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Negative Effects of the Urban River Pollution on the Environment and Human Health in Bangladesh

Kudrat-E-Khuda (Babu)*†, Md. Riaduzzaman*, Tahmina Akter and Sumaia Akther***
*Department of Law, Daffodil International University, Dhaka, Bangladesh
**Department of Law, University of Portsmouth, United Kingdom
†Corresponding author: Kudrat-E-Khuda (Babu); kekbabu@gmail.com

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ABSTRACT

Based on research findings, Bangladesh's river water, crucial for domestic, agricultural, and industrial use, has long been in a terrible situation. There have been numerous instances of significant contamination in the waterways surrounding Dhaka city, including the Buriganga River, and in Chattogram city, including the Karnaphuli River, over the past 40 years. The existing data demonstrate that other urban rivers, particularly Karatoa, Teesta, Rupsa, Pasur, and Padma, are also in severe condition due to the disposition of huge pollutants. Contaminants flowing with the water have severely polluted the downstream areas of the rivers. High metal concentrations are frequently observed in river water during the dry season. In the Buriganga River and at certain locations in the Turag, Balu, Sitalakhya, and Karnaphuli Rivers, the presence of dissolvable oxygen (DO) is nearly zero. NO_3, NO_2, and PO_4^{-3} pollution has also occurred in many rivers. Most rivers have Cr, Zn, Fe, Pb, Cu, Cd, Mn, As, and Ni concentrations beyond the legal limit for drinking water. In contrast, some rivers have metal concentrations above the legal irrigation water limit. The majority of the rivers, particularly the peri-urban rivers in Dhaka city, Teesta, Korotoa, Rupsha, Karnaphuli, and Meghna Rivers, have significantly higher metal concentrations, according to sediment data. Metal concentrations in sediment are generally higher than USEPA standards in most rivers. Metal concentrations in fish and crops demonstrate metal bioaccumulation. The trend in metal concentration follows the order of water, fish, and sediment. It has been shown that crops irrigated with tainted water contain dangerous metals. The analysis of daily intake data on carcinogenic and noncarcinogenic substances reveals that consuming contaminated food can seriously impact human health.

INTRODUCTION

Without water, a precious natural resource, life on Earth would not be imagined. Other planets don't have water like Earth, making them uninhabitable for living species. The oceans and seas comprise 97% of the planet's water, often salty and worthless (Ranjan 2020). Only 3% of water is considered freshwater, and 2% is frozen in ice and glaciers, both unusable water sources (Ahaduzzaman 2017). The only water supply for human consumption is the final 1%, kept in lakes, canals, and underground reservoirs (Sakamoto & Ahmed 2019). Therefore, appropriate water management and sustainable planning are crucial to maintaining life on Earth.

Before the industrial revolution in the eighteenth century, the concepts of water scarcity and water pollution were unthinkable (Uddin & Jeong 2020). But now, it has become one of the major concerns as millions of people suffer from various health hazards caused by water pollution. Developed nations like the USA, Japan, and South Korea have created numerous effective technologies and national strategies over time to ensure that their citizens have access to safe water (Akindele & Akinpelu 2020). On the other hand, developing and underdeveloped countries are struggling with severe water resource crises as they cannot develop a proper water resource management system. Bangladesh is a developing country with a serious water resource crisis (Islam 2019).

The riverine nation has at least 238 important rivers, the minor tributaries of the Ganges, Brahmaputra, and Meghna, and large transboundary rivers (Gray 2010). Karnafuli, Jomuna, Surma, Kushiyara, Padma, Tista, Atrai, Dudhkumar, Mohananda, Sitalakhya, Rupsa, Pasur, and Dharla are a few of the significant and prominent rivers. Earlier, irrigation completely depended on river water in Bangladesh (Doza et al. 2020). Farmers depend on groundwater for irrigation as the river water is highly contaminated (Sarkar et al. 2020). Moreover, the groundwater level is declining gradually due to intensive continuous exploitation, posing a serious threat to living species as toxic materials. Arsenic contamination currently affects millions in Bangladesh (Reza & Yousuf 2016). Most industries are set up on the rivers' banks and dump thousands of tonnes of waste into the rivers daily. Although laws and norms govern this, they virtually never adhere to them.

Also, because of high-profit objectives, several industries do not operate effluent treatment plants (ETPs). Consequently, the river water has become hazardous for living species, while the agricultural areas are also badly affected (Sultana et al. 2019). Farmers are irrigating their fields with tainted river water, which allows hazardous substances to enter the food chain and, eventually, the human body. It is extremely dangerous for people from low-income families to use this tainted water for cooking and washing. Rivers surrounding the city areas are getting more contaminated due to increasing industrialization. Sitalakhya, Balu, Turag, and Buriganga are the adjoining rivers of Dhaka, the capital city of Bangladesh, and they are nearly dead due to continuous pollution (Whitehead et al. 2019).

In summer, the water of Buriganga River looks dark black, like burned mobil, and smells bad. On the other hand, the Karnaphuli River in Chittagong, the country's port city, is being severely polluted by waste materials such as hundreds of ship-breaking industries on its bank. Several areas of the lower basin's irrigation system use river water, polluted by toxic chemicals, oils, Mobil, and tonnes of iron elements. Bangladesh has a population of approximately 162.7 million, according to the latest figure from the Bangladesh Bureau of Statistics.

To feed this vast population, only 59.8% of the total agricultural land (14.3 million ha) is accessible (Islam et al. 2018). Farmers use a large amount of inorganic fertilizer, insecticides, herbicides, and pesticides every year, hoping for more yield. Most of these are dissolved in water and move to the lower basins, eventually ending up in the rivers. In most rivers, the concentration of Pb, Cr, Cu, Ni, As, Mn, Zn, Fe, and Cd is over the standard limit for drinking water, while several metals are even beyond the recommended level for irrigation water. Most rivers have much greater metal concentrations, especially the peri-urban rivers in Dhaka, Rupsha, Korotoa, Karnaphuli, Meghna, and Teesta Rivers (Bashar & Fung 2020). Metal concentrations in sediment are generally higher than USEPA (United States Environmental Protection Agency) standards in most rivers.

The metal concentrations in fish and crops indicate metal bioaccumulation. The trend in metal concentration is like the water-fish-sediment sequence. Crops irrigated with contaminated water are found to contain harmful metals. The analysis of daily intake data on carcinogenic and noncarcinogenic substances reveals that consuming contaminated food can seriously impact human health. Sometimes, farmers apply pesticides, which are banned by the government, to their crops for more profit (Alam et al. 2020). Every year, agricultural chemicals worth millions of tonnes enter the country illegally to meet the farmers' demand.

However, the farmers are unaware of the negative effect of these toxic chemicals. Several years back, plenty of fish of many species was available in the neighboring field of agriculture water bodies. There is hardly any fish in fields and water bodies as the water quality has become extremely poisonous due to agricultural fertilizers and pesticides. This study's primary objective is to gather and evaluate existing studies on Bangladesh's rivers' water quality during the previous 40 years.

The source and trend of the pollution will be highlighted here using relevant figures and tables. The risks to human health and the environment posed by river water pollution have been displayed using the metal consumption, toxicity, and ecological risk indexes. Moreover, future challenges have also been discussed based on the current pollution scenario. On top of that, important strategies for sustainable water resource management have also been suggested in this paper.

MATERIALS AND METHODS

Throughout the study, both primary and secondary data were used. The previous paper's data and material were all gathered and utilized from primary and secondary sources. Books, periodicals, national and international legal reports, acts, and other secondary data sources are included. The data was assembled chronologically from various books, journals, booklets, sessions, bulletins, souvenirs, and reports by different institutions and organizations. Elsevier, the Internet, and Bangladesh Today, a news outlet, were used to gather the essential evidence and data. The chosen data shows that there has been serious contamination in the rivers surrounding Dhaka city over the past 40 years (taken from the chosen stations between 2021 and 2022).

It also demonstrates that other urban rivers, particularly Karatoa, Teesta, Rupsa, Pasur, and Padma, are also in severe condition due to the disposition of huge pollutants. Contaminants flowing with the water have severely polluted the downstream areas of the rivers. High metal concentrations are found in the river water during the dry season. In the Buriganga River and at certain locations in the Turag, Balu, Sitalakhya, and Karnaphuli Rivers, the dissolvable oxygen (DO) level is nearly zero. NO_3, NO_2, and PO_4^{-3} pollution have also occurred in many rivers. Research papers, thesis papers, books, articles, conference papers, and reports from various Govt. organizations, including the DoE (Department of Environment), have all been used to try and compile information about river contamination.

All of that data's conclusions have been included in this report as tables and figures. However, it is difficult to get a clear state of pollution trend due to differences in several factors such as the source points, time and data, process, and parameter selection for data analysis and sample collections. This is why the data in the statistics are not consistent. However, the key figures point out that river contamination is, at present, in a very serious state. The existing data collected from the studies conducted in recent times show an exceptionally low state of pollution in the river water, which could be attributed to these factors or certain effective initiatives taken by the government and public on water management. Therefore, considering these circumstances, an in-depth study is necessary to analyze river pollution thoroughly.

