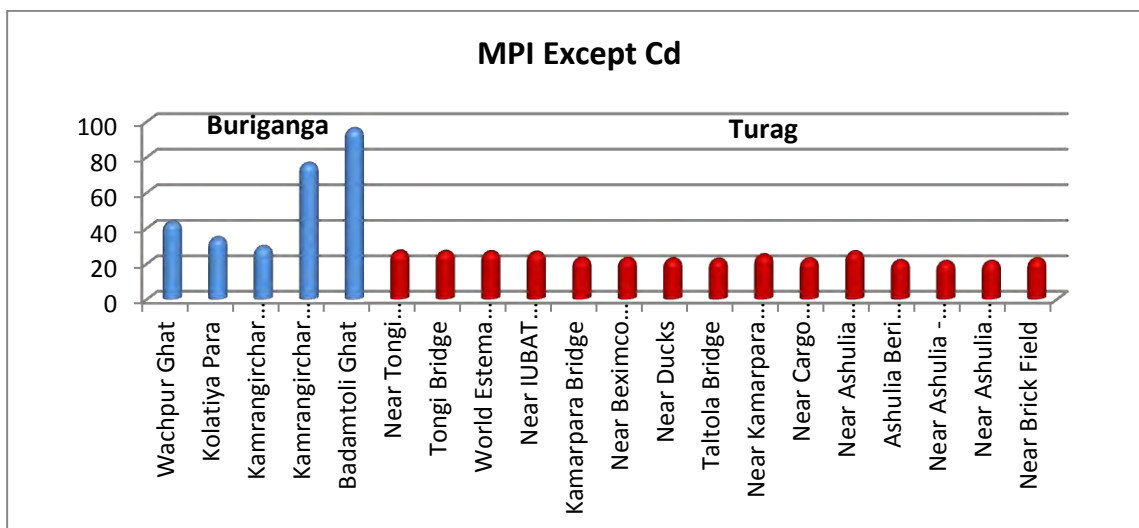
Fig. 4.7 Variation of Metal Pollution Index Except Cadmium Concentration along Turag and Buriganga river Sediments

4.4.2.2 Background enrichment indices calculation

Background enrichment indices compare the results for the contaminants with different baseline or background levels, available in literature that can be used for any study area. Sediment pollution according to toxic unit proposed by Pederson *et al.* (1998) has been calculated in this study.

a) Sediment pollution according to toxic unit

Wisconsin Consensus Based PEL has been used for toxic unit calculation.

From the toxic unit values, Table 4.8 shows that the Buriganga River is comparatively more polluted than the Turag River.

Table 4.8 Toxic Unit at different sampling location

Location	Buriganga	Location	Turag
B-1	3.33	T-1	1.42
B-2	2.33	T-2	1.40
B-3	2.02	T-3	1.37
B-4	5.56	T-4	1.43
B-5	6.85	T-5	1.22
		T-6	1.18

Location	Buriganga	Location	Turag
		T-7	1.17
		T-8	1.14
		T-9	1.31
		T-10	1.27
		T-11	1.57
		T-12	1.15
		T-13	1.06
		T-14	1.08
		T-15	1.15

Variation of Sediment pollution according to Toxic unit at different sampling location along Buriganga and Turag river is shown in Appendix A.

4.4.2.3 Ecological risk indices calculation

Ecological risk assessment is defined as a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors. In this study potential ecological risk index proposed by Lars Hakanson (1980), contamination factor and degree of contamination proposed by Tomlinson *et al.* (1980), pollution load index by Wilson and Jeffrey (1987) and mean sediment quality guideline quotient by MacDonald *et al.* (1998) was calculated.

a) Potential ecological risk index

A potential ecological risk assessment was conducted based on the analyzing results of the heavy metal (Pb, Cu, Cr, Cd, and Zn) contents in the sediments of Buriganga and Turag river using the index number techniques of single factor and Hakanson method for the quality status of the sediments. As the method is based on the hypothesis that a sediment ecological risk index for toxic substances in limnic systems. As the Turag and the Buriganga river behave like a lake during dry season, so this index is appropriate for those polluted rivers. Ecological risk index of Buriganga and Turag river is shown in Table 4.9 and 4.10 respectively.

From Table 4.9 it is shown that cadmium (Cd) has the largest pollution index and is the main pollution factor among the metals in case of Buriganga river. The ecological risk sequence of the metals is Cd > Cu > Pb > Zn > Cr. The index range of potential ecological risk was from 89.0 to 331.0, and the average index of potential ecological risk factors (RI) was 177.756. Buriganga river has a low to appreciable potential ecological risk. Cd is the most important one and its risk factor is high in B-4 and B-5. The results indicate that the range of Cd pollution in the Buriganga river is middle to high.

Table 4.9 Ecological risk index for Buriganga river

Location	Zn	Cd	Cr	Cu	Pb	RI	Grade Hakanson (1980)
	C_f^i x T_f^i	C_f^i x T_f^i	C_f^i x T_f^i	C_f^i x T_f^i	C_f^i x T_f^i		
B-1	2.56	60.00	2.68	16.83	20.58	102.64	Low
B-2	2.14	75.00	1.19	13.28	17.60	109.21	Low
B-3	1.90	60.00	1.09	10.94	15.08	89.00	Low
B-4	5.24	180.00	2.59	48.97	20.15	256.95	Appreciable
B-5	7.63	240.00	2.88	54.06	26.40	330.98	Appreciable

From Table 4.10, it can be seen that the order of potential ecological risk factor of heavy metals in sediments of the Turag river is Cd > Cu > Pb > Zn > Cr; Cd is the most important one and its risk factor is up to the appreciable grade. The results indicate that the range of Cd pollution in the Turag River is low to appreciable. Other heavy metals (Zn, Cr, Cu and Cu) have low potential ecological risk. The index range of potential ecological risk is from 17.88 to 138.02, and the average index of potential ecological risk factors (RI) is 60.04. Turag river has a low to moderate potential ecological risk due to heavy metal contamination.

