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Industrial Water Pollution in Savar Upazila: A Geospatial Approach to Ecological Sustainability

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Abstract: Industrialization is crucial for economic growth and societal advancement, with nearly 50% of Bangladesh's population engaged in agriculture. However, this rapid industrialization has led to uncontrolled urbanization, environmental alterations, and illegal riverbank development. One of the gravest threats is the discharge of industrial effluents into natural hydrological systems, causing adverse effects on human health and aquatic ecosystems. This study examines the escalating pollution of rivers surrounding Savar Upazila due to swift industrialization. Dhalweshari, Turag, and Bangshi rivers are suffering from severe contamination, with high levels of cadmium, lead, and chromium in their water and sediment. The study uses a review-based approach to address the complex interplay of industrial activities, river water quality, and broader environmental and human health concerns. Data is collected from diverse sources, including organizational reports, journals, articles, and newspapers. Advanced tools like ArcGIS 10.8 and "Google Earth-pro" are used to assess pollution dispersion patterns. To mitigate industrial pollution, the study suggests establishing an independent Environmental Impact Assessment (EIA) review board, making the EIA review and reports publicly accessible, and third-party verification and public disclosure of post-development environmental monitoring. Mitigation strategies include policy intervention, management practices, technical solutions, and raising awareness among stakeholders. Implementing these measures can enhance environmental performance and promote sustainable solutions towards environmental preservation in the face of rapid industrialization.

Keywords: EIA, Industrialization, Human Health, Economic Growth, Water Pollution.

1. Introduction

Industrialization is an essential prerequisite for rapid and continuous economic development and social progress. Industrialization is an era of socio-economic change

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that transforms human society from an agricultural society to an industrial society based on the production of goods and services, innovation and development. An increase in income and people's living standards are globally recognized dynamic benefits arising from industrial development. About 50% of the population of Bangladesh is employed in the agricultural sector, and about 70% of the entire population relies on agriculture for a living, with more than 70% of the land dedicated to crop production (FAO,2022; The Daily Star,2022). Although the rate of employment in the agricultural sector is decreasing but agriculture is the still main engine in the country's economic growth. The industrial sector has a greater average productivity than agricultural sector and most service-sector activities, so as people move out of agriculture into industry for the stability of income. Rapid industrialization and uncontrolled urbanization have drastically altered the natural environment, particularly the water sector or natural hydrological system of Bangladesh, as well as illegal riverbank development, unrestricted city expansion, and agricultural damage. The most serious hazard to our ecosystem is the discharge of industrial effluents into natural hydrological systems. Toxic industrial effluent as well as unrefined waste water discharged in the course of manufacturing processes from industries such as tanneries, textile, dying industries, steel plants, and engineering are the main sources of pollution, which have adverse impact on human health as well as the aquatic ecosystem. However, enormous prosperity came at the cost of environmental degradation. The existing law in Bangladesh, mandate the installation of such factory effluent treatment plant (ETP), which has not been effective in reducing environmental degradation. Some industries have effluent treatment plant (ETP) but they do not like to run it because of high profit goal (Uddin, Parveen and Hossain, 2016). Untreated effluents containing injurious chemicals and heavy metals which are being discharged into the rivers from nearby industries, affecting the health of people who live along the polluted rivers. As a result, river water becomes toxic to living organisms of the river and irrigation made the toxic materials to enter into the agricultural production (Uddin and Rajonee, 2016; Arefin and Mallik, 2017). Rivers especially surrounding the savar Upazila are becoming more polluted due to rapid industrialization in this region. Dhalweshari, Turag, and Bangshi are the surrounding rivers of Savar Upazila, which are in severe condition at present. The amount of effluent discharged into these rivers has increased to the level where even the rainy season's water flow is unable to wash it away. On the other hand, during dry period entire river water is replaced with hazardous industrial effluent (Reza and Yousuf, 2016). River water and sediment from the Dhalweshari, Turag, and Bangshi rivers are highly contaminated with cadmium (Cd), lead (Pb), and chromium (Cr). The study provides an assessment of the present status of the physic-chemical parameters of water and the concentration of heavy metals of the major rivers water of Savar Upazila.

2. Aims and Objectives

The main goal of this study is to look into the present scenario of industrial water pollution in Savar upazila and how it affects the ecosystem. In this context, the major objectives of current research are,

- To determine the water quality of the study area's three major rivers, as well as to compare river water quality over the last decade;
- To map the vulnerable water pollution zone in the major rivers of the study area due to the industrial waste discharge;
- To provide some recommendations for reducing the detrimental effects of the industries on the quality of the river water in this area.

