ASSESSMENT OF HEAVY METALS IN SEDIMENT, WATER, AND FISH OF THE TURAG RIVER, DHAKA CITY, BANGLADESH

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CERTIFICATE

This is to certify that the thesis entitled, "ASSESSMENT OF HEAVY METALS IN SEDIMENT, WATER, AND FISH OF THE TURAG RIVER, DHAKA CITY, BANGLADESH" submitted to the Department of Agricultural Chemistry, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in AGRICULTURAL CHEMISTRY, embodies the result of a piece of bona fide research work carried out by ***Abdullah Al Noman*** *Registration No.* ***19-10390*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: December, 2021 **Prof. Dr. Md. Tazul Islam Chowdhury**

Place: Dhaka, Bangladesh **Supervisor**

Dedicated

To

My loved Parents,

late

Grandmother and Grandfather

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LIST OF ACRONYMS AND ABBREVIATIONS

Abbreviation	Full Meaning	Abbreviation	Full Meaning
AAS	Atomic Absorption Spectrophotometer	g	Gram
BDL	Below Detectable Level	HCl	Hydrochloric Acid
Cr	Calcium	ppm	Parts per million
Cd	Cadmium	HM	Heavy Metals
Fe	Iron	HNO_3	Nitric Acid
Cu	Copper	Hg	Mercury
Cm	Centimeter		
cm^2	Square centimeter	*i.e.*	That is
L	Litter	Kg	Kilogram
et al.	And others/Associates	ADD	Average daily dose
Etc.	And the other things	THQ	Targeted hazard quotient
EU	European Union	HI	Hazard Index
Fe	Iron	M.S.	Master of Science
FAO	Food and Agriculture Organization	mm	Millimeter
RfD	Reference Doses	BDL	Below Detection Limit

LIST OF SYMBOLS

SYMBOLS	FULL MEANING
@	At the rate of
+	Plus
<	Less than
>	Greater than
°C	Degree Celsius
%	Percentage
&	And
/	Per

ABSTRACT

Metal pollutant has a harmful effect on biological systems and does not undergo biodegradation, therefore gets accumulated in the river bed, water, and into aquatic life. The present study intends to assess the level of contamination of sediments, water, and fish by heavy metals in the Turag River flowing through the Northern and Western sides of Dhaka City. To estimate the geochemical environment of the river, five trace elements, namely Cr, Cu, Cd, Pb, and Fe, were extracted from the freshly deposited river bed sediments, water, and fish of Turag River using a Di-acid mixer and analyzed at the Central Laboratory of the SAU using Atomic Absorption Spectrophotometer (Analytik Jena NovAA 400P). All the sediment and water samples were collected from eleven different locations and after preparation, samples were analyzed using standard procedure. Trace element contamination assessment reveals that the benthic sediment and water are contaminated at low to moderate levels in these areas, with a common trend of concentration of Fe>Cr>Cu>Pb>Cd for sediment, Fe>Cu>Cr>Pb>Cd for water, and fish. This indicates that the untreated and/or partially treated industrial and municipal wastewater discharges along the river bank might be the major sources of pollution. Results showed that metal concentration in sediment ranged between 0.11 to 3.81 mg/kg for Cd, 0.63 to 6.74 mg/kg for Pb, 43 to 201 mg/kg for Cr, 6.84 to 62.87 mg/kg for Cu, 1278 to 1831 mg/kg for Fe in the rainy season and 0.14-3.72 mg/kg for Cd, 0.34-12.85 mg/kg for Pb, 48-239 mg/kg for Cr, 22.7-49.62 mg/kg for Cu, and 1777-1885 mg/kg for Fe in the winter season. In water samples, the results also showed that metal concentrations ranged from 0.16-0.5 mg/kg for Cd, below the detection limit for Pb and Cu, 0.21-0.3 mg/kg for Cr, and 0.44-2.31 mg/kg for Fe respectively in the winter season and the metal concentrations also ranged from 0.4-3.61 for Fe, below the detection limit for Pb, Cr, Cu, and 0.04 mg/kg for Cd in one station among eleven in rai
ny season which is ignorable. In the case of fish, five species have only been found during the rainy season. There is no fish was found in the winter season due to higher pollution. The average results from these species are 0.55 mg/kg for Cd, 0.28 mg/kg for Pb, 0.65 mg/kg for Cr, 3.14 mg/kg, and 894.56 mg/kg for Fe. The highest contamination degree of the sediment was noticed at Location 1 (Amin Bazar Bridge, Gabtoli) and the lowest at Location 6 (near Dhaka Ashulia Highway), and the highest degree of water contamination was noticed at location 1, and the lowest contamination degree of water is noticed at location 6 in both rainy winter season. The contamination level varies systematically with the distance from the contamination source. However, it is anticipated that the sediment, water, and aquatic ecosystem may degrade in the near future due to increasing anthropogenic inputs in the river basin, hence proper management strategies are required to control the direct dumping of wastewater in the river.

CHAPTER I

INTRODUCTION

Nowadays environmental pollution is a great threat to human beings as well as to the animal kingdom over the world (Thakur and Mhatre, 2015). Water resources, being a prominent component of the environment, is getting polluted over the years. Contamination of the water environment with various pollutants has increased considerably in recent years in many parts of the world (Islam *et al.,* 2015a). Various heavy metal ions such as Zn, Cu, Cr, As, Ni, Cd, Pb, Hg, etc. are entered into the environment through various industrial processes. Those heavy metal ions are consistently present in small amounts in the environment but they are potentially toxic and can affect many species of plants and animals at water-soluble concentrations lower than 1 mg/ kg (Sattar, 1996). Municipal wastewaters usually have a high concentration of several heavy metals such as Pb, Ni, Cd, and Cr (Dhanakumar *et al.,* 2015, Larson *et al.,* 1975; Arora *et al.,* 1985).

The technological means to stop heavy metal contamination from these sources have not kept up with rapid industrialization and urbanization. Many ways trace metals might enter a river; they can come from the environment or through people. Mining, the disposal of toxic metal-containing effluents that have been partially or incompletely treated as well as metal chelates from various industries, and the indiscriminate use of pesticides and fertilizers containing toxic metals in agricultural fields are the main anthropogenic sources of heavy metal contamination (Afsar, 2003). Common heavy metals found in industrial waste include copper, lead, cadmium, chromium, and iron, all of which are harmful to aquatic life and humans in even minute concentrations. These pose risks because they build up in the food chain and constitute a health risk in drinking water sources. The Turag River is probably contaminated with numerous heavy metals because it constantly receives effluents from several industrial effluent sources. The suspended particles in river water are gradually absorbed by the heavy metals, which then settle swiftly and accumulate in the sediment bed. The pollutant stays longer in the aquatic environment due to sediment-water interaction, endangering the quality of the water greatly. Since the surface area available for heavy metal adsorption on soil determines (Cui, 2010).

Heavy metals (i.e., lead, cadmium, iron, chromium, copper, etc.) rank as major polluting chemicals in both developed and developing countries (Khalil *et al.,* 2015). Due to rapid industrialization and urbanization, the pollution load in rivers and open water has been at a rapid pace and large numbers of investigations have been conducted throughout the world, to assess the toxic concentrations in various river systems and their impact on aquatic biotopes. Human wastes and sewage and industrial effluents are discharged regularly into the river and other open water bodies (Ahmed *et al.,* 2012; Rashid *et al.,* 2012; Begum *et al.,* 2013; Islam *et al.,* 2015b).

One of the rivers with the most industrial surroundings is the River Turag, which flows through the city of Dhaka. Over the past ten years, a lot of industries have been established in and around the city of Dhaka, and this number is constantly growing.
Generally speaking, soils have a significant capacity to retain heavy metals. How efficiently added heavy metals are kept in the soil is typically closely correlated with the amount of organic matter present. These metals are very attracted to the organic component of soil materials because they can form chelates with ligands like carboxyl, phenolic, alcoholic, and carbonyl groups. Due to the synthesis of organic compounds with them, divalent metal ions may become mainly inaccessible to plants and cause leaching (Ahmad, 1998). Thus, it is necessary to evaluate and compare the degree of different heavy metals' adsorption on the organic component of the Turag River's bed sediments.

Environments such as the aquatic environment and ecological environment are continually under threat from pollution containing heavy metals and toxicants in water, sediments, and fish. These days, common issues include the dispersion of heavy metals and other contaminants in aquatic systems, as well as the sediment in rivers and fish. It may be harmful to human health, the environment, and the aquatic system. High concentrations of contaminants could build up in water bodies like rivers that are used for the disposal of solid waste and urban wastewater, as well as in sediment and fish. Studies on heavy metal contamination, detection, and removal from rivers, canals, and other waterways reveal that these places are more likely to experience pollution than rural or suburban areas in the coming years. One of the most populous cities in the world, Dhaka, contains the Turag River in its northern and western regions. Industrial and domestic sewage has been dumped into the river for a long time. As a result, it is probably significantly metal-contaminated. To determine how different home and industrial waste inputs affect the heavy metal contamination of this river's bed sediment, surface water, and fish, a comparative analysis of these contaminants has been done.

Sediments typically contain a variety of elements, including diverse mineral species and organic detritus. One of the main sinks for heavy metals released into the environment is represented by it (Gibbes, 1977). Sediment contamination can spread up the food chain, endangering marine species and perhaps having an impact on human health. Rivers, rainfall, and wind transport pollutants from industrial discharges, the burning of fossil fuels, and runoff from agricultural, urban, and suburban areas to coastal waterways, where they collect on the bottom. These contaminants are ingested by small organisms, and when they are consumed by larger organisms, they may travel up the food chain (bioaccumulation). Swimming and other recreational activities may be dangerous in areas with toxic sediments to defend.

Additionally, sediment-associated compounds can negatively impact species that live there (for example, by producing direct toxicity or changing the structure of the benthic invertebrate population) (Cui, 2010). As a result, information on chemical substance concentrations in sediment quality data is crucial for assessing the ambient environmental quality conditions in freshwater systems.

In Bangladesh, industrial pollution in the aquatic environment has caused heavy metal contamination, which is a serious concern. In the future, heavy metal toxicity will kill many people, yet our population is unaware of this fact. On the levels of heavy metals in water, fish, and soil in Bangladeshi Rivers, as well as the Turag River, there are relatively few published data available. Studies on the concentration of heavy metals in water and sediment have been conducted by Islam *et al.*, 2015; Rahman *et al.*, 2011; Das *et al.*, 2002; and Doe 2000. The concentration of heavy metals in fish and their impact on human health, however, have not yet been the subject of any in-depth research. It is urgently needed.

Therefore, the objectives of my research work are:

- To quantify the accumulation of heavy metals in some commercial fish species.
- To quantify the heavy metals in water and sediment of the Turag river system.
- To determine the risks of aquatic species using the information on their experimentally determined concentration data and reported toxicity values.
- To evaluate the association and identify possible sources of contamination, and assess the ecological and health risk for humans.

CHAPTER II
LITERATURE REVIEW

2.1 River Pollution around Dhaka City

With a population of over several million, Dhaka is one of the most congested cities in the world. This rapidly growing city is located on the northern bank of the river Buriganga and surrounded by other rivers, namely, the Turag to the west, the Tongi Canal to the north, and the Balu to the east. The rivers surrounding Dhaka are an advantage and essential for the mega city’s survival as they provide drainage systems, drinking water, different kinds of fish, and also waterways for traveling. However, being the capital of Bangladesh, one of the least developed countries in the world, the city has been developed haphazardly without considering its physical and social diminution. As a result, the environmental effects of the rapid population growth and the rise in polluting industrial, municipal, and other waste effluents are having severe adverse effects on the waterways near Dhaka. As a result, living things, including people who live near rivers, are becoming more and more at risk from the polluted river waters.

River water in the Dhaka area no longer meets the criteria for any safe or beneficial use because it has changed from its original form in terms of its physical, chemical, and microbiological makeup. The terrible taste, repulsive odors, unregulated development of aquatic weeds, the decline in the number of aquatic creatures, floatation of oil and grease, the color of the water, and other indications of contamination have become visible. In general, untreated industrial effluent discharge, urban wastewater, agrochemicals, sewage water, storm runoff, solid waste dumping, oil spillage, sedimentation, and encroachment all contribute to the pollution of the rivers that surround Dhaka. There has been significant industrialization in Dhaka over the past two decades, particularly in the textile, washing, and dyeing industries. However, out of all of them, tanning and dyeing factories are the biggest pollutants in waterways. Typically, waste from these sectors is connected to the sewerage system, which closely follows the city's rivers. All manner of solid, liquid, and chemical trash has been dumped into the waterways.