RESULTS AND DISCUSSION

Bangladesh was recently elevated from a low-income country to a lower-middle-income country (LMIC) in the World Bank's classification system (LIC). By 2021, laws are expected to have been upgraded from LDC to LMIC status according to the United Nations categorization. The country's gross domestic product (GDP) increased at its highest-ever rate of 7.86 percent in the 2017–18 fiscal year as per capita income rose to $1,751 from $1,610 in the prior fiscal year (UNCTAD 2021). Agriculture contributed 13.82 percent of GDP in the previous fiscal year, while industry and services contributed 31.18 percent and 57 percent, respectively. Mining and quarrying are included in the broad industry sector, as are manufacturing, power, gas, water delivery, and building activities.

Large and medium-sized businesses manufacture newspapers, cement, paper, chemicals, chemical products, textiles, food, leather, tobacco, pharmaceuticals, medical devices, machinery, and equipment. In the 1950s, Bangladesh started to industrialize, focusing mostly on agro-based industries like sugar, cotton, and jute. After the nation gained independence (in 1971), interest increased, but industrialization didn't get off until the late 1970s, largely due to the ready-made clothing industry (BRMG 2022). Several government initiatives, such as developing industrial estates and EPZ (Export Processing Zones), were also undertaken to stimulate industrial expansion. There were 4,560 registered textile industries in 2016-20, and about 220 tanneries, 2,500 footwear manufacturing units, and 90 big corporations are now running with leather (BRMG 2022).

There are about 257 licensed pharmaceutical companies in Bangladesh, of which about 150 are active, according to the Bangladesh Association of Pharmaceutical Industries (BAPI 2023) and the Directorate General of Drug Administration (DGDA). The Bangladesh Chemical Industries Company (BCIC) owns and operates two DAP (Diammonium Phosphate) factories, one ammonium sulfate plant, and six urea fertilizer facilities. Moreover, the Karnaphuli Fertilizer Company Limited, a joint venture between the government of Bangladesh and foreign businesses, produces urea fertilizer and additional ammonia products for export.

Additionally, Bangladesh is home to a sizable number of other industries. The current industrial growth rate negatively impacts the country's national economy and development. Bangladesh is a riverine country with over 700 rivers, including tributaries (Rakib & Fukunaga 2019). Most of them are transboundary rivers of Asia that enter Bangladesh through India and fall in the Bay of Bengal in the southern part of the country.

Fish and agriculture are mostly sourced from rivers, and canal transportation is important in many country regions. These rivers discharge a significant amount of rich silt every year. In the southern part of the country, rivers dumped over 2.4 billion tonnes of sediment, enhancing the available land for habitation. However, riverbank erosion has become one of the major concerns over the years. Since the river bed is silt, flush floods occur during the monsoon, affecting the lives, infrastructures, and crops badly.

The length of rivers, which includes various streams, canals, lakes, khals, beels, and haors, is around 24140 km (BWDB 2023). The varying temperatures and rainfall throughout the year give them and their tributaries a beautiful appearance. Some of the rivers in Bangladesh are Buriganga, Atrai, Arial Khan, Bhairab, Bangshi, Dhaleshwari, Chitra, Karatoya, Kobadak, Karnaphuli, Rupsha, Purnarbhaba, Tista, and Pasur (Fig. 1). However, the Ganges-Padma, Brahmaputra-Jomuna, Chittagong, and Surma-Meghna river systems, as well as their tributaries and distributaries, are the four principal river systems that encompass most of the country. The amount of environmental pollution created by each industrial sector, which substantially influences both the environment and public health, is one of the fundamental problems with the spread of industrialization. For instance, the tannery industry generates 232 tonnes of solid waste and around 20,000 cubic meters of liquid waste daily.

The DoE (Department of Environment) report reveals that the textile industry was responsible for generating 217 million cubic meters of wastewater in 2016, while the amount of wastewater may rise to 349 m3 in 2021 (DoE 2022). Some

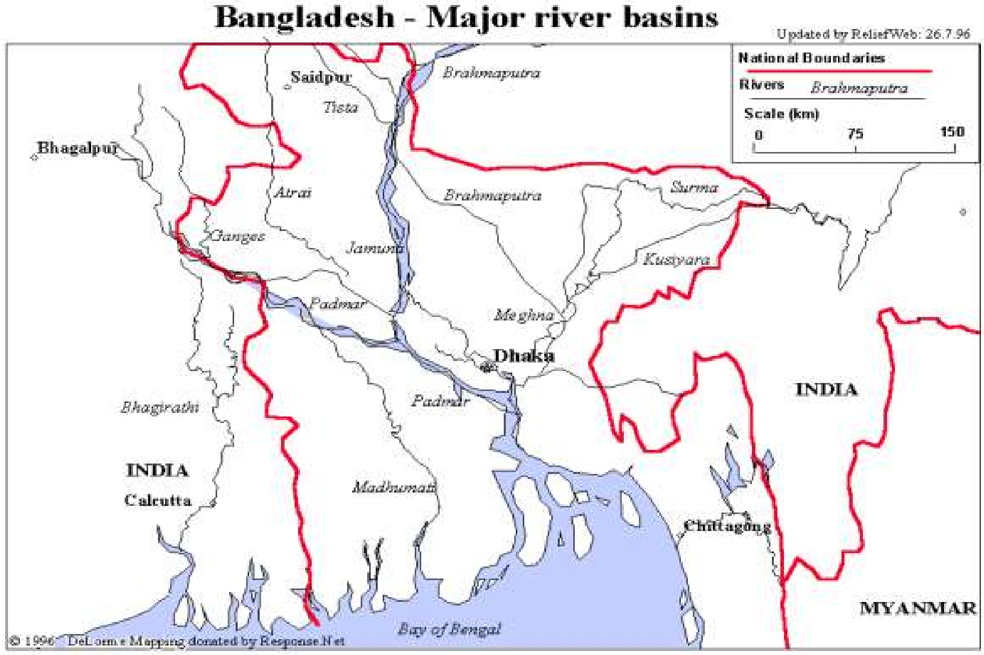


Fig. 1: Major rivers in Bangladesh.

main sources of water pollutants are dying, paper industries, pulp, sugar, and leather. Mineral resource-based enterprises, i.e., hard rock, glass, limestone, various forms of clays, and sands, are examples of non-renewable local resource-based industries, and cement and fertilizer factories are the prime polluters in this category. Metalworking, pharmaceuticals, textiles, petroleum, and plastics are among the industries that primarily rely on imported raw materials, and many of them are proven to be extremely polluting. The prime sources of water contamination in Bangladesh are depicted in Fig. 2.

In Bangladesh, open-field dumping is the main technique for removing solid and liquid trash. The liquid wastes combine with water, travel down drains to the canals, and end up in the river water. Wastes from households,

(Source: ResearchGate)

Fig. 2: Bangladesh's primary sources of water pollution.

hospitals, markets, and industries are dumped into the open field. The aerobic and anaerobic decomposition of wastes is a continuous process. Both insoluble and soluble waste materials get mixed with water during the rainy season and eventually reach the nearby canals and rivers. Most of the farmers in the country lack education, and they often apply a huge amount of agrochemicals to boost productivity.

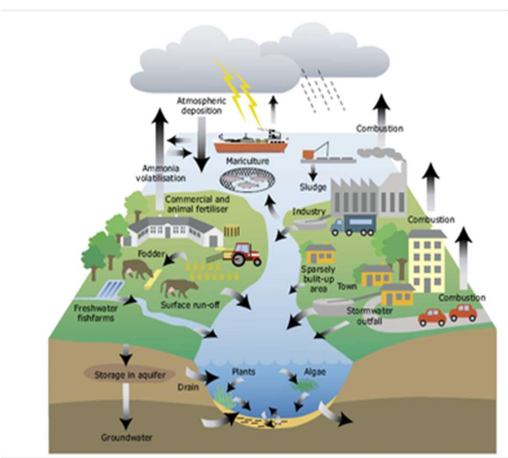
Most of these substances pollute water, pose health risks, and are swept into surface waters. Detergents, soaps, pharmaceuticals, personal care items, and oils are among the many items dispersed in water and dumped as domestic garbage into rivers. Many hazardous solid and liquid waste is also discharged into rivers, as the country has about 600 hospitals. Hundreds of launches and steamers occur daily from Dhaka city to different destinations while the passengers throw waste materials straight into the river water. These hazardous wastes contaminate the river water and settle in the southern part of Bangladesh after drifting downstream with the river currents. However, adequate data on water pollution by water vehicles is not available yet. Most of the Bazars (rural marketplace) and markets are set up on the bank and rivers, and they produce several tonnes of organic waste straightly discharged into the river.