Table 4.10 Ecological risk index for Turag river

Location	Pb	Cd	Cr	Cu	Zn	RI	Grade Hakanson (1980)
	C_f^i x T_f^i	C_f^i x T_f^i	C_f^i x T_f^i	C_f^i x T_f^i	C_f^i x T_f^i		
T-1	9.1	15	0.74	9.35	1.39	35.58	Low
T-2	9.1	15	0.74	9.35	1.39	35.58	Low
T-3	9	0	0.72	9.15	1.37	20.24	Low
T-4	8.85	60	0.72	9.05	1.33	79.95	Low
T-5	8.75	60	0.7	7.25	0.88	77.58	Low
T-6	8.6	45	0.7	7.2	0.87	62.37	Low
T-7	8.5	45	0.68	7.15	0.85	62.18	Low
T-8	8.35	30	0.68	7.05	0.85	46.93	Low
T-9	8.30	30	0.66	7.15	1.47	47.58	Low
T-10	8.10	120	0.66	7.25	0.93	136.94	Appreciable
T-11	8.0	60	1.54	7.15	0.91	77.6	Low
T-12	7.80	75	0.66	7.00	0.78	91.24	Low
T-13	7.60	30	0.64	7.00	0.73	45.97	Low
T-14	7.05	30	0.66	7.75	0.72	46.18	Low
T-15	8.60	15	0.60	7.70	0.92	32.82	Low

Variation of Ecological risk index (RI) at different sampling location along the Buriganga and the Turag river is shown in Appendix A.

b) Pollution Load Index

Pollution load index according to Wilson and Jeffrey (1987) was calculated in this study for Buriganga and Turag river sediments. Pollution load index value of zero indicates

highly polluted while PLI value of 10 indicates unpolluted sediments. Values within zero to 10 are for moderately polluted sediments.

Pollution load index at different locations of Buriganga river is shown in Table 4.11. For Buriganga river B-4 and B-5 are locations of highly polluted sediments and B-1, B-2 and B-3 are nearly highly polluted sediments. Metals contributing in pollution of sediments are arranged in the order as Zn>Cu>Cr>Pb>Cd.

Table 4.11 Pollution load index for Buriganga river

Location	Pollution load index of single metal					Combined PLI by Wilson and Jeffrey (1987)	
	Pb	Cd	Cr	Cu	Zn		
B-1	1.59	12.59	0.02	0.05	0.00	0.12	Polluted
B-2	2.14	10.00	0.66	0.17	0.01	0.43	Polluted
B-3	2.75	12.59	0.87	0.36	0.02	0.70	Polluted
B-4	1.66	2.00	0.02	0.00	0.00	0.00	Heavily Polluted
B-5	0.87	0.79	0.01	0.00	0.00	0.00	Heavily Polluted

Pollution load index at different locations of Turag river is shown in Table 4.12. For Turag river, all locations are moderately polluted as per pollution load index proposed by Wilson and Jeffrey (1987).

Table 4.12 Pollution load index for Turag river

Sample Location	Pollution load index of single metal					Combined PLI by Wilson and Jeffrey (1987)	
	Pb	Cd	Cr	Cu	Zn		
T-1	5.09	25.11	2.05	0.60	0.10	1.74	Polluted
T-2	5.10	25.11	2.09	0.61	0.10	1.75	Polluted
T-3	5.14	31.62	2.10	0.65	0.10	1.85	Polluted
T-4	5.20	12.60	2.15	0.66	0.13	1.65	Polluted
T-5	5.27	12.60	2.20	1.20	0.68	2.60	Polluted
T-6	5.34	15.85	2.26	1.22	0.70	2.77	Polluted
T-7	5.40	15.85	2.32	1.22	0.74	2.82	Polluted
T-8	5.50	19.95	2.38	1.26	0.75	3.00	Polluted
T-9	0.741	19.95	2.44	1.24	0.08	1.29	Polluted
T-10	0.751	5.01	2.51	1.20	0.55	1.44	Polluted
T-11	0.755	12.60	0.27	1.22	0.60	1.14	Polluted
T-12	0.763	10.00	2.51	1.26	0.96	1.87	Polluted
T-13	0.773	19.95	2.57	1.28	1.16	2.26	Polluted
T-14	0.796	19.95	2.51	1.02	1.20	2.17	Polluted
T-15	0.728	25.11	2.85	1.04	0.56	1.97	Polluted