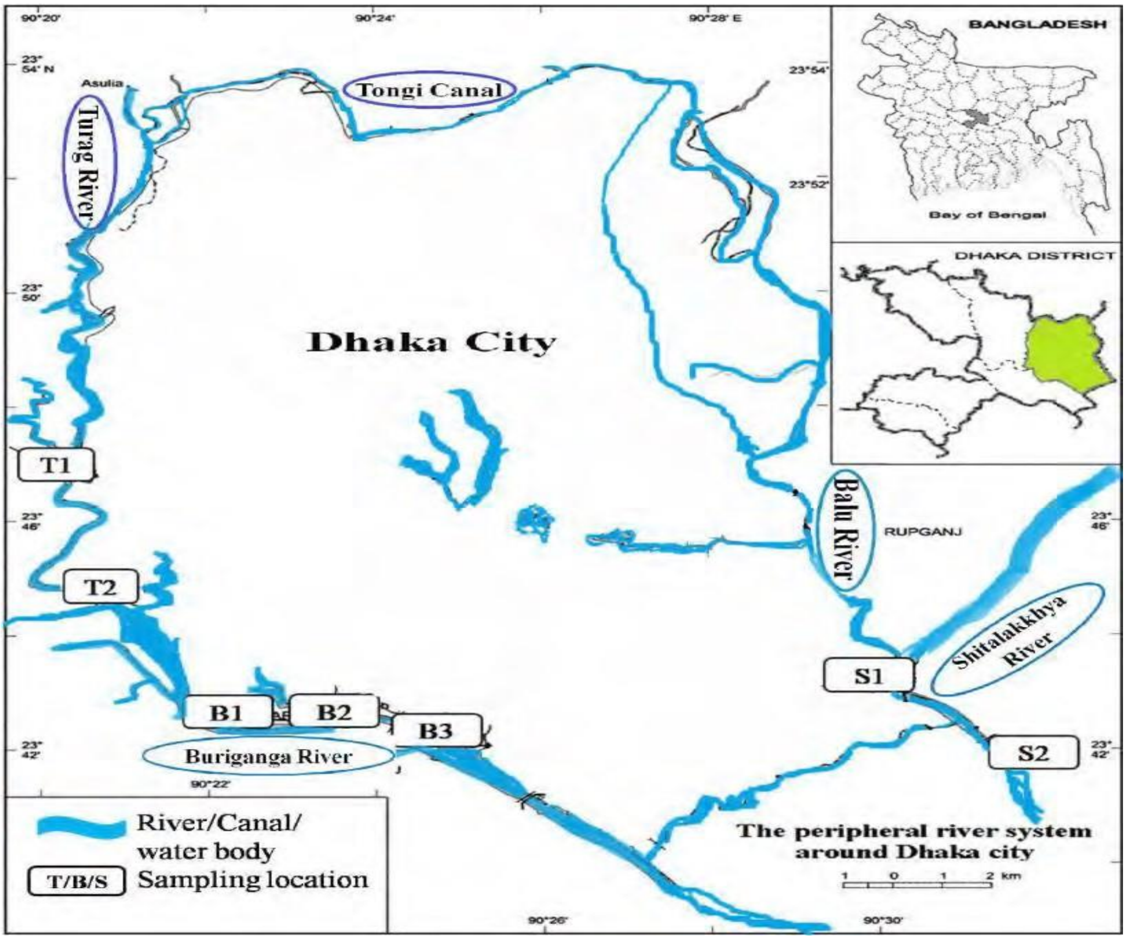

Figure 1: The peripheral river system around Dhaka city (http://en.wikipedia.org/wiki/List_of_rivers_of_Bangladesh)

The river system surrounding Dhaka City is seen in Figure1, and the contaminated water of the Buriganga, Turag, Dhaleshwari, Balu, and Narai flowing around the greater Dhaka city poses major hazards to the quality of life for the general people since it is unfit for human use. People who live close to rivers are compelled to use contaminated river water because they have no other choice. Some people drink the water despite not being aware of the health concerns. This contributes to the spread of skin and water-borne illnesses. Fish and other subaquatic species find it challenging to survive in rivers because of solid waste and various effluents that are put there. The biological oxygen demand (BOD) in the water increases when solid waste and effluents are discharged into rivers, causing an oxygen shortage for subaqueous life. The biodiversity in and around rivers is threatened as the dissolved oxygen (DO) content of the river water falls below the threshold of four milligrams per liter.

Government organizations have waged campaigns against pollutants over the years, but they have had limited effectiveness. The polluters persisted in contaminating the rivers during this time. People from all levels of the community should therefore be encouraged to participate in environmental protection to address these issues. A people-centric action plan would result from the energizing discussion of objectives and the creation of local solutions, for example, through workshops involving professionals and large numbers of people. The rivers near Dhaka would be better protected if individual, household, and community actions were taken to reduce resource consumption and trash production, clean up the urban environment, and launch information-sharing programs.

2.2 Pollution in Turag River

The Turag and other nearby rivers have gradually come under excessive and intolerable pressure due to the rapid and uncontrolled industrialization and urbanization of the Dhaka metropolis.

The pollution concentration appears to gradually diminish from the Buriganga Third Bridge to the upper stream and from Tongi Bridge to the downstream. This particular spatial pollution pattern is demonstrated by the water's color, smell, and the DoE's given statistics. Near the Mirpur Botanical Garden, the painting transitions from completely black to almost normal between the Buriganga Third Bridge and the Tongi Bridge (DOE, 1997).

The Hazaribagh tanneries, the Bashila Canal downstream, the Tongi Industrial Area at Tongi Bridge, and the Iztema Field area are all sources of a significant amount of untreated toxic liquid waste that is directly dumped into the river, which is the primary cause of the spatial pollution pattern in the Turag described above. In the rainy season, upstream flow and some tidal activity spread this extremely high pollutant concentration to other sections of the river (Ahmed, 2010). The lateral diffusion process causes the pollution concentration to drop as you get further away from the source. When the river's water level drops significantly during the dry season, the concentration of pollution correspondingly rises. The current state of the Turag river can be seen in the figure below.

Figure 2: Pollution condition in Turag River
(http://bangladeshchronicle.net/2016)

The field survey revealed that there are roughly 28 small garbage disposal outlets in the Turag River. About 20 of them are solid waste dumping areas (home, commercial, and industrial) along the embankment that discharges a significant volume of rubbish (both biodegradable and non-biodegradable) into the river. Four sluice gates dump a substantial amount of sewage waste from the DCC region into the river along the river's south-eastern bank (Ahmad, 2010). There are numerous non-point sources of contamination in the river. A wide agricultural tract, mainly paddy fields from Bagchotra, Savar to the Tongi Pourosava area, can be found along the river's northwestern side. Through overland flow caused by a significant rainstorm during the rainy season, the residue of chemical fertilizers used on cultivable land is also added to the river's pollution. The agricultural areas of Washpur and Shalmasi in Keraniganj, as well as Bashila and Katasur in Mohammadpur, have become so contaminated from excessive pollution spills during the rainy season that they can no longer support crop growth and are therefore unusable all year (Ahmad,2010). Of course, some of the areas are currently being used for other purposes, such as home developments and brickfield construction. These land uses eventually result in the unauthorized habitation of riverbanks and raise the level of pollution in the river.

Pollutants can occasionally make their way up the food chain, where they harm fish, animals, and even birds. At the beginning of the lean period, the concentration of pollutants increases suddenly as the river's water level drops significantly, but the rate at which pollutants are released into the river doesn't change. Few aquatic creatures can survive the extreme pollution during this time, and soon fish of many different species are discovered floating dead in the river water. These deceased fish slowly decay and significantly contribute to future river water contamination (The Daily Star, 8th January 2011).

2.3 Heavy Metals, Uses, and Sources

Metals with relatively high densities, atomic weights, or atomic numbers are typically referred to as heavy metals. Natural components of rocks, soils, sediments, and water include metals. However, in the 200 years since the start of industrialization, there have been enormous changes in the global budget of important chemicals at the earth's surface, defying the millions of years-old regulatory systems (Gibbes, 2009). The term "heavy metal" can indicate many things, both broadly and specifically. Some heavy metals are either relatively safe (such as ruthenium, silver, and indium) or essential nutrients (usually iron, cobalt, and zinc), but they can be harmful in higher concentrations or particular forms. Lead, mercury, and cadmium are among other hazardous heavy metals. Mining, tailings, industrial wastes, agricultural runoff, occupational exposure, paints, and treated wood are some potential sources of heavy metal poisoning.

Heavy metal physical and chemical characterizations should be used with caution because the specific metals involved are not always well-defined. Heavy metals tend to be less reactive than lighter metals and contain significantly less soluble sulfides and hydroxides, in addition to being comparatively dense. A few heavy metals, like zinc, mercury, and lead, have characteristics of lighter metals, and lighter metals, like beryllium, scandium, and titanium, have characteristics of heavier metals, even though it is generally easy to tell a heavy metal like tungsten from a lighter metal like sodium.

According to one definition, heavy metals are a class of elements on the periodic table of the elements between copper and lead, with atomic weights ranging from 63.55 to 200.59 and specific gravities higher than 4.0. Some heavy metals are necessary for trace amounts for living things, but too much of a good thing can be harmful. The periodic chart places vanadium, chromium, manganese, iron, and nickel above copper, and these elements are all very significant because of how they affect living things. They can cause major sickness in mammals when they build up over time in their bodies. According to another definition, a "heavy metal" is any metal that is heavier than the rare earth metals at the bottom of the periodic table. All of the more well-known elements, except bismuth and gold, are extremely poisonous and none of them are necessary for biological processes (Hogan, 2010).

Many locations release trace metals, particularly those classified as "heavy" from industrial and mining activities, into estuaries and coastal waterways. Any metallic chemical element with a relatively high density that is dangerous, very toxic, or poisonous at low doses is referred to as heavy metal. The rate of accumulation varies greatly between species and the concentration of heavy metals present in "clean" conditions. 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) (Binnig, 2001). The uptake of these metals through food ingestion or direct contact with contaminated sediments is less well understood. Toxic metal poisoning of the environment is spreading around the globe. The research on the fundamental, applied, and health aspects of trace metals in the environment are expanding as a result of the growing concern regarding the potential impacts of metallic pollutants on human health and the environment. Since the middle of the 1970s, there have been improvements in our knowledge of the distributions and concentrations of trace metals in the marine environment. This is mostly because techniques for contamination-free sampling have improved, clean practices for handling and analyzing materials have been adopted, and more advanced analytical techniques, including inductively coupled plasma mass spectrometry, are being used more frequently (ICP-MS).

As part of the lithosphere, heavy metals are present in the environment naturally and are released through volcanic activity and rock weathering. But human action frequently leads to the widespread release of heavy metals into the aquatic environment. Coastal regions are among the most delicate ecosystems, but due to increased urbanization, industrial growth, and recreational activities, they are under increasing human pressure. Therefore, due to neighboring land-based pollution sources, pollution levels are frequently higher on the coast. Mining, smelting, and refining are industrial processes that discharge various metals into rivers. The aquatic environment could be exposed to heavy metals from almost all industrial processes that produce waste discharges. There are numerous more clear sources of heavy metals in rivers, estuaries, and coastal waters, including domestic wastewater, sewage sludge, urban runoff, and leachate from solid waste disposal facilities. Fossil fuel combustion is responsible for a fraction of the total anthropogenic metal input in the sediments of near-shore waters that are close to areas of urban and industrial expansion. Ports, harbors, marinas, and mooring sites are additional potential sources because they are also exposed to heavy metal inputs from commercial, recreational, and occasionally military boating and shipping activities (www.lenntech.com).

The majority of sediments contain naturally occurring background levels of heavy metals as a result of soil erosion and mineral weathering. The background levels of pollution are only raised to levels that harm the environment when man's activities hasten or aggravate these processes. Because the levels are low, sediments with low concentrations of heavy metals are not necessarily "natural." They might be a combination of a few contaminants that have been mixed with a lot of naturally occurring sediment that contains few heavy metals.

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 (Banat, 2000). Under certain conditions, contaminants found in sediments can be released into the water, and thus, sediments can be important sources of contaminants in water. 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 continental 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 freshwater 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 metals 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.

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 (Harte and Shirley, 1991).

In addition to anthropogenic input, variations in the texture, composition, reduction/oxidation processes, adsorption/desorption, physical transit, or sorting might affect the concentration of heavy metals in sediments. On mineral or organic particles, either in their organic or inorganic forms, potentially hazardous substances, particularly heavy metals, are adsorbed. In the context of environmental pollution, studies on the distribution of trace metals in sediments and other media are crucial.

Inorganic and organic pollutants have contaminated the sediments of several rivers, lakes, and estuaries. Metals are a common and significant inorganic substance found as a pollutant in aquatic sediments. They are heavily impacted by the redox conditions in the sediments and are involved in several system reactions, including sorption and precipitation. Either as dissolved species in water or as a component of suspended particles, heavy metals are transported. They could be preserved in riverbed sediments or volatilized to the atmosphere. They can precipitate on the bottom while still in solution or suspension, or they can be ingested by organisms.