Due to a lack of supervision and maintenance, water vehicles go bad, and accidents occur, releasing hazardous liquids into the river that pose a serious hazard to the river basin's environment and fauna—the high concentration of Fe and As have also left Bangladesh's surface and groundwater extremely polluted. The decline of groundwater level caused by the excessive extraction for various purposes also facilitates the harmful metals, particularly Fe and As, to accumulate in the groundwater. The air quality of Bangladesh is the worst in the world due to continuous pollution, while its capital, Dhaka, ranks as the second most polluted city globally. The atmospheric deposition of hazardous metals significantly impacts surface water and agricultural fields.

Due to atmospheric deposition, many metals are added to the urban rivers every year. Newaz et al. (2020) also found a high heavy metal concentration in roadside sediments. Moreover, large quantities of hazardous metals are accumulated in crops planted in the neighborhoods of urban highways. Furthermore, the number of recognized brick fields in Bangladesh is nearly 6000, while many unregistered brick fields are also operating their activities. Since most of the brick fields are set up on the banks of the river, they are significantly contributing to the river pollution in the country. The sand, soil, and silt of the Potenga Sea beach in Chattogram City were also contaminated by geologically formed radioactive elements. Many hazardous substances are also found in the water and sediments deposited in lower basins in Bangladesh's southern coastal areas. The pollution of river water by these contaminants, as well as by local pollutants, has currently become a hot topic.

Chemical materials are now used in more industries due to rapid industrialization. As a result, many organic and inorganic hazardous metals are released from these industries into the soil, water, and air. Though the problems arise in particular places and areas, their escalating incidence, size, and possible consequences make their global issues. These industrial pollutants adversely affect people's lives, either directly through toxic action or indirectly through water quality changes. Industrial, urban, and agricultural waste pollution has reached dangerous levels in several rivers and aquatic bodies in Bangladesh.

Dhaka, the capital of Bangladesh, is among the world's most populous cities, with a population of more than 16 million. On December 31, Dhaka city topped the list of worst cities worldwide regarding air quality as the capital's air



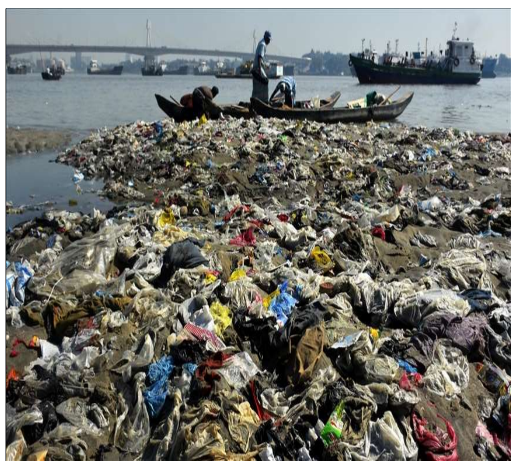


Fig. 3: & Fig. 4: River pollution in Bangladesh.

quality index (AQI) was recorded at 221. The city is situated on the Buriganga River's northern bank, while some other rivers surround it, namely Dhaleshwari, Turag, Sitalakhya, TongiKhal, and Balu.

Most of the city's factories and industries are near or along these rivers' banks (Fig. 3 and Fig. 4). On the banks of the rivers in three important sections of Dhaka city—Hazaribagh, Tejgaon, and Dhaka-Narayanganj-Demra dam—are more than 7,000 industries. A significant amount of hazardous waste from industrial regions and sewage lines and petroleum discharge from ships, launches, cargoes, boats, etc., often poison the rivers surrounding the capital city. About 60,000 cubic meters of hazardous wastes are dumped into the Buriganga and its connected rivers, i.e., the Dhaleshwari, Turag, Sitalakhya, TongiKhal, and Balu Rivers each day, mostly from nine major industrial clusters—Hazaribagh, Tejgaon, Tongi, Tarabo, Savar, Narayangonj, DEPZ, Gharashal, and Gazipur (Rai et al. 2019).

A report of Bangladesh Poribesh Andolon (BAPA 2023) reveals that the Buriganga River absorbs 6,000 tonnes of liquid waste daily, while Hazaribagh tanneries discharge 3,000 tonnes of liquid waste alone. According to the findings of another study, The Hazaribagh tanneries alone produce 88 million tonnes of solid trash and 7.7 million liters of liquid waste daily, compared to about 7000 tonnes of solid waste produced daily in and outside the Dhaka City Corporation region. This huge waste gets to the river water since domestic pipelines are linked to drains directly connected to various khals and canals. Household wastes, such as oils and chemical products used for personal care, thus, enter the river water. Moreover, hundreds of water vehicles ply the river to transport passengers from Dhaka to other destinations and contribute to river water pollution at an alarming rate.

The Buriganga River's water turns dark black and resembles burned engine gasoline during the dry season. The majority of the physicochemical characteristics of the water surpass the water standard fixed by the World Health Organisation (WHO). The dissolved oxygen in the water was 2 milligrams per liter in 2000 but turned zero in 2019, while abrupt changes in TDS, BOD, and COD are also seen. The changes might be due to the differences in various aspects such as procedure, time, and where the sample collections are kept. However, the findings of most research work clearly state that the basin area of the Buriganga River is experiencing severe pollution. The presence of heavy metals, particularly Cr, Cd, and Pb, has made the river water toxic. The research data of the last 40 years depicts that the river water turns out to be extremely poisonous in some particular periods when it becomes hazardous for drinking and irrigation. A high concentration of toxic metals is also noticed in the sediment samples as a huge amount of organic materials might be settled down in the river water with toxic metals.

Furthermore, a high concentration of toxic metals is also found in the specimens of fish taken from the Buriganga River, according to findings of certain research works. Although most of the data were below the recommended and safe limits of the DoE, they can cause serious health risks if consumed continuously. The current study data lacks essential physical and chemical examinations of the river water, sediment, and fish.

Hence, it is vitally necessary to conduct a complete investigation of organic pollutants, personal care items, pharmaceuticals, etc., to study the natural characteristics of river water, which are crucial for a successful water management system. The Buriganga River is clearly in danger, and if this pollution trend persists, The flora and fauna and people will suffer greatly, according to the research findings. The Buriganga River's water and sediment contain thirteen elements: the accumulation index (Igeo), CF, PERI, PLI, HEI, heavy metal pollution index, and NI. Akbor et al. (2020) analyzed these elements and discovered that the Buriganga River is extremely polluted with heavy metals.

Northwest of the city of Dhaka is where the Turag River is located. As the majority of the clothing industries are located on the river bank, and farmers who use they reside close to the river and use inorganic fertilizers, insecticides, and herbicides in their agricultural areas, untreated industrial wastes, agricultural runoff, and urban garbage from the slum area all have a negative impact on the water quality of this river. All these waste materials are swept with water during the rainy season and eventually end up in the river.

The extensive pollution made the Department of Environment announce the Turag River as an ecologically critical one in 2009. The water quality of the upstream river was very poor due to the extensive industrial activities in the area. Farmers irrigate their lands using the river water to cultivate crops sold in the markets. So, people who regularly eat vegetables, fish, and rice produced in this area are likely to suffer serious health hazards as toxic metals are found in them, according to the research findings. The flora and fauna's bioaccumulation of toxic metals may negatively impact human health. During the dry season, the river water looks black and stinks. According to the source and types of the discharged effluents, the pH level also varies from one point to another in the river. In addition, the dissolved oxygen (DO) in the Turag River's water is also found to be far below the recommended standards set by DoE. Besides, along with the toxic metals, high amounts of BOD, COD, and TDS are also found in the river water. The fish and sediment samples collected from the river are also found to have concentrations of toxic metals. The toxicity analysis data based on the metal concentration shows that the river water has become toxic and highly poisonous to human health and living animals.

Balu River, mainly a tributary of the Shitalakshya River, goes by through the wetlands of Beel Belai and Dhaka before it merges with the Shitalakshya at the Demerara area of Dhaka city. The river is linked to the Turag River via Tongi Khal in the northern part of the city. The river is also linked to several khals and canals, i.e., Rampura Khal, Norai Khal, and Tongi Khal. The hazardous wastes from industries are dumped into the khals and canals, where they finally find their way into the Balu River. Wastes from the TIZ, textile, pharmaceutical, food, dishwashing soap, metal, and dying industries, among others, harm the river's water.

Besides, the river absorbs wastes from municipal and agricultural fields as well. As a result of continuous extensive pollution, the DoE declared the Balu River as one of the ecologically critical rivers in 2009. The level of dissolved oxygen in the river water is nearly zero, drastically affecting the flora and fauna. The findings of some research also show the presence of excess TDS, BOD COD, and metals in the river water. The existing research data clearly state that the water of the Balu River is being polluted continuously. The research data depict many pollutants flowing to the Balu River via Tongi Khal, Norai Khal, and Tejgoan-Rampura Khal. The concentrations of pollutants in sediments are also several times higher than the recommended standard of USEPA. Farmers in the region largely depend on the water of these canals and the Balu River for irrigation. Consequently, crops are affected by various toxic substances.