Fig. 4.8 shows that, Pollution load index at different sampling location in Turag and Buriganga river. For Buriganga river B-4 and B-5 are locations of highly polluted

sediments and B-1, B-2 and B-3 are nearly highly polluted sediments. All locations of Turag are moderately polluted as per pollution load index.
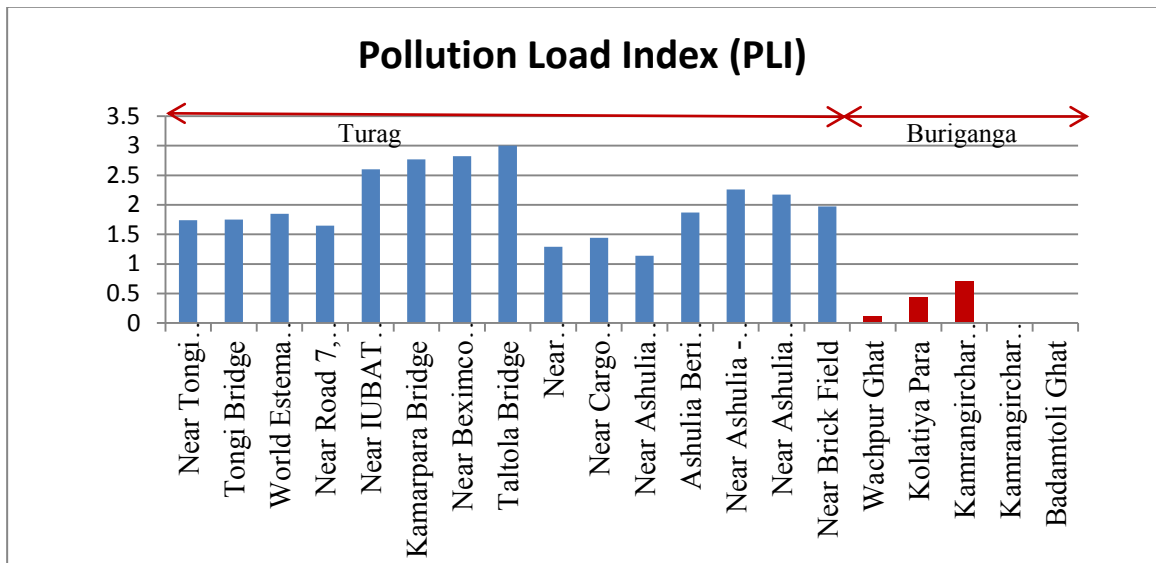
Fig. 4.8 Pollution load index by Wilson and Jeffrey (1987) at different sampling location in Turag and Buriganga river.

c) Mean sediment quality guideline quotient (SQG-Q)

In this study Wisconsin consensus based probable effect level is used for SQG-Q calculation. Sediment locations are then scored according to their impact level. SQG-Q ≤0.1: unimpacted and lowest potential for observing adverse biological effects; 0.1<SQG-Q<1: moderate impact potential for observing adverse biological effects; SQG-Q≥1: highly impacted potential for observing adverse biological effects. Mean sediment quality guideline quotient at five locations along Buriganga river is shown in Table 4.13. SQG-Q at location B-1, B-2, B-3, B-4 and B-5 are 0.67, 0.47, 0.40, 1.11 and 1.37, respectively. B-1, B-2 and B-3 locations are moderately impacted for observing adverse biological effects whereas location B-4 and B-5 are highly impacted for observing adverse biological effects.

Table 4.13 SQG-Q in Buriganga river

Location	PEL-Q					SQG-Q	Sediment quality by Long and MacDonald (1998)
	Pb	Cd	Cr	Cu	Zn		
B-1	0.63	0.08	1.18	0.72	0.72	0.67	Moderately Impacted
B-2	0.54	0.10	0.53	0.57	0.60	0.47	Moderately Impacted
B-3	0.46	0.08	0.48	0.47	0.53	0.40	Moderately Impacted
B-4	0.62	0.24	1.14	2.09	1.47	1.11	Highly Impacted
B-5	0.81	0.32	1.27	2.31	2.14	1.37	Highly Impacted

Mean sediment quality guideline quotient at five locations along Turag river is shown in Table 4.14. SQG-Q at all location ranges from 0.22 - 0.30. All locations along Turag river are moderately impacted for observing adverse biological effects.

Table 4.14 SQG-Q in Turag river

Sample Location	PEL-Q					SQG-Q	Sediment quality by Long and MacDonald (1998)
	Pb	Cd	Cr	Cu	Zn		
T-1	0.28	0.02	0.24	0.55	0.39	0.29	Moderately Impacted
T-2	0.28	0.02	0.23	0.54	0.386	0.29	Moderately Impacted
T-3	0.27	0	0.236	0.53	0.38	0.28	Moderately Impacted
T-4	0.27	0.08	0.23	0.53	0.37	0.29	Moderately Impacted
T-5	0.27	0.08	0.23	0.42	0.25	0.25	Moderately Impacted
T-6	0.26	0.06	0.226	0.42	0.24	0.25	Moderately Impacted
T-7	0.26	0.06	0.223	0.418	0.24	0.24	Moderately Impacted
T-8	0.26	0.04	0.22	0.413	0.24	0.23	Moderately Impacted
T-9	0.256	0.04	0.216	0.416	0.42	0.27	Moderately Impacted
T-10	0.25	0.16	0.213	0.42	0.26	0.26	Moderately Impacted
T-11	0.246	0.08	0.503	0.418	0.26	0.30	Moderately Impacted
T-12	0.24	0.10	0.213	0.414	0.22	0.24	Moderately Impacted
T-13	0.23	0.04	0.21	0.41	0.21	0.22	Moderately Impacted
T-14	0.217	0.04	0.213	0.45	0.21	0.22	Moderately Impacted
T-15	0.26	0.02	0.19	0.45	0.26	0.24	Moderately Impacted