The dissolution of water-soluble salts, soil erosion, and anthropogenic sources like industrial manufacturing and agricultural practices, and municipal wastewater treatment facilities all contribute to the heavy metal concentration of sediments.

2.5 Effects of Heavy Metal Contamination in Sediments

Heavy metal concentrations in estuaries and marine sediments are elevated as a result of the preferential transfer of heavy metals from the dissolved to the particulate phase. Therefore, concentrations are frequently many orders of magnitude higher than those in the water above. Heavy metal concentrations can be high and even dangerous because sediments can deposit them. In areas when conditions encourage bioavailability, exposure and uptake of even a small portion of sediment-bound metal by organisms could have a major toxicological impact. Additionally, elevated metal concentrations in pore water may have a major impact on the toxicity of the sediment. The disappearance of sensitive species or the emergence of resistance mechanisms and adaptation-intolerant forms, such as effective excretory characteristics in organisms, can serve as indicators of the lethal consequences of metal-polluted sediments. Many of the metals, according to Binning and Baird (2001), have no recognized biological purpose in the marine environment but can interact with other chemical species to make them more dangerous. By contrasting the quantities of contaminants of interest existing in sediments with sediment quality standards, it is possible to evaluate the potential impacts of increasing levels of heavy metals (SQGs). The prevalence of harmful biological impacts and the quantities of pollutants in sediments are correlated in big databases, as shown in Table 2.1, and this information was used to establish the Sediment Quality Guidelines (SQGs). They are employed in the assessment of probable Ecotoxicological consequences and sediment contamination.

Table 1. Sediment quality guidelines by USEPA, Consensus-Based, New York and Interim (Banat, 2000)

(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

Under this SQG, two risk categories are taken into account: effects low range (ERL) and effects range-moderate (ERM). While doses above the ERL but below the ERM indicate a potential range in which impacts would occasionally occur, concentrations below the ERL value are rarely connected with biological effects. Concentrations over ERM are frequently linked to detrimental ecological effects on benthic communities (Table 2.2).

Table 2. Sediment quality guidelines proposed by Long et al.1998 to characterize the toxicity of a metal (µg/g) in estuarine sediment toward 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

Acute or chronic effects of heavy metal pollutants in the sediment on benthic organisms are possible. Regardless of whether a metal is required or not, when natural quantities are surpassed, all heavy metals comprise a significant group of enzyme inhibitors. Consequently, species living in or nearby metal-affected sediments may experience toxic consequences that, in extremely contaminated environments, can be lethal (Rahman, 2007). Additionally, because heavy metals can bio-accumulate in the tissues of different biotas, metal enrichment in estuaries and coastal habitats is a significant concern. Finally, it may have an impact on the richness and composition of faunal communities, as well as the distribution and density of benthic creatures. Over the past few years, a variety of criteria have been devised to determine how metals affect marine life. The processes most prone to mental stress are often those of growth, reproduction, and recruitment. Due to the harm that heavy metal contamination has caused to humans, it has gained public attention.

A trace element's toxicity to an organism depends on the chemical species of the metal, its concentration, and the creature being harmed. Toxic effects on the organism happen when excretory, metabolic, storage and detoxifying processes can no longer keep up with absorption rates. This capability may differ between species, populations, and even individuals, and it may also rely on where an organism is in its life cycle. The main way that people are exposed to heavy metals is through the ingestion of seafood. Human effects can be seen following either a single exposure to a high non-lethal dosage (acute) or many exposures to a lower amount (chronic) (Nriagu, 1989).

2.6 Studies in the Field of Contaminated Sediments

Because of its great toxicity, abundance, and ease of accumulation by different plant and animal life, heavy metal is one of the most harmful environmental pollutants. Heavy metal pollution can be caused by industrial processes, car emissions, agricultural processes, home trash, and shipping traffic, particularly in and around harbors. Through rivers, runoff, and land-based point sources where metals are created as a result of metal refinishing by-products, heavy metals continue to be introduced to the estuarine and coastal environment as a result of the fast industrialization and economic development in coastal regions. As a result, heavy metal contamination is still a global environmental issue in both developing and developed nations.

In an aquatic setting, sediments can operate as an adsorptive sink and a scavenger for heavy metals. As a result, it is regarded as a reliable indication of heavy metal pollution. It is challenging to identify and pinpoint the origin of heavy metals present in sediment since they accumulate in sediment from both anthropogenic and natural sources in the same way.

Sediment analyses are crucial in determining how polluted the marine environment. They serve as environmental indicators that show how well marine or lake systems are functioning (USEPA, 1994). The identification, monitoring, and control of pollution sources, as well as the assessment of the environmental impact of polluted sediments, are two key uses of sediment analysis, particularly for heavy metals. Many studies carried out various analyses of sediment pollution.

The first step in determining whether sediments pose a risk to human health or the environment is to measure the quantities of heavy metals in them. A step before the determination is frequently required: sample digestion. It is necessary to use a standardized, reasonably secure dissolve technique that offers a high analytical recovery of metals bound to sediment. The amount of heavy metals in sediment is measured using a variety of digesting techniques, including various combinations of concentrated acids. The most typical tools used to digest solid sample matrices include open beakers heated on hot plates, digestion tubes in a block digester, and digestion bombs heated in microwave ovens. Due to its fast, safe, and effective performance, the microwave-assisted sample digesting approach has gained popularity specifically since the 1980s (Ahmad,2010)

Inductively coupled plasma-mass spectrometry was used by Niragu (1989) to provide 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. To complete sample dissolution, a microwave digestion method was used.

Dutch researchers have discovered that mixed farming, which combines dairy and arable farming, results in less heavy metal contamination than farming based solely on one of these. By calculating the difference between the intake and output of heavy, the team was able to determine contamination levels. They created markers to show when a metal exceeded the standards for soil, crops, or groundwater. This enables predictions, such as the one that conventional arable farming in the Netherlands will exceed the quality threshold for cadmium contamination within 70 years, assuming present input and output levels.

2.7 Studies in the field of contaminated water

Metal contamination of riverine ecosystems has become a serious environmental problem due to rapid urbanization and industrialization (Gaur *et al.,* 2005; Suthar *et al.,* 2009; Boran and Altinok, 2010). Metal contaminants enter river water through anthropogenic sources such as long-term disposal of untreated and partially treated industrial effluents containing toxic metals, and indiscriminate use of metal-containing fertilizers and pesticides in agricultural fields (Martin, 2000; Macklin *et al.,* 2006; Reza and Singh, 2010). Dike *et al.,* (2004) observed that the rapid population increase coupled with factors such as urbanization, rapid industrial development, and agriculture result in a huge accumulation of metal contaminants, which end up polluting water bodies such as rivers, streams, and lakes. Metal contaminants are a major cause of concern for the aquatic environment because of their toxicity, abundance, persistence, and subsequent accumulation in aquatic habitats (Deniseger *et al.,* 1990; Sin *et al.,* 2001). Due to uncontrolled rapid industrialization, river water pollution is posing an increasing threat to surface water irrigation in Bangladesh, and degradation of water quality is likely to cause toxic effects on crops (Roy *et al.,* 2015). In addition, they may enter the human food chain and result in health problems. There is an increasing awareness of the hazards posed by environmental contamination with toxic metal ions. Heavy metals have toxic properties, leading to adverse effects on human health even in small doses. The effects of exposure to these environmental pollutants on human health are well known. Toxicity due to heavy metals can result in significant illness and reduced quality of life (Pendias and Pendias, 2000; Ferner, 2001). Some heavy metals like cadmium (Cd), chromium (Cr), manganese (Mn), and lead (Pb) are considered highly toxic for human life including liver and kidney problems and genotoxic carcinogens (Gambrell, 1994).

Bangladesh is a developing country dependent on rivers for cleaning as well as disposal purposes. It is, therefore, very important to regularly monitor the levels of metallic contamination of its rivers. In Bangladesh, about 0.4 million m^3 of untreated industrial waste is being discharged into urban river water in a day (Rabbani and Sharif, 2005). The Turag River is one of the most important urban rivers in Bangladesh. Its vast catchment area receives untreated domestic wastewater from urban sewers and industrial effluents (Khan *et al.,* 2007; Meghla *et al.,* 2013). During the dry season, crop fields situated adjacent to the Turag River are irrigated continuously with contaminated water. The presence of heavy metals such as Cd, Cr, copper (Cu), iron (Fe), Mn, Pb, zinc (Zn), and nickel (Ni) in river water have the potential to contaminate crops such as vegetables and rice grown in the contaminated soil under such irrigation (Prabu, 2009; Phuong *et al.,* 2010; Yadav *et al.,* 2013; Benti, 2014; Rahman *et al.,* 2015). The mechanisms of food crop contamination by irrigation may be either physical contamination, where repeated irrigation may cause a buildup of contaminants on crops, or uptake of the chemical constituents through the roots from irrigation water or soil. Vegetables and rice growing in contaminated soils may be contaminated with heavy metals, posing a potential health risk. It is widely recognized that the intake of heavy metals via the soil-crop human chains is the predominant pathway of human exposure to environmental contamination in agricultural soils (Liu *et al.*, 2007).

2.8 Studies in the field of contaminated Fish

There are several ways to describe the term “heavy metal” in the literature. It is often used as a synonym for trace metals and includes essential and nonessential metals that have high atomic weight and greater density than that of water. Heavy metal is chemically defined as all matter that can become electron donors and valence ions, can switch places with H ions in acids, can form compounds with nonmetals but can’t form with each other, and has alkaline oxides. In physical terms it is defined as all matter that can conduct heat and electricity well, can be transformed into a metal plate and wire has a metallic color and luster, and is solid under normal circumstances except mercury (Rainbow, 1995; Sönmez *et al.*, 2012a; Tchounwou *et al.,* 2012). But when it comes to their effects of them, regardless of its definition any metal may be called heavy metal if it is toxic to any organism under any circumstances. Heavy metals naturally exist in various concentrations in earth’s crust, soil, air, water, and all biological matter and they have been spread widely as a result of anthropogenic activities such as cement production, iron steel industry, steam power plants, glass production, garbage and waste mud incineration facilities, mining activities, smelters and foundries, piping, combustion and traffic (Langston, 1990; Alloway and Ayres, 1993; Bolognesi *et al.,* 1999; Rether, 2002; Sönmez, 2012a). They can also diffuse around by natural events such as wind, soil erosion, and volcanic activity (Fergusson, 1990; Gregory *et al.,* 2002; Taylan and Özkoç, 2007; Karayakar *et al.,* 2017). Pollution and corresponding risks that come into existence by this rapid increase in agricultural activities, population growth, urbanization, and industrialization are critical issues about the environment (Akbulut *et al.,* 2010; Sönmez *et al.,* 2013a). There is no doubt that the most dangerous chemical pollution in water is heavy metal contamination (Sönmez *et al.,* 2012a). Heavy metals constitute a significant ecological and health concern due to their toxicity and ability to accumulate in living beings. Heavy metals have a strong influence on the stability of ecosystems but also have adverse effects on humans (IARC, 1980; 1987; 1990; Bolognesi *et al.,* 1999).

Even though some heavy metals such as zinc, iron, cobalt, and copper are essential for enzymatic activity and other biological processes at low levels they become toxic when they exceed a certain limit. On the other hand, other metals such as lead, cadmium, and mercury have no essential role in living organisms and are toxic even at too low concentrations (Bryan, 1976).

Heavy metals do not pend in water and settle down swiftly onto sediment due to their higher density than that of water. This was demonstrated with Cd and Cu exposure, metals showed a 72 to 97% decrease from their initial concentration after 96 hours of the experiment (Ghosal and Kaviraj, 2002; Ghosh *et al.*, 2016; Ghosh *et al.*, 2018).

2.8.1 Uptake of Heavy Metals by Fish

Heavy metals are mostly toxic, can cause severe damage, and become lethal for most organisms since they can bioaccumulate and biomagnify. Bioaccumulation means an increase in the concentration of a xenobiotic in an organism over time compared with xenobiotic concentration in the environment (Govind and Madhuri, 2014). Biomagnification means the transfer of a xenobiotic from food sources to an organism, resulting in a higher concentration in the organism than the sources (Connell, 1989; 1990; Rand *et al.*, 1995).

Uptake of heavy metals by fish from the environment primarily occurs through gills, food, skin, and in freshwater fish through water taken with food and taken heavy metals are carried to organs by carrier proteins via blood path and can reach high concentrations by bonding to metal-binding proteins in these tissues (Sönmez *et al*., 2016). The toxic element concentration in fish depends on the sex and age of the fish, season, and place. Pollution of water sources by anthropogenic activities leads to aquatic loss and therefore disrupts the balance of the food chain (Afshan *et al.*, 2014).