Shitalakshya River is a distributary of the Brahmaputra, the source of origin of most rivers in Bangladesh. The river runs east of Dhaka city and merges with the Meghna River at Kolagachi of Munsiganj district. The water of the Balu and Dhaleshwari rivers flows to the Shitalakshya River (the Buriganga River ends in this river). Many industries are established on the bank of this river, especially in the Narayanganj district, where industrial concentration is high. Various watercraft also use the river to travel to Chandpur and Chittagong districts. Narsingdhi district also affects the river in many ways.

The Sitalakhya River is the principal water source for various daily and commercial activities, including washing, bathing, drinking, industrial use, and irrigation. However, the enterprises situated along the riverside, such as those producing textiles, pulp, paper, fertilizer, cement, jute, sugar, etc., significantly negatively impact the river water quality. The water of the Shitalakshya River also becomes more contaminated as pollutants enter the river with water from Balu and Dhaleshwari Rivers. The Sitalakhya River near Demraghat is also the raw water source for Saidabad's water treatment plant. The findings of the research state that the extensive river pollution poses serious challenges to the drinking water plant and suggest that the existing intake point is unsafe because of the presence of poisonous substances and microbial loads. In the dry season, the dissolved oxygen level is nearly zero at several points of the Sitalakhya River. The concentrations of BOD, COD, and TDS, on the other hand, have not exceeded the standard set by DoE for surface water.

However, the data analysis affirms that the designated river's basin area has also been polluted. A huge amount of pollutants is also accumulated yearly as it is linked with other extensively polluted rivers. The river water also contains a high presence of Cu, Ni, Cr, As, and Fe, exceeding the standard DoE set for surface water. The concentration of heavy metals in sediment is also found to be higher than the safe limit determined by USEPA. Direct consumption of river water is very risky as it can invite severe health problems. Moreover, transmitting poisonous substances into fish and crops (through irrigation) can also pose serious health risks to humans.

Kaliganga and Dhaleswari are the two branches of the Jamuna River, one of the three major rivers in Bangladesh. The northern branch, Dhaleswari, flows to the Shialakhya River in the lower region. The pollutants from the Buriganga River flow to the Dhaleshwari River with water. The latter river carries them down to the lower Sitalakhya River before merging with the Meghna River. In the water of the Sitalakhya River, the presence of Cr exceeds the FAO standard value of irrigation water. The values of Cd, Ni, Pb, Cr, Cu, and sediment samples collected from the Dhaleswari River are higher than those of USEPA standards.

One of the three rivers that make up the Ganges Delta, the world's biggest and most populated delta system, is Meghna, the broadest river in Bangladesh. The river, which originates in the Kishoreganj district and is part of the Surma-Meghna River System, empties into the Bay of Bengal. It absorbs silt and pollutants from Surma, Kushiyara, Padma, and Sitalakhya Rivers at its confluence with these rivers.

The river's water is the primary source for agriculture and fish, while it is also used by many industries set up along the riverbank. However, agricultural and industrial activities largely affect the river water. While Ni, Mn, and Cd concentrations are greater than the acceptable limit for irrigation water, Cd, Mn, Ni, Cr, and fe concentrations are well over the standard threshold set by the WHO for drinking water. The amounts of Ni, Cr, Pb, Zn, and Cd in the silt exceed the USEPA regulatory limit at various locations along the river. Significant metal concentrations are also present in various riverbank locations.

The study's findings demonstrate how urbanization and industrialization have significantly influenced the Balu, Turag, Sitalakhya, and Buriganga Rivers. Due to continuous extensive contamination, these rivers were declared ecologically critical by DoE in 2009. The trend of concentrations is found in several studies to be surface<sub-surface<sediment after examining the concentrations of several physicochemical variables and metals in soil, surface water, and subsurface water. The accumulation of poisonous substances in fish samples is also a serious concern for human consumption. In Dhaka, groundwater is used for domestic purposes by at least 78% of residents, while surface water meets the remaining 22% of demand. The findings of several studies reveal that the groundwater is also severely impacted by the intense pollution in the adjacent rivers. At the same time, heavy metal concentrations have also been noticed in the water samples of several areas.

Dhaleshwari and Meghna rivers are being polluted as pollutants from upper boundary rivers enter these rivers with water. The water and silt of the duo river are also being affected by anthropogenic activity. The most alarming element is that all the studies done so far only consider a few common parameters, such as TDS, pH, BOD, DO, COD, and some metals. No consideration is given to analyses of microbiological, organic, personal care, pharmaceutical, and other harmful contaminants.

Karnaphuli is the largest and most important river in the Chittagong region. The river, located in the southeastern part of Bangladesh, flows through the port city of Chittagong and the Chittagong Hill Tracts. Exporting and importing products nationally and internationally is a very important getaway. People use the water of this river, which has been severely contaminated recently, for domestic, irrigation, and industrial purposes. Industries that greatly impact river water include tanning, textile, oil refineries, spinning mills, dyeing, fertilizer, paper, steel, cement, cotton, soap, bitumen, rayon mills, and detergent factories.

Other industries include insect killer production plants, paint manufacturing, merchant ships, naval, and ship recycling. The air in Chittagong ship breaking is also polluted due to the high concentrations of organic pollutants. The values of oil and grease in the sediment collected from the river are high. Geo-accumulation index (Igeo) for Zn, Fe, Ti, Y, Zn, and Rb in silts of the ship-breaking area illustrates that the presence of these elements moderately pollutes the silts. The research data demonstrate that the quality of Karnaphuli River water is very poor as most of the physicochemical properties in the river waterfall are below the standard level recommended by DoE for drinking and surface water. The river's water is becoming dangerous for humans, flora, and fauna due to a gradual decrease in DO concentration and increased BOD and COD values. Severe pollution occurs at specific key points during the selected period.

It is evident from the EC and Cl values that the water of Karnaphuli River is comparatively salty. Therefore, the low presence of metals is found in the Karnaphuli River water (Fig. 5). However, at the locations where khals and canals merge with the rivers, high metal concentration is found, according to some studies, and it is evident that the river is being polluted uninterruptedly. For instance, according to a study by Kibria et al. (2016), the Karnaphuli River and the Bay of Bengal coastal region exhibit significant levels of Cd, Ni, Pb, U, Hg, Cr, and Cu contamination. The study recognizes the 'hotspots' of pollution and the origin of pollutants.

The level of dissolved oxygen is below 4 percent in the water of the Halda River, while the concentrations of Fe and Mn are higher than the stipulated standard set by FAO for irrigation water. Similarly, the concentrations of Cu and Pb exceed the ESEPA standard limit in the sediments of the Bakkhali River. At the same time, a high amount of Ni, Cr, Cu, Zn, and Pb is also traced in the Sangu River's water, originating from neighboring Myanmar.

Fig. 5: Karnaphuli River pollution.

Various metropolis and agricultural activities also affect the Korotoa, Teesta, Atrai, and Padma rivers in northern Bangladesh. The concentrations of Fe, Cr, Pb, As, Ni, and Mn in the Korotoa River water exceed the WHO stipulated standard limit for irrigation water. At the same time, those of Cr and Cd are higher than the FAO-recommended values. The highest concentrations of Pb, Cu, As, Ni, Cr, Pb, and Cd in the sediment of Korotoa River are determined to be 183, 163, 118, 51, 2.9, and 84 mg/kg, correspondingly. According to the analysis of Pollution Load Index (PLI) values of the existing research data, the silts of the river are severely polluted (PLI>1), particularly for the high presence of Cr, Cd, and Pb.

The Contamination Fact (CF) calculation also demonstrates a high amount of As and Cd CF>1). At the same time, the Enrichment factor (EF) analysis confirms that human activities have also affected the river. The possible causes of the pollution are the wastes released by various industries, such as textile, steel, gasoline, and tanning industries, municipal, agrochemicals, and atmospheric deposition. The presence of Zn, Cu, Pb, Cd, As, Cr, and Ni in sediments samples obtained from the Korotoa River is higher than the USEPA recommended standard, which clearly states that the river is polluted.

Islam et al. (2018) have also found heavy metal concentrations in the water and sediment of the Teesta River, which originated in the Pauhunri Mountain of the eastern Himalayas and confluences with the Jamuna River in Bangladesh, flowing through the Indian states of Sikkim and West Bengal. Teesta flows across the country's northern area, including the Ranpur and Bogura districts. Cd in the river's water is higher than the recommended value set by the WHO for drinking water. Besides, the concentrations of Fe and Mn are also found to exceed the FAO recommended standard for irrigation water.