The spatial variation of sediment quality guideline quotient along Buriganga and Turag river are shown in Fig. 4.9. As per SQG-Q, among the rivers, Buriganga river are the most polluted by heavy metals as sediments are moderately to highly impacted and Turag river sediments are moderately impacted to adverse biological effects.
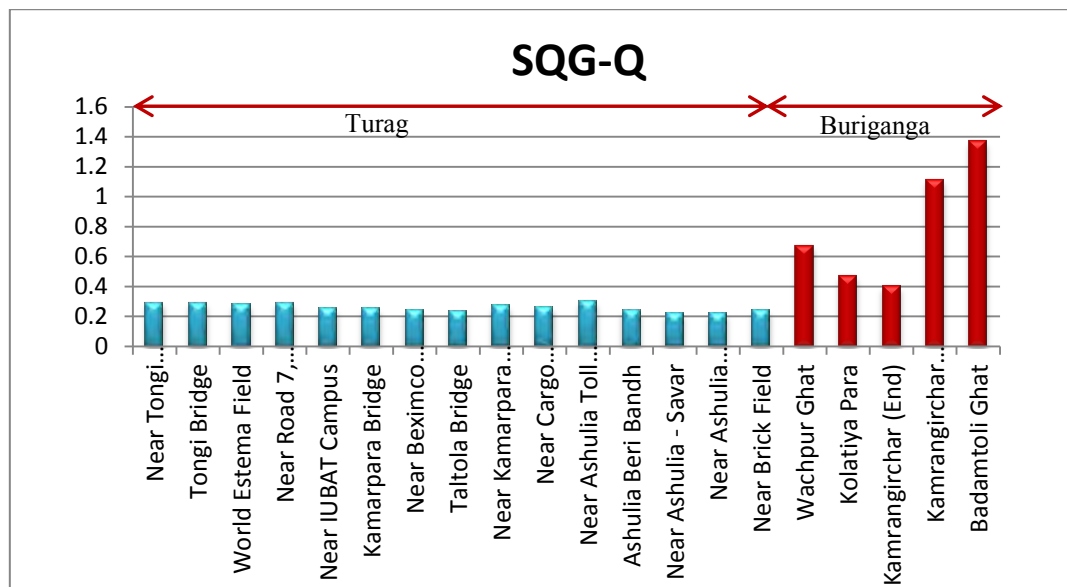
Fig. 4.9 Spatial variation of sediment quality guideline quotient along Turag and Buriganga river

Among the two rivers, SQG-Q of all location of Turag river is low to moderate as metals concentrations are low to moderate. SQG-Q in Kamrangirchar (North) and Badamtoli Ghat of Buriganga river is exceptionally high as that metals concentrations are high.

4.4.3 Data Analysis by Statistical Methods

During the study, exploratory data analysis techniques were employed for obtaining relevant information about the data set. The main purpose of these techniques is to reduce the data set and obtain possible relationships between the variables (concentration of the metals) of the samples collected. The one exploratory data processing techniques used in this work are:

Principal Component Analysis (PCA)

The SPSS software (version 12.0) has been used to conduct the statistical analysis. The large dataset obtained is subjected to the PCA to evaluate information about the similarities and dissimilarities present among the different sampling sites to ascertain the influence of the pollution sources in the Buriganga and the Turag river.

4.4.3.1 Pearson's correlation of heavy metals in the sediment

The correlation between two variables reflects the degree to which the variables are related. It is widely used in the sciences as a measure of the strength of linear dependence between two variables. Pearson's correlation coefficient between two variables is defined as the covariance of the two variables divided by the product of their standard deviations. The correlation coefficient ranges from -1 to 1. A value of 1 implies that a linear equation describes the relationship between X and Y perfectly, with all data points lying on a line for which Y increases as X increases. A value of -1 implies that all data points lie on a line for which Y decreases as X increases. A value of zero implies that there is no linear correlation between the variables.

Pearson's correlation coefficient matrix among the selected heavy metals of Turag river sediments is presented in Table 4.15. Significant correlations between the contaminants of Cr and Zn (r=0.45), Pb and Cd (r=0.45), Pb and Cr (r=0.49) could indicate the same or similar source input.

Table 4.15: Correlation matrix between heavy metals in sediment samples from Turag river

	Pb	Cd	Cr	Cu	Zn
Pb	1				
Cd	0.45	1			.
Cr	0.49	0.26	1		
Cu	0.006	0.051	0.39	1	
Zn	0.000	0.17	0.45	0.000	1

Pearson's correlation coefficient matrix among the selected heavy metals from Buriganga river is presented in Table 4.16. Significant correlations between the contaminants of Cd and Zn (r=0.99), Cd and Cu (r=0.98), Zn and Cu (r=0.97), Pb and Zn (r=0.89), Pb and Cr (r=0.85), Cd and Pb (r=0.82), Pb and Cu (r=0.80), Cr and Cu (r=0.75) could indicate the same or similar source input.

Table 4.16: Correlation matrix between heavy metals in sediment samples from the Buriganga river

	Pb	Cd	Cr	Cu	Zn
Pb	1				
Cd	0.82	1			
Cr	0.85	0.66	1		
Cu	0.80	0.98	0.75	1	
Zn	0.89	0.99	0.74	0.97	1

4.4.3.2 Principal Component Analysis

The five variables (metal concentrations) of 15(fifteen) sampling locations for the Turag river and 05 (Five) sampling locations for the Buriganga river were used as the multivariate data sets. Each data set was submitted to PCA to visualize the presence of principal groupings. The first two principal components describe higher than 96% of the overall variance for Buriganga and 78% for Turag river.

PCA for Buriganga river

Principal Component Analysis (PCA) using Varimax normalized rotation was conducted for common source identification. The dimensionality of the metal contamination is reduced from 5 original variables to only 2 factors. These new variables, which accounted for 96.92% of the total variance, are built by means of a linear combination of the original variables and the eigen vectors. The principal components score plotting (Fig. 4.10) shows the parameter lines obtained from the factor loadings of the original

variables, which represent the contribution of these parameters to the samples. Component loadings of heavy metals of Buriganga river is shown in Table 4.17. The closer the two parameter lines lie together, the stronger is the mutual correlation. Factor 1, accounting for 87.9%, reflects Cd, Cu and Zn and factor 2, accounting for 9.05% indicates Pb and Cr contamination. Cu, Cd and Zn lines indicate a very strong correlation between them. There is a strong correlation between Pb and Cr.