3. Data Sources and Methods

This study adopts a review-based approach with the primary aim of investigating the influence of industrial activities on river water quality within the designated study region. The research endeavors to assemble pertinent data through an extensive survey of literature sources, encompassing both published and unpublished materials such as organizational annual reports, diverse books, scholarly journals, articles, and newspapers that pertain to industrial pollution. These collected resources serve as the foundation for a comparative analysis, facilitating an assessment of the river water quality in the study locale, along with an exploration of the ecological and human health implications associated with the presence of harmful chemicals in the environment. To achieve these objectives, the study employs advanced tools including ArcGIS 10.8 and "Google Earth-pro" for a comprehensive evaluation of the river's pollution dispersion patterns. Additionally, the research employs spatial analyses executed within the ArcGIS software, enhancing the depth and accuracy of the study's findings. Through this multidimensional approach, the study strives to shed light on the intricate interplay between industrial activities, river water quality, and the wider environmental and human health concerns. This study uses Geographic Information Systems (GIS), spatial data analysis, and remote sensing to reveal the intricate pathways pollutants follow within aquatic systems. The study highlights the potential ecological hazards posed to aquatic ecosystems, impacting both nature and human inhabitants. By integrating geospatial data with ongoing environmental monitoring, a proactive approach to pollution management emerges, enabling swift responses to pollution events. The study highlights the importance of understanding the geospatial intricacies of pollution and the potential ecological risks associated with industrial activities.