For the first time in Bangladesh, the Positive Matrix Factorization (PMF) receptor model is used by Islam et al. (2018) for the identification of the source of pollutants and the pollution in sediment in Pasur, Teesta, Meghna, Korotoa, Sitalakhya, and Rupsa Rivers. Data obtained from Risk Index and Geo-accumulation Index demonstrates the sediment of the rivers to be severely contaminated by Cd. The findings of the studies reveal that Ni, Fe, and Mn have a significant co-occurrence network with Cr.

The data collected by the PMF receptor model recognized four sources of sediment pollution, and they are – the mixed source (for Cd), industrial (for Ni and Mn), anthropogenic (for Cd), and agricultural (for Cu and As) (for Fe and Cr). The water and sediment quality data analysis demonstrates that severe pollutant consumption has drastically affected the Teesta River. The findings of several research data also point out the presence of radioactive and toxic metals in Teesta River water that can pose serious health hazards like cancer.

On the banks of the Padma River stands Rajshahi City, the divisional city of the northern districts. This river enters Bangladesh through the Chapainawabganj district from neighboring India and flows through many districts before its confluence with the Meghna River in Chandpur. The Padma River gets many pollutants from the city through various drains, khals, and canals. The Rajshahi region has been facing severe deforestation for a long. The water of the Padma River is being contaminated continuously due to the depositing of garbage on the open field, industrial and household wastes, and direct sewer lines.

Since the region is an agricultural-based area, farmers apply many fertilizers, pesticides, and insecticides, most of which are inorganic, in their fields, and all of these materials eventually enter the river with water. In summer, an excess amount of coliform and Vibrio cholera counts are found in the river's water, according to Haque et al., 2018. The analysis of fish samples collected from the Padma River also reveals high concentrations of Cr, Cu, Cd, Zn, Pb, and Mn, which can pose serious health problems if consumed continuously.

Rapid and unplanned urbanization and industrialization in the southern part of the country largely affect the lower basin of Meghna, Kirthankhola, and Rupsa Rivers, various tributaries, and Distributary Rivers, canals, and khals as almost all of the cities are established on the river banks. Being adjacent to the Bay of Bengal, nearly every southern river contains salty water in most parts. The intrusion of salty water during the rainy season is common in this region. People nowadays complain of more frequent intrusion of salty water. The reason for this frequent intrusion may be the result of climate change. Each year, the coastal areas face natural calamities such as Aila, Sidr, and Fani that cause serious damage to crops, plantations, and households. The most important problem this region faces following any natural catastrophe is that a large area is submerged under salty water. Both the natural hazards and human activities have a severe impact on the ecology of this area.

Barisal City, one of the nation's oldest cities and river ports, is built on the bank of the Kirtankhola River and flows through south-central Bangladesh. Many wastes, including domestic and industrial effluents, used water, sewerage, and organic loads, straightly enter the Kirtankhola River from the city through various canals and khals. Moreover, the city has numerous hospitals and clinics that generate sensory waste daily.

Besides, a significant amount of garbage is also produced daily by the municipal corporation, and these are left in an open field, namely "Moilakhola," as the city does not have any waste management system to tackle sensorial wastes. Consequently, most of these wastes are washed away into the Kirtankhola River with water during the rainy season. The river water is constantly contaminated by cement, pharmaceutical, food, textile industries, brick kilns, and watercraft. Similar pollution also occurs in Khulna's Rupsha River and Rajshahi's Padma River. Generally, water from upper rivers flows to the lower point and meets large bodies such as the ocean.

Similarly, pollutants enter the rivers and eventually the Bay of Bengal. The research findings on the surface water quality in the Barishal region include high concentrations of suspended solids, turbidity, Nitrate, phosphate, and electrical conductivity in the water of the Kirtankhola River, which are above the permissible levels. Generally, the water of surface water also affects groundwater. The findings of several studies demonstrate that the quality of the upper aquifer is mostly affected by salty water and arsenic. Arsenic in groundwater is one of the long-standing problems that people of the Barisal region have been facing.

However, there is a lack of enough research data on metals and other organic and inorganic pollutants, and it cannot be determined how bad or good the water of the Kirtankhola River is. Pashur, a distributary of the Ganges River, flows in the southwestern region of Bangladesh, while the Rupsha River is the continuation of the first one. The concentrations of Nitrate in the Rupsha River water are also higher than the safe limit recommended by FAO for irrigation. The metal concentrations are also noticed above the permissible limit at several river points.

The research findings reveal a high amount of Fe, Pb, Cr, Mn, and Ni in the river water at several points, and it exceeds the standard values recommended by WHO and FAO for drinking and irrigation water, respectively. The wastes from Khulna City and anthropogenic activities are the primary sources of pollution in that area. In addition, the groundwater of that region contains a high concentration of natural arsenic which forces people to use the surface water for drinking, household activity, and irrigation purposes. Therefore, pollution in surface water adds to the woe of the people in that region. The water of Rupsha River contains higher concentrations of Cd, Ni, As, Pb, and Cr, while eighty-five percent of the samples pose a mild ecological concern. Khulna region is very popular for shrimp farming which may contribute to further pollution there. The sediments collected from the Rupsha River also contain a high amount of Zn, Cu, Pb, Cd, As, Cr, and Ni, higher than the standard level recommended by USEPA, hinting that the river is highly polluted.

Research papers, thesis papers, books, articles, conference papers, and reports from various government organizations, including the Department of Environment, have all been used to try and compile information about river contamination. Tables and figures presenting the results of all those data have been included in this publication. However, it is difficult to get a clear state of pollution trend due to differences in factors such as the source points, time, data, process, and parameter selection for data analysis and sample collections. This is why the data in the statistics are not consistent.

However, the key figures point out that river contamination is, at present, in a very serious state. The existing data collected from the studies conducted in recent times show an exceptionally low state of pollution in the river water, which could be attributed to these factors or certain effective initiatives taken by the government and public on water management. Therefore, considering these circumstances, an in-depth study is necessary to analyze river pollution.

Since Bangladesh is a riverine country, most soils fall within the 'Inception' category, demonstrating that they are formed continuously. During rainy reason, a huge amount of sediment is accumulated in the soils of riparian areas. As silty soil is usually more fertile, farmers prefer this type of soil for cultivating various crops and vegetables. Furthermore, the growers can easily use the river water for irrigation as it is cheap and easily available. Currently, most rivers are polluted with a high concentration of heavy metals, a large portion of which ultimately accumulate in soils and enter the food chain through irrigation.

According to Uddin et al. (2014), the soil samples taken from the Shitalakshya River had values of 86, 36.24, 17.75, and 0.12 mg/kg of Zn, Cu, Pb, and Cd, respectively. For experiment purposes, Kalmi (Ipomoea aquatic), one type of vegetable, was cultivated on a piece of land close to the Sitalakhya River, and the river water was used for irrigation. The concentration of Zn, Cu, Pb, and Cd in the harvested vegetable (growing time: 35 days) was 113.16, 36.69, 14.07, and 0.08 mg/kg, respectively. Some researchers have found high concentrations of toxic metals by analyzing and comparing the soil samples collected from the river basin area with uncontaminated soil samples. A huge amount of heavy metals is also found in the crop cultivated and irrigated in the polluted soil and by river water respectively than the crop is grown in pure soil and with safe water. Most of the researchers found that the soil, water, and crops they took from the farmland next to the contaminated river had a significant level of toxicity. Aside from these few investigations, very little is known about the metal concentrations in the upper soil layer. Significant research is needed to examine the concentration of heavy metals in the upper soil layer to better understand how heavy metals travel from rivers to agricultural soil and from soil to crops.

The pattern of metal concentration trend in the Buriganga, Turag, Sitalakhya, and Meghna rivers is nearly alike –water from fish and fish from sediment. However, the metal concentrations in the Buriganga River are comparatively higher than the remaining three rivers. While the trend for Cd is similar for the rivers Turag, Buriganga, Sitalakhya, and Meghna, the level of Pb and Cr in fish samples from the Buriganga and Sitalakhya rivers is also found to be high.

When a chemical enters an organism through any exposure channel (water, sediment, soil, air, or diet), the process is known as bioaccumulation and is quantified by a bioaccumulation factor (BAF). According to the existing research data analysis, the BAF trend of all metals is like Turag < Buriganga < Sitalakhya < Meghna. However, the Buriganga River has a significantly greater BAF of Cr. The following are the bioaccumulation sequences in Turag, Buriganga, Sitalakhya, and Meghna: CrPbCd, CdCrPb, CdPbCr, etc.

Sarah et al. (2019) showed that the bio-concentration of metals in fish liver and kidney occurs in the following order: Fe-As-Cd-Zn-Pb and Zn-Fe- As-Cd-Pb, respectively. The existing data have been chosen for this paper through a random selection process (though our target was to collect data on water, silt, and fish from a particular year's research works, it was sometimes troublesome because of the lack of enough available research data). Though metal concentrations in the river water were low, they were higher in fish. The reason for this difference might be the bioaccumulation of metals into fish. In addition, large quantities of toxic metals may be dumped by various pollutant outlets with water, and most of them are stored in sediments. At the same time, the uninterrupted deposition increases their concentrations above the toxic limit. About 90 types of vegetables and 60 types of fruits are grown in Bangladesh, most of which are cultivated during winter.