2.8.2 Effects of Heavy Metals on Fish

Some aquatic organisms can store heavy metals up to a certain amount. Even though these heavy metals are not harmful or toxic, they can reach humans via the food chain and affect human health (Merlini, 1971) As general rule toxicity occurs when heavy metal concentrations reach above certain levels. Also, heavy metals piled in water join the food chain from many stages and threaten ecosystem safety, fish, and human health. (Jain *et al.*, 2008; Sönmez *et al.*, 2013).

Fish are at the top of the aquatic food chain, and they can accumulate preexisting metals in various tissues and organs (Mansour and Sidky 2002; Sönmez et al., 2012).

Aquatic organisms such as fish and shellfish accumulate metals to concentrations many times higher than present in water or sediment (Olaifa *et al.*, 2004, Gumgum *et al.*, 1994; Al-Weher, 2008). Accumulated metals in fish tissues up to toxic concentrations are based on certain environmental conditions such as food chain, predation competition, water chemistry (salinity, pH, water hardness,) and hydrodynamics in the water (Förstner and Wittmann, 1981; Guven *et al.*, 1999; Akgün *et al.*, 2007; Al-Weher, 2008). Furthermore, the interaction between metals may also influence accumulation (Pagenkopf, 1983; Cicik, 2003).

Studies carried out on fish revealed that all heavy metals, even though some of them are essential for life, have adverse effects on living organisms through metabolic interference and mutagenesis. These adverse effects are a decrease in fitness, interference in reproduction that leads to carcinoma, and eventually death (Govind and Madhuri, 2014).

Despite the carcinogenic effects of heavy metals are not known well, several studies suggest genotoxic effects may exist (Snow, 1992). Heavy metals enhance genotoxicity either directly or indirectly by inducing the toxicity of other chemical agents (Bolognesi et al., 1999). Heavy metal exposure reduces estrogenic and androgenic secretion and also causes pathological changes in fish (Ebrahimi and taherianfard, 2011).

2.9 Review of Relevant Studies

Including Khan (2017) They have used instrumental neutron activation analysis to examine the compositional trends of rare earth elements (REEs: La, Ce, Nd, Eu, Tb, Dy, Yb, Lu), Th, and U in soil samples taken from a potential coal-based power plant site and to conduct a preliminary assessment of the environmental impact of the proposed power plant in terms of REEs, Th, and U. A sufficient data baseline for the abundances of REEs, Th, and U at the sampling site is ensured by recurrent examination of IAEA-Soil-7 and IAEA-SL-1. Chondrite-normalized abundance patterns show the heavy REEs-light rare earth elements, Th-U fractionations, and a sizable negative Eu anomaly in their sample set. Our study area has a thorium/uranium ratio that was higher than that of the top continental crust, ranging from 4.55 to 6.07. NIST-SRM-1633b (coal fly ash), which will be the main byproduct of the power plant, is used as a pollutant in the preliminary assessment of the environmental effect of the proposed power station. According to previous research in the literature and our current data, the proposed power plant won't have a significant impact on soil-originated biota or human health in terms of REEs, Th, and U abundances. However, it is also important to consider the long-term excessive levels of REEs, Th, and U as well as other elements' abundances originating from coal-fly ash.

By using the enrichment factor (EF), contamination factor (CF), accumulation index (Igeo), and pollution load index, the metal contamination in the sediments was also assessed (PLI). According to the enrichment factor (EF), the sediments from the Euphrates River have very high enrichment for Pb, extremely high enrichment for Cd, moderate enrichment for Zn, significant to very high enrichment for Ni, extremely high to very high enrichment for Co, moderate to significant enrichment for Mn, and significant to very high enrichment for Cr. Cd and Cr are responsible for a very high level of contamination, according to the contamination factor (CF). Igeo claims that the sediments of the Euphrates River are moderate to severely contaminated with Cd. All sampling sites indicate no overall site quality pollution based on PLI.

CHAPTER III

MATERIALS AND METHODS

In this chapter, a logical technique is introduced for determining the degree and current condition of heavy metal pollution in the Turag River as a result of industrial waste, sewage, and other trash. The approach was designed to choose eleven sample collection stations, and concentrations of five trace elements (Cr, Fe, Cu, Cd, and Pb) in water, fish, and sediments of the Turag River at various sites were measured. The method for station selection, point sources, photos of the stations and any pollution-vulnerable areas, sample collection, sample preservation, laboratory test technique, data compilation, and analysis are all covered in the following sections.

3.1 Selection of Site for Sample Collection

One of Bangladesh's most developed areas, the Turag River basin has the greatest population density in the nation. Large volumes of industrial, agricultural, and urban sewage have been produced by the rapid industrial expansion and urbanization along this river, and untreated water has been dumped straight into the river. As a result, the river basin has become very polluted, impeding regional growth and posing a significant risk to the aquatic ecology and public health. Three significant industrial regions of the Dhaka district, Gazipur, and Hazaribagh get their water mostly from the river. The Dhaleshwari River's major tributary, the Bangshi River, from which the Turag originates, runs through Gazipur before joining the Buriganga near Mirpur in the Dhaka District. Industry, agriculture, and urban areas make up the majority of the land use and land cover in the river basin. The most heavily contaminated areas, locations near point sources of pollution, locations near water treatment plants, ease of sample collection, and year-round availability of water were taken into consideration while choosing sample collection locations.

The research region is in Bangladesh's capital city of Dhaka, and sample locations will be along the Turag River (Dhaka city). There were eleven composite sampling stations in the Turag River for the collection of sediment, water, and fish samples (Stations placed between Gabtoli Bridge and Ashulia Bridge). 33 different sampling stations were used to create each of the eleven samples.

Additionally, there is severe water contamination there. The river has been slightly widened, but most of the industry has made little effort to abide by environmental laws, and the water has noticeably changed color. As can be seen in Table 3, a total of

49 (22 water + 22 sediment + 5 Fish) samples of river water, sediment, and fish were taken. The sites for the sample are displayed in Figure 3 below.

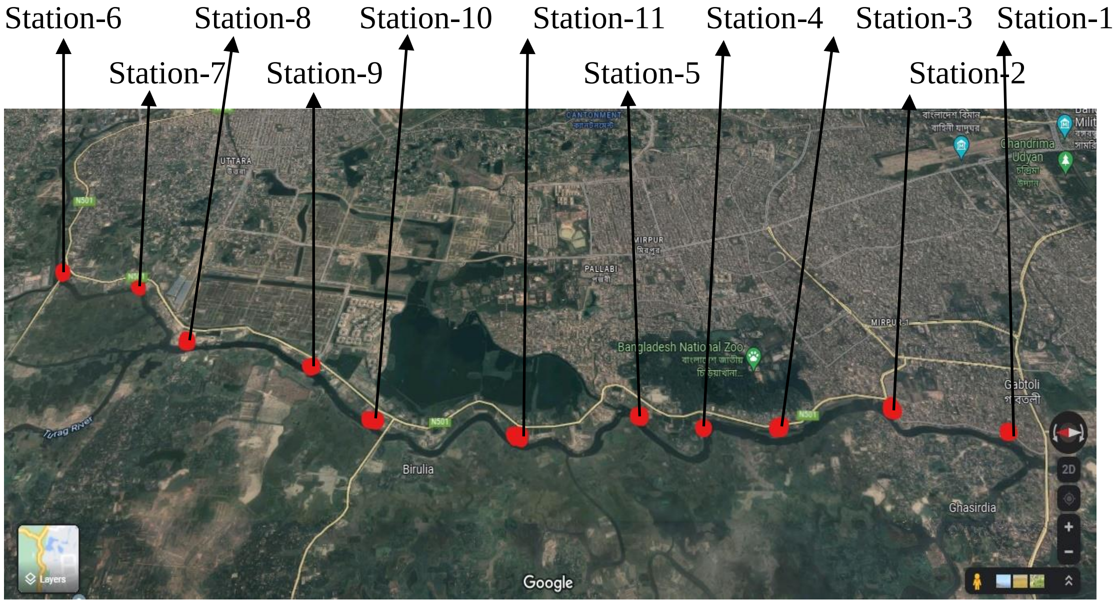

Figure 3: Study area along the Turag River.

3.3 Sample Preparation

3.3.1 Water sample collection:

Water samples from the Turag River were collected, and screened for dissolved metal concentrations using 110mm Millipore filters and placed in polypropylene tubes (BD Plastipak, 100 mL). The use of filters and syringes were preceded by a thorough water rinsing. Before analysis, samples were stored at 4 °C in the dark. To eliminate unwanted solid and suspended elements, the water samples were filtered using filter paper (Whatman No.41).

3.3.2 Sediment Sample collection and Preparation:

The sediment sampling equipment Ekman Dredge was took sediment samples from the Turag River and stored them in brand-new plastic bags. The sediment samples were crushed and sieved using a 2-mm sieve after drying at room temperature. The samples were than be properly labeled for laboratory examinations before being stored in polythene bags. A dry, spotless digestion jar was used to hold the 1.0 g sediment sample. The vessel was received one ml of $HClO_4$ and two ml of HNO_3 (1:2). The digesting vessel was then be put on a heating block and heated for one hour at 180°C and two hours at 120°C. After cooling, the digested samples were filtered using Whatman no.41 filter paper and diluted to 100 ml with deionized water before being put into a plastic container. In a digestion tube, 1g of the sediment sample was obtained, and 10-15 ml of a diacid combination (2:1) HNO_3:HClO4 added. The material is heated vigorously at first and then for two hours at 150°C. Following digestion, the material is put through a filter constructed of Whatman No. 41 paper, rinsed with a 5 percent HNO_3 solution, and formed into a 100 ml volume.

3.3.3 Fish Sample Collection and Preparation:

During the rainy season, fish were collected from the Turag River. The fish were kept on ice in a thermos right away to maintain a temperature of around 4°C. About 3 to 5 g of samples were obtained from the fish that have been gathered, and 10-15 ml of the diacid combination (2:1) HNO_3:$HClO_4$ was added. The mixture was allowed to sit overnight. After that, the 5 species of fish samples were digested for two hours at 150°C after first being heated to a low temperature. Nearly colorless or light-colored material will show signs of digestion being finished. The substance was then filtered using Whatman No. 41 filter paper, rinsed with 5 percent HNO_3, and a volume of 100 ml of polyethylene/bottles was created.

Table 3. Selected Locations for sample collection

Sl. No.	Sampling stations	Sample ID.
1	Aminbazar bridge	Station-1
2	Beribad Nawka-ghat (Jahurabad kacha bazar)	Station-2
3	Mirpur Beribad (Chotbari, Bot-tola)	Station-3
4	Karim asphalt and ready mix	Station-4
5	Birulia bridge	Station-5
6	IFL factory	Station-6
7	Ashulia landing station	Station-7
8	Near BUFT	Station-8
9	NDE ready mix	Station-9
10	Crown Cement ready mix	Station-10
11	Near the Dhaka Boat Club	Station-11

3.4. Sample Analysis:

In the Turag River, sediment, water, and fish were collected at several sample sites between January and December 2021 and 2022 (winter and rainy seasons). The gathered samples were placed into distinct, marked polythene bags (for sediment and fish) and PVC bottles (for water). These samples were sent to the Sher-e-Bangla Agricultural University's Agricultural Chemistry Laboratory.

3.5. Data analysis

The content of heavy metals (Pb, Cu, Cr, Cd, and Fe) was estimated in sediment, water, and fish samples. Apart from content, the following parameters were calculated to estimate environmental pollution and health risks associated with the uptake of heavy metals from polluted sources.

3.5.1. Toxic and heavy metals contamination assessment in soil and water:

3.5.1.1 Geo-accumulation (Sediment)

Geo-accumulation index (Igeo), contamination factor (CF), and potential ecological risk index (PERI) can be used to assess pollution, evaluate the pattern of contamination and determine the potential risk due to exposure to ecological sensitivity, concentration, and toxicity of TMs and HMs in soil. Igeo was calculated by using a formula (Mohammadi *et al.*, 2019).

$$I_{geo} = Log_2(Cn/1.5 \times Bn)$$

where Cn is the concentration of an element in the soil sample while Bn (mention in appendx-3) is the geochemical background value of non-effected soil at the site of the city. The constant 1.5 allowed us to minimize effect variation in background concentration due to lithogenic impacts (Chonokhuu *et al.*, 2019). Soil quality can be distinguished by Igeo index classification as follows, Igeo≤0 (uncontaminated), 0<Igeo<1 (uncontaminated to moderately contaminated), 1<Igeo<2 (moderately contaminated), 2< Igeo<3 (moderately to heavily contaminated), 3< Igeo<4 (heavily contaminated), 4<Igeo<5 (heavily to extremely contaminated), 5< Igeo (extremely contaminated).