Table 4.17 Rotated Component Matrix of heavy metals from Buriganga river

	Component	
	1	2
Pb	0.585	0.759
Cd	0.931	0.364
Cr	0.354	0.918
Cu	0.874	0.449
Zn	0.872	0.483
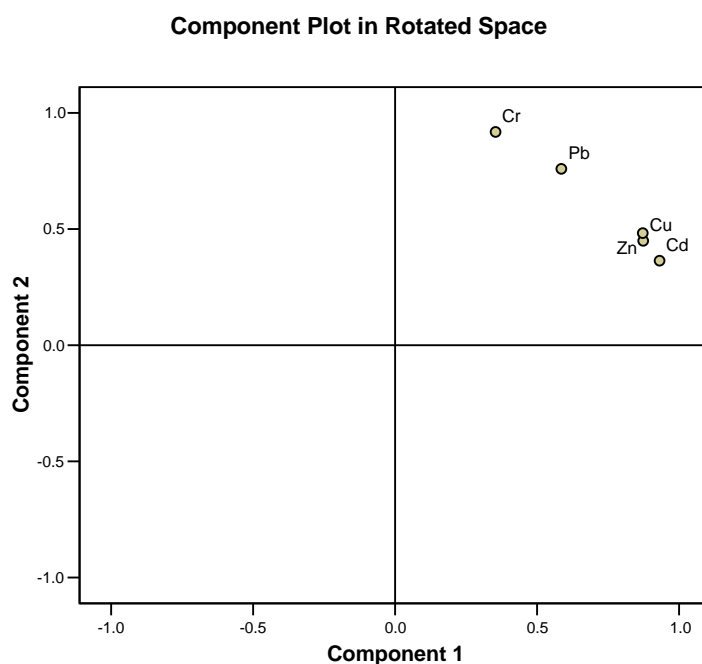
Fig. 4.10 Principal component plot in a rotated space for heavy metals of Buriganga river

PCA for Turag river

Principal component analysis (PCA) using Varimax normalized rotation was conducted for common source identification. The dimensionality of the metal contamination was reduced from 5 original variables to only 2 factors. These new variables, which accounted for 78.7% of the total variance, are built by means of a linear combination of the original variables and the eigen vectors. The principal components score plotting (Fig

4.11) shows the parameter lines obtained from the factor loadings of the original variables, which represent the contribution of these parameters to the samples. Component loadings of heavy metals of Turag river was shown in Table 4.18. The closer the two parameter lines lie together, the stronger is the mutual correlation. Factor 1, accounting for 43%, reflects Cr and Zn with high loadings and factor 2, accounting for 35.8% indicates mainly Pb and Cu contamination. Cu-Pb, Zn-Cr lines indicate a very strong correlation between them. The almost perpendicular relation between Cd with Cu and Pb indicates a very weak correlation between them.

Table 4.18 Rotated Component Matrix of heavy metals from Turag river

	Component	
	1	2
Pb	0.006	0.846
Cd	-0.775	-0.051
Cr	0.832	-0.448
Cu	0.058	0.882
Zn	0.924	0.301

Component Plot in Rotated Space
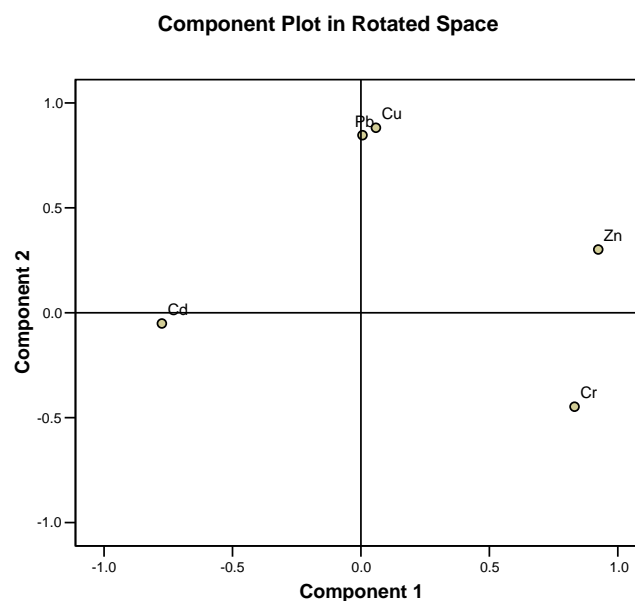
Fig. 4.11 Principal component plot in a rotated space for heavy metals of Turag river

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 General

This chapter provides the major conclusions of the present study and recommendations for future study.

5.2 Conclusions

1. a) The sediments of Buriganga river assessed in this study have been found to be highly polluted with respect to Cu, Pb and Zn; unpolluted to moderately polluted with respect to Cd and moderately polluted to highly polluted with respect to Cr on the basis of USEPA sediment quality guideline.

    b) The sediments of Turag river assessed in this study have been found to be moderately to highly polluted with respect to Cr, Cu, Zn; unpolluted with respect to Pb and Cd on the basis of USEPA sediment quality guideline.

2. Concentrations of heavy metal after performing TCLP test have been found to be well below the regulated level as per USEPA. That indicate regarding the readily toxicity pollution by heavy metal, Buriganga and Turag river sediment condition is not in severe state. However, the Buriganga and the Turag river have a low to appreciable potential ecological risk due to heavy metal contamination as per Ecological Risk Index.