The existing research data shows that the river water's pollution level is comparatively high this season. In Bangladesh, riverbanks are ideal for growing vegetables since water is simply available for irrigation. Crops cultivated around the riverbank with river water are more prone to high concentrations of toxic metals. Some researchers have also identified the presence of a heavy load of metals in crops cultivated in the polluted area and with the water from the polluted river. The findings of Khan et al. (2014) demonstrated the high presence of specific metals in the crops cultivated in the surrounding areas of the Buriganga River. The vegetables gathered from various markets and bazaars in Dhaka city also have high levels of heavy metals. According to the research data findings, vegetables cultivated in urban areas accumulate more heavy metals than those in rural areas. A high presence of metals, particularly Pb, is noticed in the vegetables grown in roadside areas. The analysis of geo-accumulation index values reveals that the soils of the Dhaka city area are extensively contaminated. A high amount of Cd, Ni, Pb, Zn, As, and Cr is also identified in the agricultural soils of the city areas in the country.

In this case, the primary source of metal contamination is the massive use of agrochemicals and polluted river water. Ecologically, Bangladesh has been facing arsenic problems in its water, soil, and even crops. Generally, a high accumulation of arsenic is found in crops irrigated with water with a high arsenic level. And crops, including rice and vegetables contaminated by arsenic, are consumed in many areas of the country. Thus, we take the metals in our bodies by consuming the accumulated crops. As a result, routinely consuming contaminated foods will result in a high concentration gradient of hazardous metals in the body, which may lead to both non-cancerous and cancerous health issues.

Along with surface water, groundwater, the most important safe water source, is also affected due to the continuous accumulation of heavy metals. In Bangladesh, about 96% of people rely on groundwater, which meets nearly 86% of Dhaka city's drinking water demand. The Dupi Tilla sand aquifer, which lies under the Modhupur clay layer and has a 10m thickness, is Dhaka's key groundwater reservoir. Generally, the thickness of the aquifer ranges from 100 m to 200 m. The surrounding rivers to which this aquifer is exposed facilitate groundwater recharge to the aquifer.

Due to extensive exploitation and contamination, groundwater is unsafe and cannot be used without proper treatment. The groundwater level dropped by nearly 20 m in the last decade while 70 m since 1990. The deep tube wells installed by the DWASA for extracting groundwater must be repositioned due to river pollution. Groundwater is more likely to be polluted by contaminants moving into groundwater downward from nearby contaminated rivers. The findings of Khan et al. (2014) revealed that harmful metals in river water and soil leach with infiltrating water and mix with groundwater, posing a serious health risk. Metal concentrations in groundwater may rise as a result of excessive groundwater exploitation. These concentrations in the aquifer may also rise if a high amount of metals deposited in riverbed silt get mixed with groundwater flow.

In Dhaka city, approximately 1% of tube well water has a high concentration of Pb than the standard level recommended by WHO for drinking water. As DDT, ammonia, Fe, Ni, Co, Nitrate, Mn, arsenic, and B have been found in groundwater in significant amounts across the nation, the extensive use of inorganic fertilizers, herbicides, and insecticides has an effect on groundwater. Both surface and groundwater are continuously contaminated due to various natural processes and anthropogenic activities. Pollutants move into the aquifers, the main source of drinking water in Bangladesh, during the recharge process of groundwater between the river water and aquifers.

Water contamination is causing major health problems for people living in developing countries, and surprisingly, most people have little knowledge about the cause of their suffering. Asia has the largest concentrations of dissolved heavy metals among the five continents (these continents are: North America, South America, Europe, Asia, and Africa)- while Europe has the lowest concentrations. Asia saw the greatest decline in cancer risk owing to Cr contamination from 1970 to 2017, followed by Africa and North America. However, the existing research data analysis reveals that Bangladesh is experiencing severe Cr pollution.

People in various parts of the country have long been facing serious health hazards caused by arsenic in both surface and groundwater. Moreover, the researcher has found bioaccumulation of toxic metals in the fish samples collected from rivers. The excessive presence of different harmful metals is also found in the foods cultivated in the surrounding areas of polluted rivers or with the water of contaminated river water. When people consume these foods, these metals enter the human body, causing various toxic effects.

Also, human health is very vulnerable to various diseases due to hazardous microorganisms in surface water. Common diseases caused by consuming contaminated water include cholera, typhoid, diarrhea, fever, dengue, viral hepatitis, and gastroenteritis. Because of the severe surface and groundwater contamination, many people in Bangladesh suffer from waterborne hazards yearly. The hazardous level in heavy metals is often calculated using several variables, including target TR, HI, and THQs, and compared to a predetermined set of values. Human health is very vulnerable to potential diseases when the value of THQ is >1. On the other hand, if TR is > 106, there is a chance of adverse health effects.

Islam et al. (2018) demonstrated the excessive presence of THQ (THQ>1) for Pb in vegetables and As in grains, which can be fatal for human health. In Karatoa River, adjacent to Bogura City, the value of TR is found to be>106 for intake of Pb and As from food, suggesting the risk of serious cancer. Besides, water samples from Teesta, Pashur, Meghna, Sitalakhya, Karatoya, and Rupsa Rivers have also been examined to determine the status of As, Pb, and Cr and their possible threat to public health. According to the analysis of HI value, people, especially children, and adults, are exposed to serious health risks if they consume water from these rivers. Furthermore, the presence of Cr was higher than USEPA's recommended value for drinking water, which can also pose a serious threat to public health.

Ali et al. (2020) assembled six fish samples from the vicinity of Karnaphuli River and examined the concentration

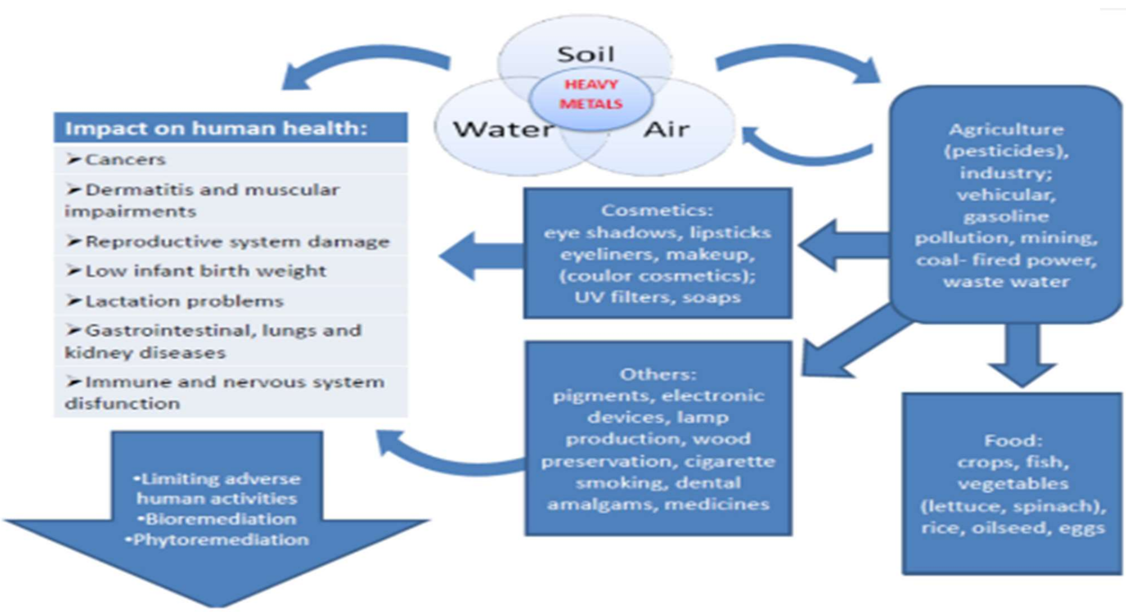


Fig. 6: Heavy metals and human health.

of heavy metals in them. According to the THQs and TR values of the analysis, people consuming these fish are vulnerable to noncarcinogenic and carcinogenic health consequences. People living in the southwestern (Turag-Buriganga- Dhaleshwari) region in Dhaka city are also exposed to severe health risks due to the analyzed HQ and HI values in the groundwater of that area. Besides, people consuming vegetables cultivated in the basin area of the Buriganga River are also vulnerable to deadly cancer problems since the TCR value for Cr, Ni, and Pb in these grains is found to be higher than the USEPA-recommended value. Hasan et al. (2020) also examined the concentrations of ten heavy metals in the fish samples taken from the Dhaleshwari River and found the excessive presence of Ni and Cr.