3.5.1.2 Contamination Factor (Sediment)

CF was estimated by the following equation. (Mohammadi *et al.,* 2019)

$$CF = \frac{Cn}{Cb}$$

where Cn is the concentration of an element in the soil sample while Cb is the geochemical background value of non-effected soil at the site of the city. Soil quality can be classified by CF value as follows, CF < 1 (low contamination), 1 ≤ CF < 3 (moderate contamination), 3 ≤ CF < 6 (considerable contamination), and CF ≥ 6 (very high contamination). (Mohammadi *et al.*, 2019)

3.5.1.3 The potential ecological risk (Sediment & Water)

The potential ecological risk of the individual metal element can be determined as follows (Hanfi *et al.*, 2020):

$$E_r = \frac{Cs}{Cn} \times Tr$$

Where,

Cs = concentration of an element in the sample

Cn = geochemical background value of non-effected soil

Tr = toxic response factor for each metal

Er=Ecological risk

Toxic response factor was taken 2 for Cr, 5 for Cu and Pb, 10 for As, 1 for Fe, and 50 for Cd (Zhang et al., 2014). Soil quality can be classified by Er value as follows, Er< 40 (low risk), 40 ≤ Er< 80 (moderate risk), 80 ≤ Er< 160 (considerable risk), 160 ≤ Er < 320 (high risk), and Er≥ 320 (very high risk).

3.5.2. Human health risk assessment for sediment and water:

To evaluate the human exposure to TMs and HMs in soil and water, the estimation of risk was determined by using the average daily dose (ADD), the non-carcinogenic target hazard quotient (THQ), hazard index (HI), and lifetime carcinogenic risk (LCR) coefficients (Boateng *et al.,* 2019; Kamunda *et al.*, 2016; Mohammadi *et al.*, 2019).

Average daily dose. ADD of three exposure pathways of soil including ingestion (ADDig), inhalation (ADDinh), and dermal contact (ADDderm) in mg/kg/day of metals including Cr, Mn, Cu, As, Cd, Ba, Hg, and Pb was calculated by using the formula (Mohammadi *et al.*, 2019; Hanfi *et al.*, 2020; Dehghani *et al.*, 2019; Karimi *et al.*, 2020).

$$ADD_{ing} = C \times \frac{IngR \times EF \times ED}{BW \times AT} \times 10^{-6}$$

$$ADD_{inh} = C \times \frac{InhR \times EF \times ED}{PEF \times BW \times AT}$$

$$ADD_{derm} = C \times \frac{SA \times AF \times ABF \times EF \times ED}{BW \times AT} \times 10^{-6}$$

where C is the concentration of TMs and HMs in mg/kg, IngR is ingestion rate in mg/day (IngR = 200 for children, and 100 for adults), EF exposure frequency in days/year (180), and ED is exposure duration (6 years for children, and 24 years for adults), BW is the average body weight (child = 15 kg and adult = 70 kg), AT is the average time (365 × ED), InhR is inhalation rate in mg/cm^2 (20 for both adult and children), PEF is particle emission factor in m^3kg^{-1} (1.36 × 109 for both adults and children), SA is the surface area of the exposed skin in cm^2 (2145 for adult and 1150 for children), AF is the skin adherence factor for the soil in $mgcm^2kg^{-1}$ (0.2 for adults and 0.07 for children), and ABF presents the dermal absorption factor (0.03 for As and 0.001 for other metals). While ADD_{ing} and ADD_{derm} of water in mg/kg/day of metals including Cr, Mn, Cu, As, Cd, Ba, Hg, and Pb was calculated by using the formula given above for soil whereas IngR is the ingestion rate of water is 2.2 L/day for adult and 1.5L/day for children, EF is 365 days/year, SA is 5700 cm^2 and rest of parameters are same as mentioned above. (Kamunda, *et. al.*, 2016)

Table 4. RfD and CSF values used in this study for water and sediments (UEPA,1991)

Elements	RfD_{ing}	RfD_{inh}	RfD_{der}	CSF_{ing}	CSF_{inh}	$CSF_{derdicate}$
Cd	3×10^{-3}	2.86×10^{-5}	6×10^{-5}	0.5	-	41.0
Pb	4×10^{-2}	4.03×10^{-2}	1.2×10^{-2}	-	-	-
Cr	1×10^{-4}	1×10^{-4}	1×10^{-5}	0.38	-	6.3
Cu	3.5×10^{-5}	3.25×10^{-3}	5.25×10^{-4}	0.0085	-	0.042

3.5.4. Total hazard quotient and index for sediment and water: THQ is the ratio of ADD (from three exposure pathways) and RfD (chronic reference dose for each metal in mg/kg BW/day) which is typically used to estimate the potential non-carcinogenic risk of metals exposure to humans in three different pathways (Chonokhuu *et al.*, 2019).

$$THQ = \frac{ADD(ingestion, inhalation,\ and\ dermal)}{RfD}$$

RfD in mg/kg BW/day for Cd, Pb, Cr, Cu, and Fe respectively are presented in Table.5 whereas THQ < 1 considers the exposed population to experience no significant health risk. Whereas the hazard index (HI) is equal to the sum of all expected HQs (non-carcinogenic risks) through inhalation, oral, and dermal, pathways and is employed to compute the total potential non-carcinogenic risks of different contaminants through the 3 exposure routes mentioned above (Mohammadi *et al.,* 2019).

$$HI = ADD_{ing} + ADD_{inh} + ADD_{derm}$$

If the HI score is less than 1, there is no appreciable danger of non-carcinogenic consequences. However, there is a chance that non-carcinogenic consequences may manifest themselves when HI > 1, and that chance grows as HI rises (Radford *et al.,* 2018; Qasemi *et al.,* 2019).

3.5.5. Carcinogenic risk assessment water: Cancer risk for lifetime exposure (LCR) of Cr, As, Cd, Pb, and Hg were estimated to determine the health risk by calculating the cumulative life cancer risk rating using the formula below for each exposure pathway (Rusin *et al.*, 2014).

$$LCR = ADD(ingestion, inhalation,\ and\ dermal) \times CSF$$

where CSF is the cancer slope factor which is given in Table 3.5.3 for each metal for three exposure pathways. Whereas LCR < 10^{-6}, LCR > 1×10^{-4}, and LCR 1×10^{-6} to 1×10^{-4} in no carcinogenic risk, high risk of developing cancer, and signifies acceptable risk to humans respectively.

3.5.6. Human health risk assessment of heavy metals from consuming fish

3.5.6.1 Non-Carcinogenic risk for fish

Determination of target hazard quotients (THQ): The Target Hazard Quotient (THQ) is defined as the ratio of the exposure and the recommended doses, it expresses the risk of non-carcinogenic effects. A THQ value less than 1 means the level of exposure is less than the reference dose, implying that there will not be any obvious risk. Thus, daily exposure at this level is not likely to cause any adverse effects during the lifetime of an individual. On the other hand, a population exposed to a dose equal to or greater than the RfD will experience health risks, and therefore calls for concern. The method for the determination of THQ was provided in the United States EPA Region III risk-based concentration table (USEPA, 2000). The dose calculations were carried out using standard assumptions from an integrated United States EPA risk analysis.

The models for estimating THQ are given by equations 1 and 2 (Nwadozie *et al.*,1998; Chien *et al.*, 2002):

$$\mathbf{THQ} = \frac{EFr \times EDtot \times FIR \times C}{RfD \times BW \times AT} \times 10^{-3}$$

Where THQ is the target hazard quotient; EFr is exposure frequency (365 days/year); EDtot is the exposure duration (70 years, average lifetime); FIR is the food ingestion rate (kg/day) i.e., Bangladesh per capita consumption of fish is 0.063kg/day (BBS, 2019). This follows that the daily intake of fish per person is 0.063 kg/day for Bangladesh; C is the heavy metal concentration in fish (mg/kg or ppm); RfD is the oral reference dose (mg/kg/day, Table.5); BW is the average adult body weight (60.0 kg); and AT is the averaging exposure time for non-carcinogens (365 days/year x the number of exposure years, assuming 70 years). The total THQ which is the sum of the individual metal THQ values is given by:

Total THQ (TTHQ)=THQ (toxicant1) + THQ (toxicant2) + --- +THQ (toxicant n)

The THQ>1 may not translate to people experiencing adverse or severe health effects instead it means that there exists a relative possibility of adverse effects.

Table 5. RfD values for fish (USEPA, 1985)

Metals	Cd	Pb	Cr	Cu	Fe
RfD(mg/kg/day)	1×10^{-4}	4×10^{-3}	5×10^{-3}	-	9×10^{-3}

3.5.6.2 Carcinogenic risk for fish

For carcinogens, the risk was estimated as the incremental probability of an individual developing cancer over a lifetime of exposure to that potential carcinogen (USEPA 2011). The target carcinogenic risks derived from the intake of As and Pb were calculated using the equation provided in the USEPA Region III Risk-Based Concentration Table:

$$TR = \{EFr \times ED \times FIR \times C \times CSFo / BW \times AT\} \times 10^{-3}$$

Where EFr is the exposure frequency (365 days/year), ED is the exposure duration (70years) (USEPA, 2006) and AT is the average time for carcinogens (365 days/year×70 years). CSFo is the oral carcinogenic slope factor from the Integrated risk Information System (USEPA, 2010) database was 41×10^{-3}, 6.1×10^{-3}, and 8.5×10^{-3} (mg/kg/day)-1 for Cr, Cd, and Pb, respectively.

3.6. Statistical analysis

The mean concentrations of heavy metals in Fish, sediment, and water samples and one-way variance (ANOVA) were analyzed using a Microsoft excel computer package.

3.8. Metal Analysis Methods

The most popular analytical techniques for identifying trace elements as consequences are flame and graphite furnaces, and atomic absorption spectrometry (AAS).

3.8.1 Atomic Absorption Spectrometry (AAS)

The method is used in analytical chemistry to establish the concentration of a specific element (the analyst) in a sample was subjected to analysis. Over 70 distinct elements may be identified with AAS, either directly in solid samples or in solutions. Below is a picture of an AAS figure (Figure 4). 8 lamp changers for maximum automation and sample throughput Single and double beams are available. D2 background correction. Integrated RFID Tool for working with coded lamps. Integrated super lamp power supply for best analytical performance. Integrated High-end Vision Tool for best observation and control of sample injection and sample drying in the graphite tube. Direct analysis of solid samples.

Figure 4: Atomic Absorption Spectrophotometer (Analytikjena, NovAA-400P)

To determine the concentration of an analyst in a sample, the procedure makes use of absorption spectrometry. In essence, by absorbing a specific amount of energy, the electrons of the atoms in the atomizer may be promoted to a higher orbital (excited state) for a brief amount of time (nanoseconds) (radiation of a given wavelength). A given electron transition in a particular element corresponds to this amount of energy or wavelength. The technique's elemental selectivity is because each wavelength typically corresponds to just one element and each absorption line's width is only on the order of a few picometers (pm). A detector is used to measure the radiation flux with and without a sample in the atomizer. The difference between the two readings (the absorbance) is then translated to analyte concentration or mass using Beer-Lambert Law (Parry, S.J. (1991).

3.9 Quality control

Accuracy is a very important and prime factor in analytical results because these results are subject to errors which cause the results to differ from the true concentration of determinants. The acquired results affect the ability of decisions based on these results. Various factors such as purity of reagents, standards, the magnitude of matrices effects, instrument’s stability, and environmental condition of the laboratory. So to ensure accuracy during the analysis of Cd, Cr, Pb Cu, and Fe in real samples sediments, fish, and water (NovAA400) were analyzed and results were presented in terms of % recovery studies. The recovery results obtained ranged between 90 and 110% which determines the excellent extraction efficiency.