3. The sediments of the Buriganga river are moderately to highly impacted; the sediments of the Turag river are moderately impacted due to adverse biological effects on the basis of Sediment Quality Guideline Quotient (SQG-Q).

4. According to Pollution Load Index, sediments of Kamrangirchar (North) and Badamtoli Ghat of the Buriganga river are highly polluted and Wachpur, Kolatiya Para and Kamrangirchar (End) are nearly highly polluted and sediments of all locations of the Turag river are moderately polluted.

5. a) Cd-Cu-Zn; Pb-Cr may have same or similar source input in the sediments of Buriganga river and Cr-Zn; Pb-Cu may have same or similar source input in

the sediments of Turag river on the basis of Principal Component Analysis (PCA).

b) Cr-Zn, Pb-Cu, Zn-Cu are significantly correlated (r= 0.34-0.71) in the sediments of Turag river; Cd-Zn, Cd-Cu, Zn-Cu, Pb-Zn, Pb-Cr, Cd-Pb, Pb-Cu and Cr-Cu are significantly correlated (r= 0.75-0.99) in the sediments of Buriganga river on the basis of Pearson's correlation. This indicates that those contaminants may have same or similar source input.

5.2 Recommendations for the further studies

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

2. Assessment of heavy metal contamination in water samples can be carried out and correlation of heavy metal contamination between sediment and water samples can be prepared.

3. Other rivers including major Khals around Dhaka city may be considered for further analysis.

4. GIS and Remote Sensing based maps on sediment contamination can be prepared. Sediment contamination can be shown for aggregation, data transmission and visualization using GIS and Remote Sensing, including the full GIS capabilities of overlaying data, DBMS (Database Management Systems) and modeling. These tools would be helpful for decision making processes and management involving natural resources.

5. Sediments extraction of heavy metals may be carried out to assess the enrichment of metal concentration due to industrial discharge and solid waste disposal.

6. It has been suggested by many scholars, authors and researchers that pH, salinity, temperature etc. all affect uptake and retention of metals in the sediments. This aspect should be investigated further to fully comprehend metals in this environment of Turag river and its vicinity.

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APPENDIX - A

Table A1: Sieve analysis result of Sediment Samples from the Turag River

Sieve size (ASTM)	T- 1 % retains (gms)	T- 2 % retains (gms)	T- 3 % retains (gms)	T- 4 % retains (gms)	T- 5 % retains (gms)	T- 6 % retains (gms)	T- 7 % retains (gms)	T- 8 % retains (gms)	T- 9 % retains (gms)	T- 10 % retains (gms)	T- 11 % retains (gms)	T- 12 % retains (gms)	T- 13 % retains (gms)	T- 14 % retains (gms)	T- 15 % retains (gms)	Average
1/4"	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
No. 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
No.8	4.12	7.33	4.89	0.70	2.52	4.36	4.50	4.78	7.23	7.44	6.55	6.57	5.56	1.25	2.89	4.72
No. 16	4.31	12.2	6.82	7.61	6.59	4.55	10.23	6.75	9.23	9.12	7.24	11.85	7.89	8.99	9.52	8.19
No. 30	6.83	11.43	7.07	12.48	8.77	6.42	11.26	7.13	7.57	8.36	8.54	7.07	9.93	11.11	13.13	9.14
No. 200	53.32	40.3	50.01	44.37	49.51	40.26	45.23	50.21	41.24	45.07	44.05	41.01	38.06	43.22	50.32	45.08
Pan	30.72	29.42	30.58	33.64	31.86	44.41	28.78	31.13	34.73	30.01	33.62	33.50	38.56	35.43	24.14	32.70
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Coarse Particle	8.43	19.53	11.71	8.31	9.11	8.91	14.73	11.53	16.46	16.56	13.79	18.42	13.45	10.24	12.41	12.91
Medium Particle	60.85	51.05	57.71	58.05	59.03	46.68	56.49	57.34	48.81	53.43	52.59	48.08	47.99	54.33	63.45	54.39
Fine Particle	30.72	29.42	30.58	33.64	31.86	44.41	28.78	31.13	34.73	30.01	33.62	33.50	38.56	35.43	24.14	32.70

Table A2: Sieve analysis result of sediment sample from Buriganga river

| | B1 | B2 | B3 | B4 | B5 | |
| | Wachpur Ghat | Kolatiya Para | Kamran girchar (End) | Kamran girchar (North) | Badam toli Ghat | |
Sieve size (ASTM)	% retains (gms)	% retains (gms)	% retains (gms)	% retains (gms)	% retains (gms)	Average
1/4"	0.75	6	1.17	0.47	0	0.69
No. 4	1.38	1.38	1.44	0.76	0.37	1.066
No.8	9.07	6.96	7.02	9.23	4.96	7.448
No. 16	15.14	10.26	11.59	16.89	11.36	13.048
No. 30	10.35	6.82	8.45	14.03	10.6	10.05
No. 40	4.06	4.12	3.77	7.18	4.51	4.728
No. 50	4.95	5.25	5.41	7.03	5.61	5.65
No. 100	17.5	22.59	17.56	13.64	17.52	17.762
No. 200	13.95	17.84	15.14	9.82	14.33	14.216
Pan	22.86	23.71	28.44	20.95	30.74	25.34
Total	100	100	100	100	100	100
Coarse Particle	2.13	2.44	2.61	1.23	0.37	1.756
Medium Particle	5.02	73.84	68.94	77.82	68.89	72.902
Fine Particle	22.86	23.71	28.44	20.95	30.74	25.34