Humans consuming these contaminated fish are subject to experiencing various carcinogenic (TR>104) health hazards. The presence of Pb, Cd, As, Ni, and Cr in estimated daily intakes (EDIs) is also above the maximum tolerable daily intake (MTDI), indicating food consumption as the possible source of these metals. The value of PHQ (combined hazard quotient) is found to be >1 in fish, vegetables, fruits, and rice samples, which may pose a serious health threat to the city residents (Fig. 6). The findings of Palash et al. (2020), who examined the values of Cr, As, Cu, Cd, Zn, Pb, and As in nine fish samples obtained from the Meghna River, reveal that fish may not, in accordance with the EDI value, pose any toxicity to public health.

Moreover, all metals, with the exception of those that remain in fish bodies in their biological form, have a THQ value of 1. They have concluded that Cd can pose a cancer risk among children and elderly people. Macrobrachium rosenbergii, an economically significant gigantic freshwater shrimp, gathered from various farms, Meghna and Karnaphuli rivers are also analyzed to determine the concentrations of heavy metals. The analysis findings reveal elevated Pb, Cr, Cu, Pb, and Mn concentrations in the collected water and fish. The calculated value is also higher than the acceptable level for Pb and Cr.

Furthermore, the THQ values of Zn, Cu, Cd, and Pb are also found to be less than one, while the TR values for Ni and Pb exceed the standard limit. Researchers have observed that prawn species have greater quantities of hazardous metals that can pose serious health hazards. Two searchers, Saha and Zaman, employed THQ and HI factors to examine vegetable, fruit, and seafood samples obtained from Rajshahi City's major market in 2012. According to the findings of their calculation, vegetable, fruit, and fish samples can seriously harm one's health if consumed regularly. Poisonous metals and detrimental microorganisms can pose serious health complications to aquatic life, including damaging tissue, DNA, and cellular, and severely cause restlessness, hyperactivity, neurotoxicity, genotoxicity, etc.

It is also found that people consuming fish from the Buriganga River are exposed to severe toxic consequences, including genotoxicity since the Cr concentration in them exceeds the standard value. Besides, fish species are also exposed to severe toxicity due to the presence of an elevated amount of Cr in polluted rivers. Hilsa fish is known worldwide for its unique deliciousness, and over half of the total production of this popular fish occurs in various rivers and the Bay of Bengal in Bangladesh.

However, the interrupted river water contamination and climate changes have badly affected the Hilsa fish production and genotypic alterations of the kind. The largest natural spawning habitat for carp fishes like Cirrhinus cirrhosis, Gibelioncatla, and Labeorohita is the Halda River in Bangladesh's southeast. Analysis of heavy metal concentrations in seven economically significant shellfish and fish species' edible tissue reveals that certain species' amounts of Zn, Ni, and Pb are higher than the dietary limit values.

According to the bioaccumulation factor BAF, dangerous metals have inevitably bioaccumulated in the studied species. According to figures from Fulton's condition factor, some fish species are unhealthy. Even when the CR, THQ, and EWI values appear under the acceptable limit, Monte Carlo simulation data reveals that Pb concentration causes significant carcinogenic and noncarcinogenic health concerns to children.

Islam et al.'s (2018) analysis of the sediment pollution data in 2020 suggested that flora and fauna in Bangladesh's headwater, midstream, and downstream rivers are experiencing frightening conditions. In addition, EF, Igeo, and contamination factor data analysis on metal concentrations in river sediment revealed moderate to high contamination concentrations for Ag, Co, and Hg. According to calculations for probable impact concentration (PEC) and threshold effect concentration, only Cr and Ni concentrations occasionally showed harmful effects on ecosystems (TEC). According to research, Ag, Ni, and Hg originate from several anthropogenic causes.

Bangladesh has passed numerous ordinances, laws, rules, acts, and policies to control environmental pollution. The Bangladesh Environment Policy of 1992, the Environmental Conservation Act of 1995 (as amended in 2000, 2002, and 2010), the Environment Pollution Control Ordinance of 1977, the Environmental Conservation Rules of 1997 (as amended in 2002, 2005, and 2010), the National Water Policy of 1999, the National Policy for Safe Water Supply and Sanitation of

1998, the Bangladesh Environment Court Act of 2000, the National Policy for As Mitigation of 2004, the Environment Court Act of 2010, and the Bangladesh Environment Policy of 1992 are among the laws and regulations currently exist.

To carry out the Environmental Conservation Act of 1995, the government of Bangladesh also formed the Department of Environment (2023), whose top administrative officer is a director, a general-level officer. This division is in charge of monitoring all national environmental pollution activities. Additionally, the Centre for Environmental and Geographic Information Services, often known as CEGIS for short, was founded to support inclusive growth, a healthy environment, and clean water for the nation's benefit. Environmental pollution in Bangladesh must be protected, and appropriate actions must be taken by the Ministry of Water Resources, Ministry of Environment, Forest, and Climate Change.

The Water Supply and Sewerage Authority, a signatory authority, regulates surface water contamination in cities. They have offices in important cities where they supervise the supply and management of water. A joint venture titled "To the Prime Minister: Save Rivers, Save Dhaka" was taken by Channel-I, a popular television channel, and a reputed English daily newspaper, in 2009. They highlighted the critical state of water contamination in the four rivers that encircle Dhaka. Based on it, the concerned officials immediately took certain actions to control pollution. However, sudden news accompanied by sparse data proved inadequate to significantly influence the current pollution rate. In recognition of this and light of the necessity, the High Court announced the rivers as"legal entities" with rights comparable to those of living things on February 3, 2019. It formed a river protection commission to oversee and prevent contamination.

After its measures, the High Court noted that DWASA was in charge of 68 subterranean drainage and sewerage lines that were interruptedly contaminating river water. On December 9 of the same year, the High Court also ordered DWASA to suspend all sewage lines and directed the Department of Environment to take indispensable measures against contamination. The Department of Environment is now working to monitor and regulate river contamination.

The findings of several types of research demonstrate that the current water quality in significant city rivers is not favorable for human health and the environment. High reliance on groundwater and irresponsible surface water treatment is ineffective in saving the Earth from being dearth. As per the United Nations Report 2012 estimation, the demand for water by 2030 will be 40% higher than the amount available. Specific (S), measurable (M), assignable (A), realistic), and time-based (T) are all part of the acronym SMART. Bangladesh needs SMART water management immediately, considering the extent of river contamination.

According to available research data, the Balu, Turag, Buriganga, Karnaphuli, and Sitalakhya Rivers are the most contaminated. Besides, Rupsha, Teesta, Korotoa, Karnaphuli, and Meghna rivers are also facing contamination, according to the data analysis on water quality. In many areas of the country, groundwater level has already decreased and is affected badly due to ongoing contamination. Both anthropogenic and geological pollutants contribute to the contamination of river water. Bangladesh's population increased to 149.77 million in 2011 from 76.2 million in 1974. The estimated populations for 2030 and 2050 are 186 and 202 million, respectively (Uddin et al. 2014). People now largely depend on groundwater for drinking, irrigation, and industrial purposes, causing gradual depletion in groundwater levels.

River water is, therefore, the most crucial resource for supplying the enormous demand for water. However, the research data analysis reveals that the current quality of river water is unsafe for agriculture and drinking. According to toxicology analysis data, consuming foods and fish cultivated and collected with and from contaminated river water may cause people to develop both cancerous and non-cancerous diseases. Some common health problems people in Bangladesh face include fever, obesity, pain, hypertension, coughing, heart failure, mental disorder, brain stroke, diabetes, tumor, cancer, etc. According to study data on the current ground and surface water status, Bangladesh is already experiencing a safe water crisis, which will become a serious situation shortly.

Natural hazards are common and frequently occur in Bangladesh. The chemistry of the chemical constituents of water is negatively altered by salinity intrusion in rivers and groundwater. According to the analysis of available research data, nearly two crore people living in southern Bangladesh are experiencing safe water deficiency. The research data analysis on climate change demonstrates that the safe water crisis will affect the country's coastal areas adversely in the future. Being Bangladesh, a riverine country, its land is filled with fertility. The lone way to meet the country's huge demand for water in the future is to implement the SMART river water management system. Most parts of Bangladesh are covered by several rivers, which act as natural reservoirs to retain rainfall and rehydrate the groundwater. The environmentally friendly strategy to control water demand and protect human health and the environment is switching from groundwater to river water.

Hence, importance should be given to strengthening laws and monitoring urgently with a proper concentration on the current situation. Contamination-specific research is required to assess the accumulation and destiny of elements and compounds in human health and the ecosystem. The government ought to make an effort to create awareness among people about the use of surface water and gain public confidence in safe water. Unattended automated water quality measurement stations can be installed along a river's course. A central monitoring system for many rivers can keep the river clean of pollutants. It is possible to use a variety of software and programming models (SCADA-Supervisory control and data acquisition) to monitor and measure river water quality. Data from both public and commercial studies may be shared to get a more accurate and realistic picture of pure water quality management.