Table 6. The Output of Accuracy Check

Method Name	**Element Name**				
	Cu	Cr	Cd	Pb	Fe
Linear range	0.1-1.0	0.1-1.0	0.1-0.8	0.1-0.8	0.5-2.0
Replication	3	3	3	3	3
Determination Coefficient (R^2)	0.99584	0.99105	0.99646	0.99734	0.94425
Method SD (mg/L)	0.01449	0.02234	0.01730	0.01204	0.15051
Method Sensibility (mg/L)	0.0381	0.0835	0.0099	0.0708	0.0467
Method LOD (mg/L))	0.0354	0.0676	0.0456	0.0375	0.0982
Method LOQ (mg/L)	0.1298	0.2529	0.1667	0.1431	0.4472
Spilled Sample	0.4	0.4	0.6	0.4	1.5
Accuracy (%)	94.6	98.7	95.4	92.5	97.2
Precision (%))	2.9	2.3	3.4	1.7	1.9

Linear equation (Cu) $y= 0.0008635 + 0.117211x$

(Cr) $y= - 0.0005579 + 0.0531213x$

(Cd) $y= 0.0017465 + 0.5672551x$

(Pb) $y= - 0.0055112 + 0.0623100x$

(Fe) $y= 0.0054010 + 0.0613200x$

Table 7. The output of the Analytical Method

Name	Element Name				
	Cu	Cr	Cd	Pb	Fe
Wave Length	324.75	357.87	228.8	217.0	248.3
Lamp	HCl	HCl	HCl	HCl	HCl
Flame	Air - Ac	Air - Ac	Air - Ac	Air - Ac	Air - Ac
Air/Ac Flow (L/min)	50	100	50	65	65

CHAPTER IV
RESULTS AND DISCUSSION

Determination of heavy metal concentration is the first step to evaluating the extent of pollution in the bed surface sediment. This chapter will enhance the analysis of heavy metal pollution in benthic sediment as well as water samples, variation of the metals at different depths, and the level of radioactivity in Turag river sediments.

4.1. Heavy Metal Distribution on Bed-sediments of Turag River:

From the eleven stations of the turag river, the collected sediments contain different types of heavy and toxic metals. Among them, maximum, minimum, and average values of Cadmium, lead, Chromium, Copper, and Iron are considered to assess achieving the goal of the study.

Table 8. Maximum, minimum, and average values of sediment samples(mg/kg)

Metals	Cd		Pb		Cr		Cu		Fe	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Rainy Season	0.11	3.81	0.63	6.74	43	201	6.84	62.87	1278	1810
Winter season	0.14	3.72	0.34	12.85	48	239	22.7	49.62	1777	1885
Mean	Rainy Season	Winter season	Rainy Season	Winter season	Rainy Season	Winter season	Rainy Season	Winter season	Rainy Season	Winter season
	1.24	1.98	3.3	4.84	117.3	128.9	27.9	32.4	1576.3	1831.7

From table 8, it is illustrated that Cd(Cadmium), Pb(Lead), Cr(Chromium), Cu(Copper), and Fe(Iron) are range from 0.11-3.81mg/kg, 0.63-6.74mg/kg, 43-201mg/kg, 6.84-62.87mg/kg, and 1278-1810mg/kg with the average value of 1.24mg/kg, 3.3mg/kg, 117.3mg/kg, 27.9mg/kg, 1576.3mg/kg respectively in the rainy season, and also these are ranges from 0.14-3.72mg/kg, 0.34-12.85mg/kg, 48-239mg/kg, 22.7-49.62mg/kg, and 1777-1885mg/kg with an average of 1.98, 4.84, 128.9, 32.4, and 1831.7 mg/kg respectively in the winter season. From the above concentrations, it can say that the accumulation of metals is higher in the winter season than rainy season.

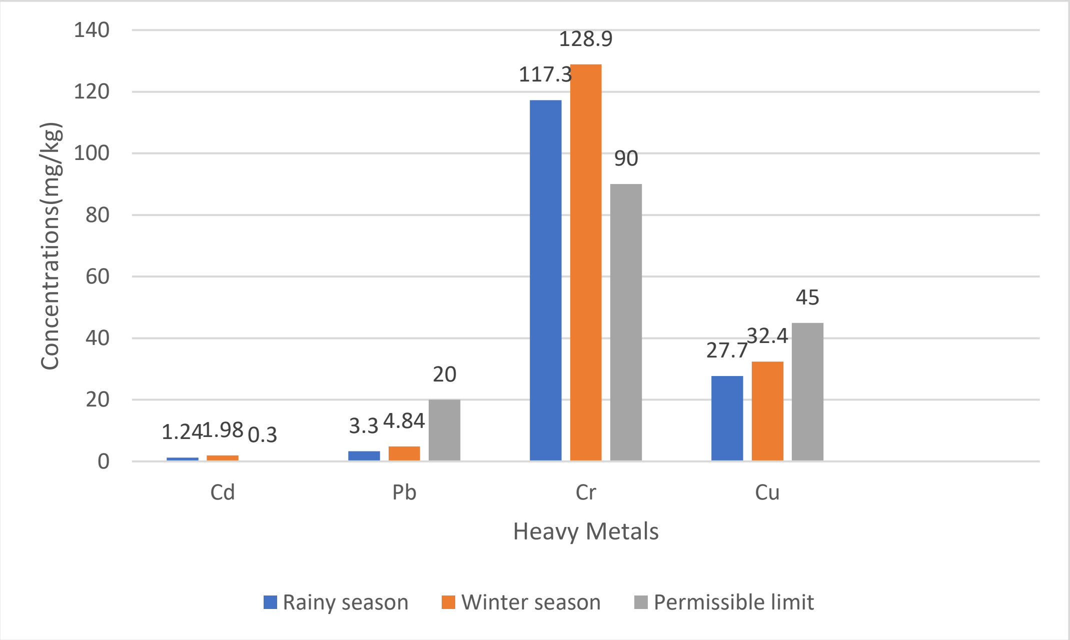

Figure 5: Comparison between average values of different metals in sediments with their permissible limit.

4.3.1 Geo-accumulation Index of sediments: Geo-accumulation index is represented by I_{geo}. The following table represents different I_{geo} classes according to different concentrations.

Table 9. The measure of metal pollution in aquatic sediment and solid waste (Muller, 1969)

Index of Geoaccumulation	I_{geo} class	Designation of sediment quality
10-5	6	Extremely contaminated

4-5	5	Strongly/Extremely contaminated
3-4	4	Strongly contaminated
2-3	3	Strongly/Moderately contaminated
1-2	2	Moderately contaminated
0-1	1	Uncontaminated/Moderately contaminated
0	0	Uncontaminated

Table 10. I_{geo} of different metals in sediment

Metals	Fe		Cu		Pb		Cr		Cd	
Seasons	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
I_{geo}	0.01	0.01	0.12	0.14	0.03	0.04	0.26	0.53	0.0083	0.0132

From Table 10 Geo-accumulation Index of every metal is below 1 which belongs to I_{geo} class-1 according to table 4.2. From that class, it is illustrated that sediments of the turag river are moderately contaminated in both rainy and winter seasons.

Table 11. Contamination factor of Sediment

Metals	Cd		Pb		Cr		Cu		Fe	
Seasons	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
CF	0.0413	0.066	0.165	0.242	1.3	1.43	0.62	0.72	0.033	0.038

From Table 11, it can be illustrated that sediments of the turag river are in a lower contamination situation by all metals in both seasons except Cr. Cr is considerably contaminating the sediments of the turag river.

Table 12. Potential Ecological Risk (PER) of Sediment

Metals	Cd		Pb		Cr		Cu		Fe	
Seasons	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
PER	0.3	0.68	1.045	2.905	0.55	1.09	5.52	1.265	2.5	5.11

Soil quality can be classified by Er value as follows, PER< 40 (low risk), 40 ≤ PER< 80 (moderate risk), 80 ≤PER< 160 (considerable risk), 160 ≤PER< 320 (high risk), and PER≥ 320 (very high risk). According to the above statement, potential ecological risk of sediments in the turag river is at low risk. According to the above statement, it can be illustrated that each heavy metal's PER (potential ecological risk) is below 40, which means the sediment of the turag river is an ecologically low risk according to the values from table no. 12.

4.3.2 Human Health risk assessment:

4.3.2.1 Non-carcinogenic risk

Average daily dose: ADD in mg/kg/day of metals including Cr, Cu, Cd, Pb, and Fe was calculated based on three exposure pathways of soil such as ADDing, ADDinh, and ADDderm. ADD trends (Table 13 and 14) in both adults and children were found in order ADDing> ADDderm> ADDinh for sediments. Among the ADD of soil, ADDing, and ADDinh for children had the maximum dose for all metals than adults while ADDderm was higher in adults. In conclusion, children are exposed to heavy metals more than adults.

Table 13. Average Daily dose of sediment for adults

Metals	Cd		Pb		Cr		Cu		Fe	
Seasons	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
ADD_{ing}	8.7×10^{-7}	1.4×10^{-6}	2.3×10^{-6}	3.4×10^{-6}	8.2×10^{-5}	9×10^{-5}	1.9×10^{-5}	2.2×10^{-5}	1.1×10^{-3}	1.2×10^{-3}
ADD_{inhl}	1.28×10^{-10}	2.05×10^{-10}	3.4×10^{-10}	4.6×10^{-10}	1.21×10^{-8}	1.34×10^{-8}	2.9×10^{-9}	3.3×10^{-9}	1.6×10^{-7}	1.89×10^{-7}
ADDderm	1.1×10^{-7}	1.7×10^{-7}	2.9×10^{-7}	4.3×10^{-7}	1.06×10^{-5}	1.16×10^{-5}	2.5×10^{-6}	2.9×10^{-6}	1.4×10^{-4}	1.6×10^{-4}

Table 14. Average Daily dose of sediment for children

Metals	Cd		Pb		Cr		Cu		Fe	
Seasons	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
ADD_{ing}	8.15×10^{-6}	13.02×10^{-6}	7.71×10^{-4}	8.47×10^{-4}	2.17×10^{-5}	3.18×10^{-5}	1.8×10^{-4}	2.1×10^{-4}	1.03×10^{-2}	1.2×10^{-2}
ADD_{inhl}	6×10^{-10}	1×10^{-9}	1.59×10^{-9}	2.3×10^{-9}	5.67×10^{-8}	6.23×10^{-8}	1.34×10^{-8}	1.57×10^{-8}	7.6×10^{-7}	8.8×10^{-7}
ADDderm	3.2×10^{-9}	5.2×10^{-9}	8.7×10^{-9}	1.2×10^{-9}	3.1×10^{-7}	3.4×10^{-7}	7.3×10^{-8}	8.5×10^{-8}	4.17×10^{-6}	4.8×10^{-6}

Total hazard quotient and index: HQ trend (Table 15 and 16) in both adults and children was found in order HQ*ing*> HQ*derm*> HQ*inh* for soil for all metals except Cd and Cu which followed HQ*derm*>HQ*ing*>HQ*inh*. HI values for an individual metal by all exposure pathways of soil in both adults and children were less than one which indicates no significant health risk. HI, values of Cr and Cu in children were about 7 and 7.5 times higher than in adults respectively. So, data from Tables 17 and 18, demonstrated that the HI value for all metals in sediments is less than one which indicates no significant health risk except Cr and Cu. The HI of Chromium in both rainy and winter seasons is more than one which indicates a significant health risk for adults and children. And also the HI value of Cu for adults is less than one which demonstrated no significant risk and for children more than one in both seasons which indicates a significant health risk for children from Cu and Cr.

Table 15. THQ of sediment for Adults

Metals	Cd		Pb		Cr		Cu	
Season	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
THQ_{ing}	1.1×10^{-4}	1.7×10^{-4}	8.28×10^{-5}	1.2×10^{-4}	0.82	0.9	0.54	0.62
THQ_{inh}	4.4×10^{-6}	7.2×10^{-6}	8.4×10^{-9}	1.14×10^{-8}	1.21×10^{-4}	1.34×10^{-4}	8.9×10^{-7}	1.02×10^{-6}
THQ_{derm}	1.8×10^{-3}	2.8×10^{-3}	2.4×10^{-5}	3.5×10^{-5}	1.06	1.16	4.76×10^{-3}	5.5×10^{-3}

Table 16. THQ of sediment for the child

Metals	Cd		Pb		Cr		Cu	
Season	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
THQ_{ing}	2.71×10^{-3}	4.3×10^{-4}	5.4×10^{-4}	7.9×10^{-4}	7.71	8.47	5.14	6
THQ_{inh}	2.09×10^{-5}	3.5×10^{-5}	3.95×10^{-8}	5.9×10^{-8}	5.67×10^{-4}	6.23×10^{-4}	4.18×10^{-6}	4.8×10^{-6}
THQ_{derm}	5.33×10^{-5}	8.67×10^{-5}	7.25×10^{-7}	1×10^{-6}	3.1×10^{-3}	3.4×10^{-3}	1.4×10^{-4}	1.6×10^{-4}

Table 17. HI of sediments for Adults

Metals	Cd		Pb		Cr		Cu	
Season	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
HI	1.91×10^{-3}	2.98×10^{-3}	1.07×10^{-4}	1.6×10^{-4}	1.88	2.06	0.54	0.62

Table 18. HI of sediments for Children

Metals	Cd		Pb		Cr		Cu	
Season	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
HI	2.78×10^{-3}	5.5×10^{-4}	5.4×10^{-4}	7.9×10^{-4}	7.71	8.47	5.14	6.00

Carcinogenic risk assessment: The carcinogenic slope factor was used to assess the carcinogenic risk from a lifetime exposure of Cr, Cd, and Pb, by different exposure pathways like ingestion, inhalation, and dermal. In the case of Cu and Fe, there is no cerebrospinal fluid(CSF) value. LCR < 10^{-6}, LCR > 1×10^{-4}, and LCR 1×10^{-6} to 1×10^{-4} indicate no carcinogenic risk, high risk of developing cancer and signifies acceptable risk to humans respectively. LCR values for Cr and Cd by different exposure pathways of Sediments have crossed for both adults and children in rainy and winter seasons who are at risk for cancer (Tables 19 and 20). Therefore children are more at risk than adults in this study area where the ingestion route is a major contributor to access LCR followed by dermal and inhalation pathways. Igeo, CF, and PERI evaluated the pattern of contamination and determine the potential risk due to exposure to ecological sensitivity while the ADD, THQ, and CR coefficients were demonstrated to evaluate the human health risk, which is the strength of the present research. Whereas the remediation approach is to create a final solution that is protective of human health and the environment the limitation of this research work is done on sediments near a landfill site.