Table A3 : Correlation matrix between heavy metals in TCLP test from the Turag River

	Pb	Cd	Cr	Cu	Zn
Pb	1				
Cd	0.93	1			
Cr	0.24	0.05	1		
Cu	0.32	-0.04	0.41	1	
Zn	0.57	0.49	-0.11	0.39	1

Table A4: Correlation matrix between heavy metals in TCLP test from Buriganga River

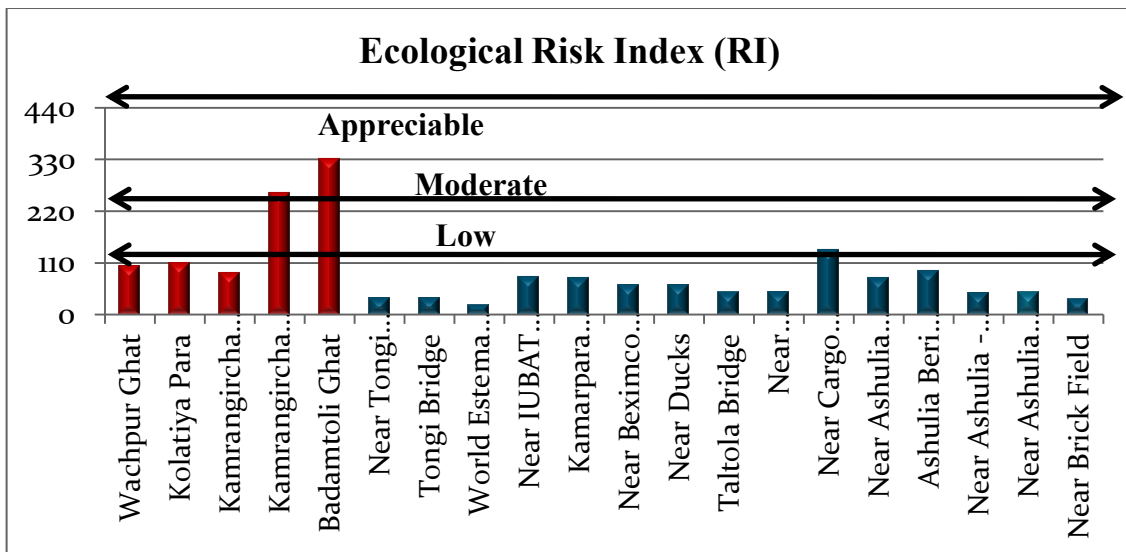|	Pb	Cd	Cr	Cu	Zn
Pb	1				
Cd	0.14	1			
Cr	-0.32	0.60	1		
Cu	-0.77	0.43	0.82	1	
Zn	0.17	0.97	0.54	0.40	1

Fig A1 : Variation of Ecological risk index (RI) at different sampling location along Buriganga and Turag river.
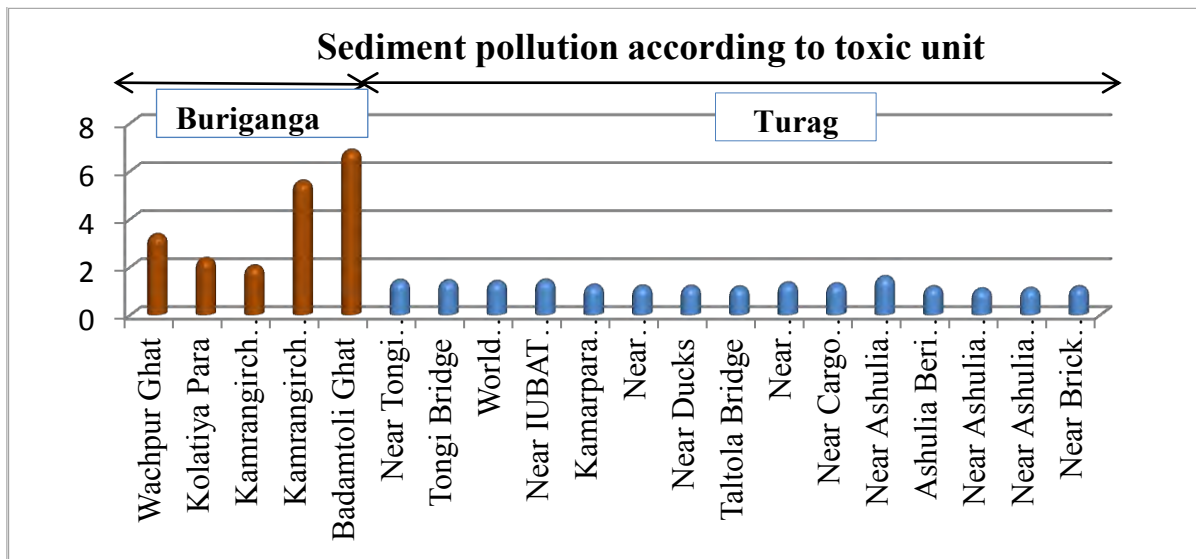
Fig A2 : Variation of Sediment pollution according to Toxic unit at different sampling location along Buriganga and Turag river.

Turag River

Factor Analysis

Table B1: Correlation Matrix among heavy metals of sediments of the Turag river

		Pb	**Cd**	**Cr**	**Cu**	**Zn**
Correlation	Pb	1.000	0.006	-0.316	0.504	0.268
	Cd	0.006	1.000	-0.417	-0.067	-0.584
	Cr	-0.316	-0.417	1.000	-0.361	0.708
	Cu	0.504	-0.067	-0.361	1.000	0.340
	Zn	0.268	-0.584	0.708	0.340	1.000

Table B2: Communalities of heavy metals of sediments of the Turag river

	Initial	Extraction
Pb	1.000	0.716
Cd	1.000	0.603
Cr	1.000	0.892
Cu	1.000	0.781
Zn	1.000	0.944

Extraction Method: Principal Component Analysis.