CONCLUSION

This paper has collected and compiled the research data of the past 40 years on river pollution in Bangladesh and has attempted to convey river pollution patterns and current conditions using a tabular and graphical representation. According to trends of physicochemical and hazardous metals data, intense contaminations have occurred but are not frequent. Most of the metrics in the Buriganga and Turag River water exhibit a similar surge from 2008 to 2012, and the Sitalakhya River also shows a similar surge from 2011 to 2015.

This may result from severe Turag and Buriganga Rivers contamination, which eventually flows into the Sitalakhya River. Karnaphuli River experienced a high level of contamination between the periods 2012-2015. The analysis of the existing research data reveals that the water and sediment of the Turag, Buriganga, Balu, Sitalakhya, and Dhaleshwari Rivers are polluted with harmful metals, and at certain samplings locations, are higher than the standard values for surface water, irrigation, and drinking. Lower Basin Rivers constantly get these massive amounts of pollution while anthropogenic contamination also goes along the river banks.

In the Karnaphuli River, heavy metals are higher than the standard value for safe drinking water. The concentrations of Cd, Ni, Mn, and Cr also exceed the standard limit for irrigation water. Fe and Mn concentrations in the Teesta River are above irrigation standards, as are the concentrations of Cd and Cr in the Korotoa and Fe, Mn, Zn, and Cr in the water of the Rupsha River. The sediment samples of the rivers also have high concentrations of metals. Metal concentrations in the Old Brahmaputra River are below the USEPA recommended standard limit. Most river silt is contaminated with Cr, Cd, Zn, Fe, Cu, Pb, and Ni at levels above standard values. Accumulation of these metals in groundwater has the potential to contaminate groundwater. The groundwater in some areas of Dhaka City requires treatment before consumption due to the concentrations of toxic metals. The contaminated river causes heavy metals to bioaccumulate in fish bodies, posing hazardous consequences. Consuming this tainted fish can have serious toxic effects on the human body.

Additionally, grains grown close to the contaminated river contain high metal concentrations. Numerous studies have examined data on TCR, THQ, EDI, TR, and HI and found that long-term consumption of food contaminated with metals may have serious carcinogenic and noncarcinogenic health effects in people. According to research findings, it is evident that all the key urban rivers are receiving pollutants while some of them are experiencing severe contamination.

Furthermore, all the research data that is currently accessible is based on only physicochemical and metals evaluation. It is not common practice to undertake studies on organics, antibiotics, microplastics, personal care products, and other hazardous pollutants in river water. Therefore, it is urgently necessary to stop Bangla'esh's river pollution, and in-depth research, ongoing observation, and strict laws and regulations are needed.

REFERENCES

Ahaduzzaman, P.S. 2017. Overview of Bangladesh's main industries. J. Chem. Eng., 30(1): 51-58.

Akindele, E.O. and Akinpelu, O.T. 2020. Heavy metal toxicity in a degraded tropical stream benthic sediments and water column. Ecotoxicol. Environ. Saf., 190: 110153.

Alam, M., Uddin, M. and Sattar, M. 2020. Water quality and garbage loads in the Buriganga River vary seasonally and are visualized using GIS. Bangladesh. J. Sci. Ind. Res., 55(2): 113-130.

Ali, M. M., Ali, M. L., Proshad, R. and Mamun, A. A. Heavy metal concentrations in commercially valuable fishes with health hazard inference from Karnaphuli river, Bangladesh. Hum. Ecol. Risk. Assess. 26(5). DOI: 10.1080/10807039.2019.1676635.

Bangladesh Association of Pharmaceutical Industries (BAPI). 2023. Competitive edge of Bangladesh Pharma. Retrieved from http://www.bapi-bd.com (accessed date February 7, 2023).

Bangladesh Poribesh Andolon (BAPA) 2023. BAPA Report-2023. Retrieved from https://www.bapa.org.bd (accessed date January 11, 2023).

Bangladesh Ready-Made Garments (BRMG) 2022. Bangladesh Made Clothing. Retrieved from https://www.newclothmarketonline.com

Bangladesh Water Development Board (BWDB) 2023. River Management Improvement Program (RMIP) Environmental Management Framework (E-F) - Ministry of Water Resources of the People's Republic of Bangladesh. Retrieved from https://bwdb.gov.bd/annual-reports (accessed date February 1, 2023).

Bashar, T. and Fung, I. 2020. Water contamination in Dhaka, a megacity with a large population. Water, 12(8): 1-13.

Department of Environment (DoE) 2023. Bangladesh Report: State of the Environment. Retrieved from http://www.doe.gov.bd (accessed date November 30, 2022).

Doza, M.B., Islam, S.M.D. and Rume, T. 2020. Assessment of the quality of the groundwater and the risks to human health for a secure and long-lasting water supply for Bangladesh's residents of Dhaka City. Groundwater Sustain. Dev., 10: 374.

Gray, N.F. 2010. A Primer for Engineers and Scientists Working in the Environmental Field. CRC Press, London, pp. 152.

Hasan, M. R. Mawa, Z. and Hassan, H. U. 2020. Impact of eco-hydrological factors on growth of the Asian stinging catfish *Heteropneustus fossilis* (Bloch, 1794) in a Wetland Ecosystem. Egypt. J. Aquat. Biol. Fish., 24(5): 77-94.

Islam, G.M.M., Tarafder, S.K. and Hasan, A.B.M.M. 2018. Physical-chemical evaluation of water quality indicators in Bangladesh's Khulna region's Rupsha River. Int. J. Eng. Sci., 7(2): 57-62.

Islam, N. 2019. What Happened to Our Waterways in 2019? Retrieved from https://www.thedailystar.net

Khan, S., Anwar, K., Kalim, K., Saeed, A., Shah, S. Z., Ahmad, Z., Ikram, H. M., Khan, S. and Safirullah 2014. Nutritional evaluation of some top fodder tree leaves and shrubs of district Dir (lower), Pakistan as a quality livestock feed. Int. J. Curr. Microbiol. App. Sci., 3(5): 941-947.

Newaz, K.K., Pal, S. K., Hossain, S. and Karim, A. 2020. Evaluation of heavy metal pollution risk associated with road sediment. Environ. Eng. Res., 26(3): 200239. DOI: https://doi.org/10.4491/EER.2020.239

Palash, M. L., Jahan, I., Rupam, T. H. Harish, S. and Saha, B. B. 2020. Novel technique for improving the water adsorption isotherms of metal-organic frameworks for performance enhancement of adsorption driven chillers. Inorganica Chim. Acta, 501. DOI: https://doi.org/10.1016/j.ica.2019.119313.

Rai, P.K., Lee, S.S. and Kim, K. H. 2019. Risks to human health, destiny, processes, and control of heavy metals in food crops. Environ. Int., 125(1): 365-385.

Rakib, M. A., and Fukunaga, M. 2019. In Bangla'esh's southwest coastal region, where drinking water is severely salinized, and there are related health risks, migration risk is increased. J. Environ. Manag., 240(1): 238-248.

Ranjan, A. 2020. Bangladesh's water problems: Escalating pollution and poor administration. Asian Aff., 51(2): 328-346.

Reza, A. and Yousuf, T.B. 2016. Trash dumping affects Bangladesh's Buriganga River's water quality and potential solutions. J. Environ., 11(1):35-40.

Sakamoto, M. and Ahmed, T. 2019. Bangladesh's textile industry and water pollution: a result of poor business practices or limited opportunity? Sustainability, 6: 11.

Sarah, R., Tabassum, B., Idrees, N., Hashem, A. and Abdullah, E, F. 2019. Bioaccumulation of heavy metals in *Channa punctatus* (Bloch) in river Ramganga (U.P.), India. Saudi J. Biol. Sci., 26(5): 979-984.

Sarkar, A.M., Rahman, A.K. and Islam J.B. 2020. Bangladesh's surface and groundwater pollution: A review. Asian Rev. Environ. Earth Sci., 6(1):47-69.

Sultana, M.N., Latifa, G. A. and Hossain, M. S. 2019. Evaluation of the Balu River's water quality in Dhaka, Bangladesh. Water Conserv. Manag., 3(2):8-10.

Uddin, M.J. and Jeong, Y.K. 2021. Urban river pollution in Bangladesh over the past 40 years: Potential risks to public health and the environment, existing regulations, and potential future directions for smart water management. Heliyon, 7(2): 1-23.

Uddin, M.J., Mamun, S.A. and Huq, S. I. 2014. Wastewater irrigation's effects on the development and nutrient status of kalmi (Ipomoea aquatica Forssk.). Dhaka Univ. J. Biol. Sci., 23(2): 1-8.

United Nations Conference on Trade and Development (UNCTAD) 2021. Least Developed Countries Ranking. Retrieved from https://unctad.org (accessed date November 10, 2022).

Whitehead, P.G., Bussi, G. and Alabaster, G. 2019. calculating the impact of tannery pollution control on the levels of heavy metals in the Buriganga River System, Dhaka, Bangladesh. Sci. Total Environ., 13: 409.