Table 19. LCR of sediments for Adults

Metals	Cd		Pb		Cr	
Season	Rainy	Winter	Rainy	Winter	Rainy	Winter
LCR	0.0102	0.0155	1.71×10^{-6}	2.5×10^{-6}	43.87	48.61

Table 20. LCR of sediments for Children

Metals	Cd		Pb		Cr	
Season	Rainy	Winter	Rainy	Winter	Rainy	Winter
LCR	1.36×10^{-3}	7.09×10^{-4}	4.6×10^{-6}	6.76×10^{-6}	3.98	4.37

4.4 Heavy Metal Distribution on the water of Turag River: From the eleven stations of the turag river the collected water contains different types of heavy and toxic metals. Among them, maximum, minimum, and average values of Cadmium, lead, Chromium, Copper, and Iron are considered to assess achieving the goal of the study.

Table 21. Maximum, minimum, and average values of water samples (mg/L)

Metals	Cd		Pb		Cr		Cu		Fe	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Rainy Season	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.4	3.61
Winter season	0.0063	0.0075	BDL	BDL	0.0393	0.0611	BDL	BDL	0.44	3.68
Mean	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
	BDL	0.13	BDL	BDL	BDL	0.04	BDL	BDL	1.07	1.27

From table 21, it is illustrated that, the concentration of Cd (Cadmium), Pb (Lead), Cr (Chromium), and Cu (Copper) are at the below detection limit except Fe and it ranges from 0.4-3.61 mg/kg in the rainy season, and also these are ranges from 0.16-0.5 mg/L for Cd, 0.21-0.3 mg/L for Cr, 0.44-3.68 mg/L for Fe, and at the below detection limit for Pb and Cu respectively in winter season. From the above concentrations, it can say that the accumulation of metals is higher in the winter season than rainy season.

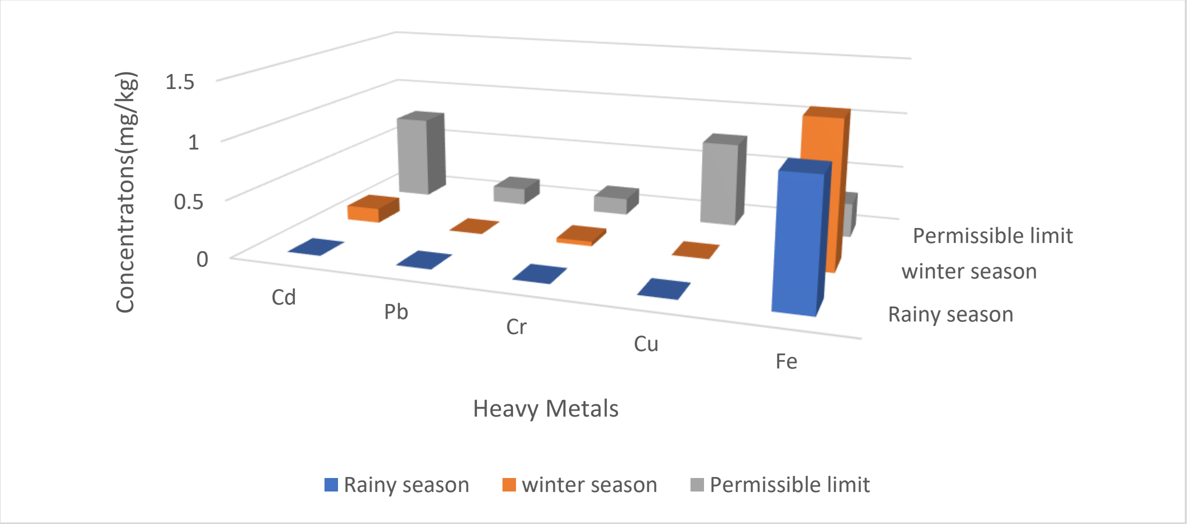

Figure 6: Comparison between average values of different metals in water with their permissible limit.

Table 22. Potential Ecological Risk (PER) of Water

Metals	Cd		Pb		Cr		Cu		Fe	
Seasons	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
PER	BDL	0.325	BDL	BDL	BDL	0.16	BDL	BDL	2.7×10^{-5}	2.7×10^{-4}

Water quality can be classified by Er value as follows, PER< 40 (low risk), 40 ≤ PER< 80 (moderate risk), 80 ≤PER< 160 (considerable risk), 160 ≤PER< 320 (high risk), and PER≥ 320 (very high risk). According to the above statement, potential ecological risk of sediments in the turag river is at low risk. According to the above statement, it can be illustrated that each heavy metal's PER(potential ecological risk) is below 40, which means the water of the turag river is an ecologically low risk according to the values from table 24.

4.4.1 Human Health risk assessment:

Non-Carcinogenic risk

Average daily dose: ADD in mg/kg/day of metals including Cr, Cd, was calculated based on three exposure pathways of water such as ADD_{ing}, ADD_{inh}, and ADD_{derm}. ADD trends (Table 23 and 24) in both adults and children were found in order ADD_{ing}> ADD_{derm}> ADD_{inh} for water only in winter season. Among the ADD of water, $ADD_{ing,}$ and ADD_{inh} for children had the maximum dose for all metals than adults while ADD_{derm} was higher in adults. In conclusion, children are exposed to heavy metals more than adults.

Table 23. Average Daily dose of water for adults:

Metals	Cd		Pb		Cr		Cu		Fe	
Seasons	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
ADD_{ing}	BDL	3.1×10^{-8}	BDL	BDL	BDL	9.7×10^{-9}	BDL	BDL	2.6×10^{-7}	3.06×10^{-7}
ADD_{inhl}	BDL	4.2×10^{-5}	BDL	BDL	BDL	1.3×10^{-5}	BDL	BDL	3.4×10^{-4}	4.1×10^{-4}
ADDderm	BDL	6.8×10^{-11}	BDL	BDL	BDL	2.1×10^{-11}	BDL	BDL	5.7×10^{-10}	6.8×10^{-10}

Table 24. Average Daily dose of water for children

Metals	Cd		Pb		Cr		Cu		Fe	
Seasons	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
ADD_{ing}	BDL	7.7×10^{-5}	BDL	BDL	BDL	5.5×10^{-7}	BDL	BDL	2.8×10^{-6}	3.34×10^{-6}
ADD_{inhl}	BDL	2.3×10^{-4}	BDL	BDL	BDL	7.1×10^{-5}	BDL	BDL	1.9×10^{-3}	2.3×10^{-3}
ADDderm	BDL	7.9×10^{-10}	BDL	BDL	BDL	2.4×10^{-10}	BDL	BDL	6.7×10^{-9}	7.9×10^{-9}

Total hazard quotient and index: HQ trend (Table 23 and 24) in both adults and children was found in order HQ*ing*> HQ*derm*> HQ*inh* for water for all metals. HI values for an individual metal by all exposure pathways of water in both adults and children were less than one which indicates no significant health risk. So, data from Tables 27 and 28, demonstrated that the HI value for all metals in water is less than one, which indicates no significant health risk.

Table 25. THQ of water for adults

Metals	Cd		Pb		Cr		Cu	
Season	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
THQ_{ing}	BDL	1.03×10^{-5}	BDL	BDL	BDL	9.7×10^{-5}	BDL	BDL
THQ_{inh}	BDL	1.5	BDL	BDL	BDL	0.13	BDL	BDL
THQ_{derm}	BDL	1.08×10^{-6}	BDL	BDL	BDL	2.1×10^{-6}	BDL	BDL

Table 26. THQ of water for the children

Metals	Cd		Pb		Cr		Cu	
Season	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
THQ_{ing}	BDL	0.025	BDL	BDL	BDL	5.5×10^{-3}	BDL	BDL
THQ_{inh}	BDL	8.04	BDL	BDL	BDL	0.71	BDL	BDL
THQ_{derm}	BDL	1.3×10^{-5}	BDL	BDL	BDL	2.4×10^{-7}	BDL	BDL

Table 27. HI of water for Adults

Metals	Cd		Pb		Cr		Cu	
Season	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
HI	BDL	4.2×10^{-5}	BDL	BDL	BDL	1.3×10^{-5}	BDL	BDL

Table 28. HI of water for Children

Metals	Cd		Pb		Cr		Cu	
Season	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
HI	BDL	3.1×10^{-4}	BDL	BDL	BDL	7.2×10^{-5}	BDL	BDL

Carcinogenic risk assessment: The carcinogenic slope factor was used to assess the carcinogenic risk from a lifetime exposure of Cr, Cd, and Pb, by different exposure pathways like ingestion, inhalation, and dermal. In the case of Cu and Fe, there is no cerebrospinal fluid(CSF) value. LCR < 10^{-6}, LCR > 1×10^{-4}, and LCR 1×10^{-6} to 1×10^{-4} indicate no carcinogenic risk, high risk of developing cancer and signifies acceptable risk to humans respectively. LCR values of every metal in the water of the turag river by different exposure pathways for both adults and children in rainy and winter seasons which are at significant risk of cancer for Cd, and high risk of developing cancer for Cr at both adults and children (Table 29 and 30).

Table 29. LCR of water for Adults

Metals	Cd		Pb		Cr	
Season	Rainy	Winter	Rainy	Winter	Rainy	Winter
LCR	BDL	1.7×10^{-3}	BDL	BDL	BDL	8.6×10^{-5}

Table 30: LCR of water for Children

Metals	Cd		Pb		Cr	
Season	Rainy	Winter	Rainy	Winter	Rainy	Winter
LCR	BDL	1.2×10^{-3}	BDL	BDL	BDL	8.6×10^{-5}

4.5 Heavy Metal Distribution in the fish of Turag River:

Non-Carcinogenic risk

The result of the heavy metal analysis in the samples of fish collected from the study area is given in Table 31. The mean concentrations of heavy Fe, Cd, and Cr in different species of fish are above the WHO limit only Cu and Pb in below the WHO permissible limit. So, people should be worried about its bioaccumulation over time as higher concentrations of heavy metals can even cause irreversible brain damage (WHO 2008). Lead is a commutative poison and a possible human carcinogen. It may also cause the development of autoimmunity in which a person's immune system attacks its cells. This can lead to joint diseases and ailments of the kidneys, circulatory system, and neurons (Lawrence 2014). Cadmium exposure has been reported to enhance kidney damage and hypertension (Yujun *et al.,* 2011; Sivaperumal *et al.,* 2007; Lawrence 2014). Humans are exposed to cadmium through food and the average daily intake for adults has been estimated to be approximately 50 mg (Calabrese *et al.*, 1985). The threshold for acute cadmium toxicity is reported to be total ingestion of 3-15 mg/day. Severe toxic symptoms are reported to occur with ingestions of 10-326 mg. Fatal ingestions of cadmium, producing shock and acute renal failure, occur from ingestions exceeding 350mg (NAS-NRC 1974,1975,1977,1982). Chromium is an essential trace element (Mertz 1969) and the biologically usable form of chromium plays an essential role in glucose metabolism. It has been estimated that the average human requires nearly 1 g. Deficiency of chromium results in impaired growth and disturbances in glucose, lipid, and protein metabolism (Calabrese *et al.*, 1985). It has also been reported that long-term exposure to Cr can cause damage to the liver, kidney circulatory, and nerve tissues, as well as skin irritation (Tseng *et al.*, 2003; Smith *et al.*, 1992]. Excess amount of iron (more than 10 ppm) is reported to cause a rapid increase in pulse rate and coagulation of blood in blood vessels, hypertension, and drowsiness (WHO 2008). As it is well known that one of the most important factors that play a significant role in heavy metal accumulation in aquatic animals is metabolic activity (US EPA 1985; Kabata 2011.