Table B3: Total Variance Explained of heavy metals of sediments of the Turag river

Component	Initial Eigenvalues(a)			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.149	42.979	42.979	2.149	42.979	42.979	2.149	42.979	42.979
2	1.787	35.746	78.725	1.787	35.746	78.725	1.787	35.746	78.725
3	0.585	11.692	90.417						
4	0.479	9.583	100.00						
5	0.000	0.000	100.00						

Extraction Method: Principal Component Analysis.

Table B4: Component Matrix of heavy metals of sediments of the Turag river

	Component	
	1	2
Pb	0.012	0.846
Cd	-0.775	-0.046
Cr	0.829	-0.453
Cu	0.064	0.881
Zn	0.926	0.295

Extraction Method: Principal Component Analysis.
2 components extracted

Table B5: Reproduced Correlations of heavy metals of sediments of the Turag river

		Pb	Cd	Cr	Cu	Zn
Reproduced	Pb	0.716(b)	-0.048	-0.374	0.746	0.261
Correlation	Cd	-0.048	0.603(b)	-0.621	-0.090	-0.731
	Cr	0.374	-0.621	0.892(b)	-0.346	0.633
	Cu	0.746	-0.090	-0.346	0.781(b)	0.320
	Zn	0.261	-0.731	0.633	0.320	0.944(b)
Residual (a)	Pb		0.055	0.058	-0.242	0.007
	Cd	0.055		0.204	0.024	0.148
	Cr	0.058	0.204		-0.014	0.074
	Cu	-0.242	0.024	-0.014		0.021
	Zn	0.007	0.148	-0.074	0.021	

Extraction Method: Principal Component Analysis.

a.   Residual are computed between observed and reproduced correlations. There are 6 (60.0%) non redundant residuals with absolute valves greater than 0.05

b.   Reproduced communalities

Table B6: Component Matrix of heavy metals of sediments of the Turag river

	Component	
	1	2
Pb	0.006	0.846
Cd	-0.775	-0.051
Cr	0.832	-0.448
Cu	0.058	0.882
Zn	0.924	0.301

Extraction Method: Principal Component Analysis.

Rotation Method : Varimax with Kaiser Normalization.

Rotation converged in 3 iterations

Buriganga River

Factor Analysis

Table B7: Correlation Matrix among heavy metals of sediments of the Buriganga river

		Pb	Cd	Cr	Cu	Zn
Correlation	Pb	1.000	0.824	0.853	0.802	0.892
	Cd	0.824	1.000	0.662	0.976	0.988
	Cr	0.853	0.662	1.000	0.754	0.742
	Cu	0.802	0.976	0.754	1.000	0.966
	Zn	0.892	0.988	0.742	0.966	1.000

Table B8: Communalities of heavy metals of sediments of the Buriganga river

	Initial	Extraction
Pb	1.000	0.919
Cd	1.000	1.000
Cr	1.000	0.968
Cu	1.000	0.965
Zn	1.000	0.993

Extraction Method: Principal Component Analysis.

Table B9: Total Variance Explained of heavy metals of sediments of the Buriganga river

Component	Initial Eigenvalues(a)			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.393	87.866	87.866	4.393	87.866	87.866	2.859	57.190	57.190
2	0.452	9.049	96.915	0.425	9.049	96.915	1.986	39.725	96.915
3	0.149	2.978	99.893						
4	0.005	0.107	100.00						
5	0.000	0.000	100.000						

Extraction Method: Principal Component Analysis.

Table B10: Component Matrix of heavy metals of sediments of the Buriganga river

	Component	
	1	2
Pb	0.931	0.228
Cd	0.955	-0.297
Cr	0.849	0.497
Cu	0.963	-0.194
Zn	0.983	-0.167

Extraction Method: Principal Component Analysis.
2 components extracted.

Table B11: Reproduced Correlations of heavy metals of sediments of the Buriganga river

		Pb	Cd	Cr	Cu	Zn
Reproduced	Pb	0.919(b)	0.822	0.904	0.853	0.877
Correlation	Cd	0.822	1.000(b)	0.644	0.977	0.988
	Cr	0.904	0.644	0.968(b)	0.722	0.752
	Cu	0.853	0.977	0.722	0.979(b)	0.979
	Zn	0.877	0.988	0.752	0.979	0.993(b)
Residual (a)	Pb		0.002	-0.051	-0.051	0.015
	Cd	0.002		-0.001	-0.001	0.000
	Cr	-0.051	-0.001		0.032	-0.001
	Cu	-0.051	-0.001	0.032		-0.013
	Zn	0.015	0.000	-0.010	-0.013	

Extraction Method: Principal Component Analysis.
c. Residual are computed between observed and reproduced correlations. There are 2 (20.0%) non redundant residuals   with absolute valves greater than 0.05
d. Reproduced communalities

Table B12: Rotated Component Matrix of heavy metals of sediments of the Buriganga river

	Component	
	1	2
Pb	0.585	0.759
Cd	0.931	0.364
Cr	0.354	0.918
Cu	0.874	0.449
Zn	0.872	0.483

Extraction Method: Principal Component Analysis.
Rotation Method : Varimax with Kaiser Normalization.
Rotation converged in 3 iterations