Table 31. The concentration of the selected heavy metals in the fish samples with their mean values

Metals / Fish	Cd(mg/L)	Pb(mg/L)	Cr(mg/L)	Cu(mg/L)	Fe(mg/L)
Khalisha	1.52	0.58	1.1	1.101	1370
Tengra	0.03	0.24	1.3	3.87	544.7
Punti	0.89	0.41	0.69	5.44	960.2
Mola	0.14	0.11	0.09	4.44	875.6
Taki	0.17	0.08	0.07	0.86	722.3
Mean	0.55	0.28	0.65	3.14	894.5

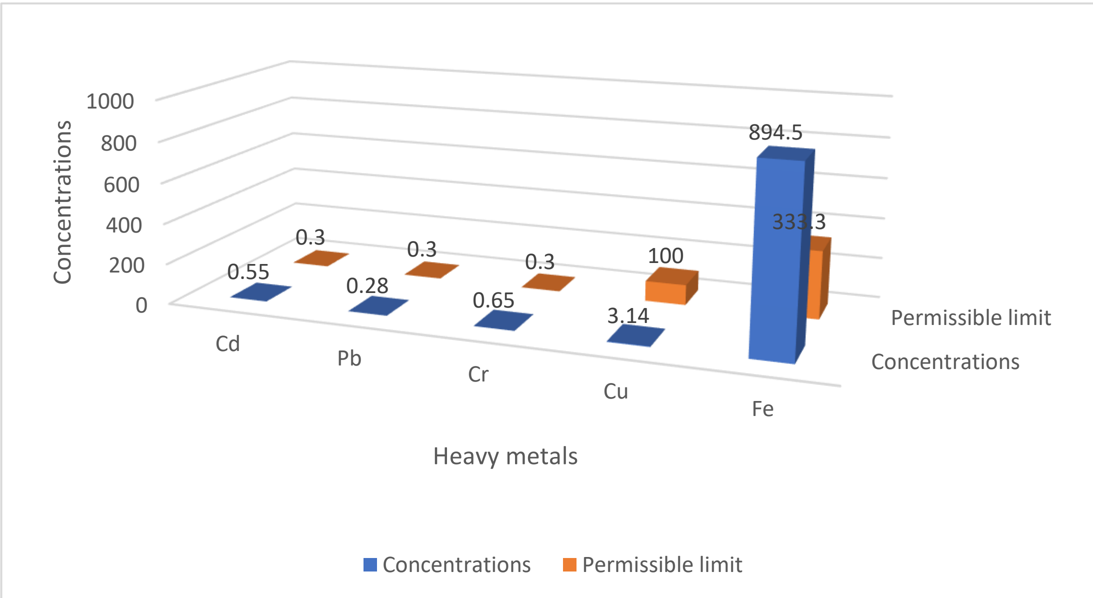

Figure 7: Comparison between average values of different metals in fish with their permissible limit.

Determination of target hazard quotients (THQ): The Target Hazard Quotient (THQ) is defined as the ratio of the exposure and the reference doses, it expresses the risk of non-carcinogenic effects. A THQ value less than 1 means the level of exposure is less than the reference dose, implying that there will not be any obvious risk. Thus, daily exposure at this level is not likely to cause any adverse effects during the lifetime of an individual. On the other hand, a population exposed to a dose equal to or greater than the RfD will experience health risks, and therefore calls for concern (Yujun *et al.*, 2011). The method for the determination of THQ was provided in the United States EPA Region III risk-based concentration table (USEPA, 2000). The dose calculations were carried out using standard assumptions from an integrated United States EPA risk analysis.

Table 32. THQ of fish

Metals	Cd	Pb	Cr	Fe
THQ	5.78×10^{-4}	7.35×10^{-5}	1.36×10^{-4}	0.104

Carcinogenic risk

The carcinogenic risk (TR) was assessed from the concentration of Cd, Cr, and Pb in fish species. Cd, Cr, and Pb have noncarcinogenic and carcinogenic effects based on exposure dose. The cancer risk value of Pb is 2.5×10^{-9}, Cd is 3.5×10^{-9}, and Cr is 2.5×10^{-9}. Pb, Cd, and Cr are probable carcinogens based on animal studies (USEPA). The reference value for cancer risk is ranged from 10^{-6} to 10^{-4}. If the TR value is below 10^{-6}, the risk of cancer is negligible and TR value of more than10^{-4} is not safe for humans that may cause cancer (USEPA 1989, 2010). In the present study, cancer risk for Pb, Cd, and Cr was several times below the reference value. Consumption of the present study fish species is exposed to Cd, Pb, and Cr with a lifetime of no cancer risk the for rainy season.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Through the outfalls positioned at several sites along the river, the Turag River has long been receiving a sizeable volume of home and industrial sewage. In addition, the pollution of the river's water, sediment layer, and fish is a result of surface runoff and subsequent rains. The main findings of the current study are presented in this chapter along with suggestions for more research.

5.1 Conclusions

Heavy metal abundance in the top layer of the river bed is shown by analysis of heavy metals in the Turag River. Cr, Cu, and Fe were discovered to be present in moderate to high concentrations in the sediments, water, and, fish of the Turag River. Fe>Cu>Cr>Pb>Cd are the heavy with the mean concentrations that were examined in this study.

The untreated industrial wastes with Fe, Cu, Cr, Cu, and Pb as the main contaminants have severely polluted the Turag river sediments, water, and fish all over the stations which covered the area from Amin Bazar Bridge of Gabtoli to Ashulia Bridge. The nearby industrial regions and urban wastewater discharge may be the likely sources, trapping the metals in the river. As there are several brick kilns and different ready mixes nearby are the possible sources of the pollution of river water and bed sediment, which is frequently contaminated with different metals. This is demonstrated by the sample from this area having a significant amount of heavy metals present.

The municipal and industrial effluents of that region's likely sources for the worsening of sediment and water quality include untreated and/or partially treated waste inputs.

Results indicated that Station 7 (near Ashulia Bridge) had the lowest amount of total sediment and water contamination, which may be due to the absence of large-scale enterprises. Additionally, the kinetics of the deposition of the sediment and associated adsorbed heavy metals are significantly influenced by river hydrodynamics and bathymetry.

The information from this study will be useful for managing future ecological hazards to the delicate Turag River ecosystem as well as for quantifying the amounts of trace element contamination.

5.2 Recommendations for the further studies

For additional investigation and in-depth study, other heavy metals (Ni, As, Mn, Al, Hg) as well as other factors like organic content, total organic carbon, sediment oxygen demand, moisture content, and so on, may be taken into consideration.

It is possible to evaluate the heavy metal contamination in water samples and create a link between the heavy metal contamination in sediment, water, and fish samples.

For a more thorough examination, more rivers and significant canals around Dhaka city may be taken into account.

It is possible to create maps of sediment pollution using GIS and remote sensing. With the use of GIS and remote sensing, river pollution may be shown for data aggregation, transmission, and visualization. This includes employing all of GIS's modeling, DBMS (Database Management Systems), and data overlaying features. These technologies would be beneficial for managing and making decisions affecting natural resource processes.

Future research might include more analyses of water, sediments, and river fish to discover a seasonal change in the trace elements.

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Appendices

Appendix-1: Concentrations of water in turag river

metals / stations	Cd(mg/L)		Pb(mg/L)		Cr(mg/L)		Cu(mg/L)		Fe(mg/L)	
	Seasons		Seasons		Seasons		Seasons		Seasons	
	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
Station-1	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	3.61	3.68
Station-2	BDL	0.49	BDL	BDL	BDL	BDL	BDL	BDL	0.98	1.16
Station-3	BDL	0.16	BDL	BDL	BDL	BDL	BDL	BDL	1.73	2.18
Station-4	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.64	2.31
Station-5	BDL	0.5	BDL	BDL	BDL	0.3	BDL	BDL	BDL	BDL
Station-6	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2.61	2.88
Station-7	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.4	0.48
Station-8	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.44
Station-9	0.04	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

Station-10	BDL	0.27	BDL	BDL	BDL	0.21	BDL	BDL	BDL	BDL
Station-11	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.76	0.81

Appendix-2: Concentrations of sediment in turag river

metals / stations	Cd(mg/kg)		Pb(mg/kg)		Cr(mg/kg)		Cu(mg/kg)		Fe(mg/kg)	
	Seasons		Seasons		Seasons		Seasons		Seasons	
	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter	Rainy	Winter
Station-1	0.11	0.14	2.58	3.71	201	239	28.91	30.88	1797	1855
Station-2	0.36	2.22	6.74	4.68	169	208	62.87	39.71	1667	1885

Station-3	0.17	1.29	1.71	2.56	88	98	47.15	23.28	1442	1837
Station-4	3.81	2.14	2.71	2.37	119	117	27.1	23.33	1331	1873
Station-5	0.27	1.67	5.11	4.5	89	101	46.44	28.99	1653	1870
Station-6	0.46	2.12	3.56	0.34	136	126	6.84	22.7	1567	1842
Station-7	3.27	1.53	6.4	4.15	97	103	42.38	27.33	1278	1829
Station-8	2.11	2.18	2.43	6.05	130	150	10.51	40.93	1363	1872
Station-9	0.84	1.71	1.77	4.62	141	147	10.88	32.41	1779	1813

Station-10	0.63	3.05	0.63	7.45	43	48	13.03	37.22	1810	1796
Station-11	1.66	3.72	2.67	12.85	78	81	11.63	49.62	1653	1677

Appendix-3: Heavy metal concentrations(mg/kg) on the surface sediments of major rivers in India and Bangladesh with average shale values of unpolluted sediments

Element	LG[a]	U & MG[b]	LB[a]	MB[b]	MEG[a]	IA[b]	LT[c]	Average Shale
Fe	38000	21600	42200	29000	46500	29000	41076	47200
Cd	-	-	-	-	-	-	-	30
Cr	82	52	110	100	130	87	97	90
Pb	15	25	19	13	22	15	24	20
Cu	23	21	28	17	32	28	49	45

LG= lower Ganges: U&MG: upper and middle Ganges; LB: lower Brahmaputra; MB: middle Brahmaputra; MEG: Meghna; IA: Indian average; LT: lower Turag

a Datta and Subramanian (1998) b Subramanian et al. (1985)

c This study (average) d Turekian and Wedepohl (1961)

Appendix-4: Toxic response factor

Metals	Cd	Pb	Cr	Cu	Fe
T_r	50	5	2	5	1

T_r =Toxic response factor Zhang *et. al.* (2014)

Appendix-5: The permissible limit of water

Elements	Permissible limit (mg/kg)
Cd	0.5-0.75
Pb	0.1-0.15
Cr	0.1-0.15
Cu	0.1-0.15
Fe	0.2-0.3

(WHO, 2004,2011; US-EPA, 2017)

Appendix-6: RfD and CSF values used in this study for water and sediments

Elements	RfD_{ing}	RfD_{inh}	RfD_{der}	CSF_{ing}	CSF_{inh}	CSF_{der}
Cd	3×10^{-3}	2.86×10^{-5}	6×10^{-5}	0.5	-	41.0
Pb	4×10^{-2}	4.03×10^{-2}	1.2×10^{-2}	-	-	-
Cr	1×10^{-4}	1×10^{-4}	1×10^{-5}	0.38	-	6.3
Cu	3.5×10^{-5}	3.25×10^{-3}	5.25×10^{-4}	0.0085	-	0.042

(Kamunda, et. al. 2016; UEP, 1991)

Appendix-7: RfD values for fish

Metals	Cd	Pb	Cr	Cu	Fe
RfD(mg/kg/day)	1×10^{-4}	4×10^{-3}	5×10^{-3}	-	9×10^{-3}

(USEPA, 1985)

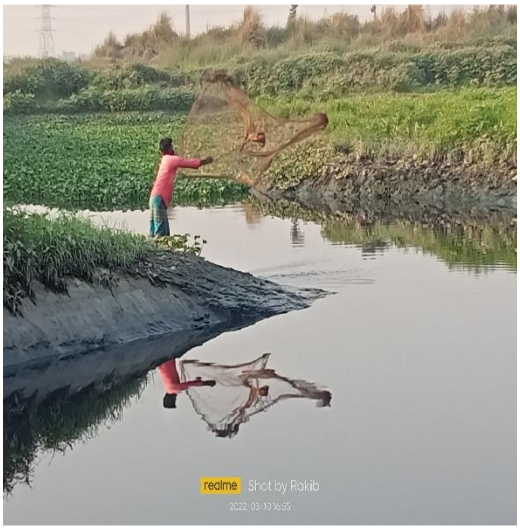
Appendix-8: The permissible limit of heavy metals in fish

Metals	Cd	Pb	Cr	Cu	Fe
Concentrations(mg/kg)	0.05-0.3	0.3	0.05-0.3	100	333.3

(FAO/WHO, 2002)

Appendix-9:Some photographs of research work

Sample collection



Sample Preparation and digestion:


novAA


novAA