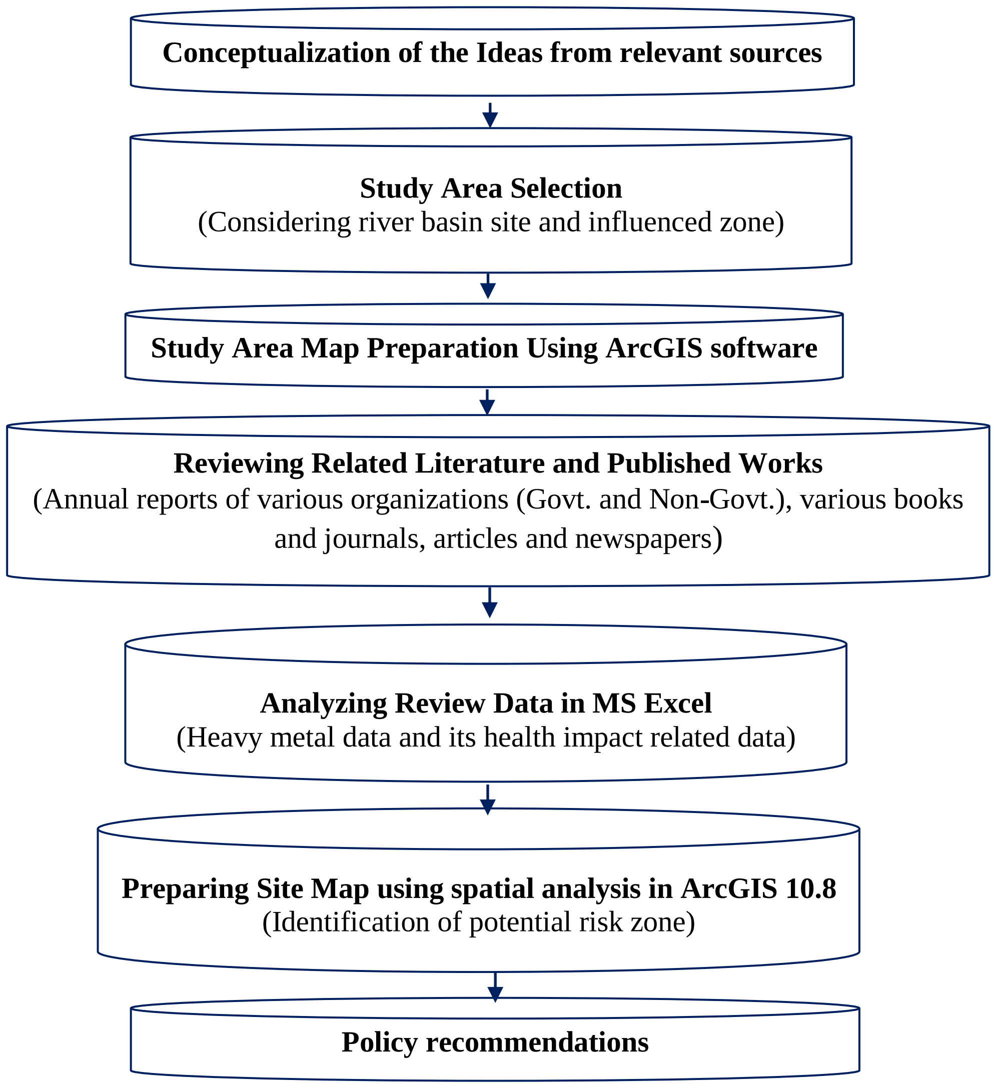
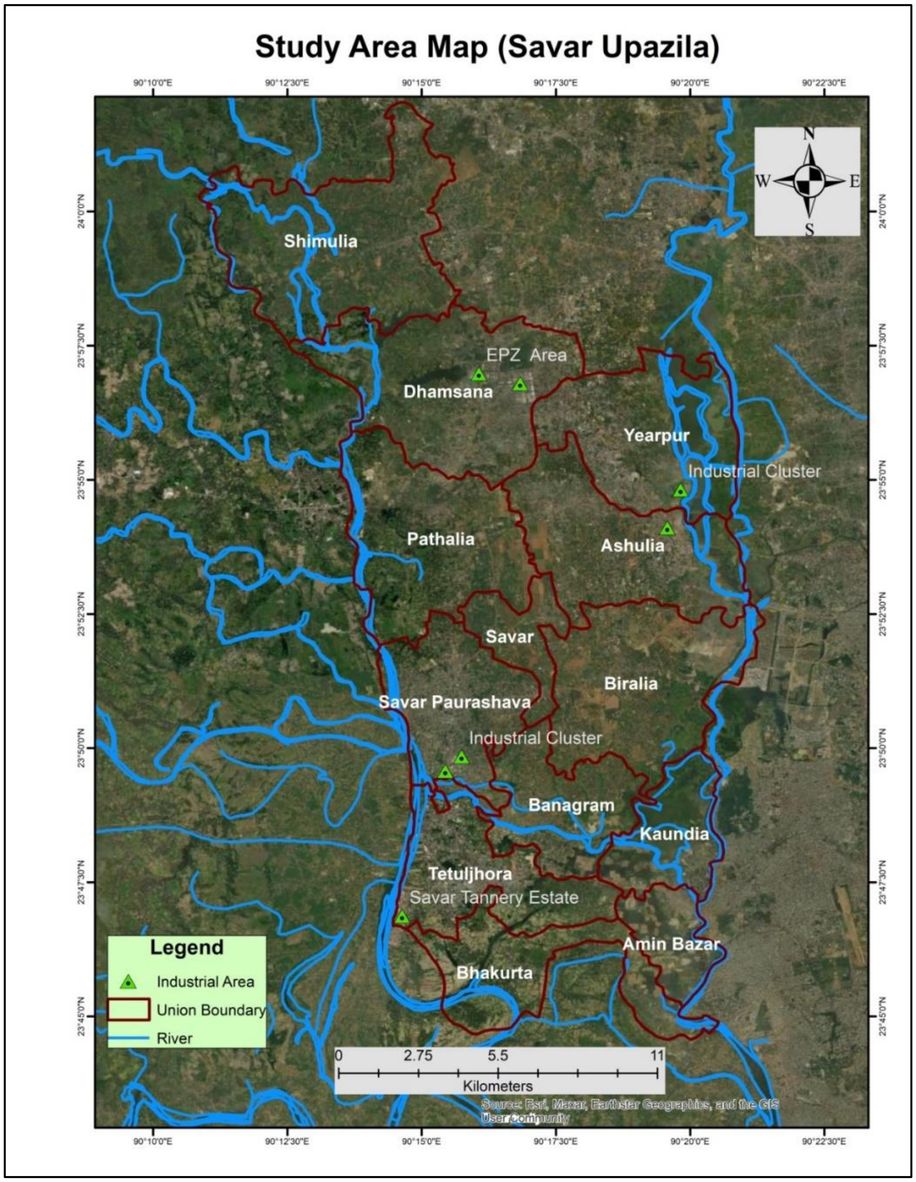


Figure 1: Methodological flowchart of the study

4. Study Area

Savar Upazila has undergone fast population increase and changes in traditional agricultural land usage in recent decades as a result of growing urbanization and industrialization (Sultana et al., 2017). Savar is the second-largest upazila in the Dhaka district and 9th largest cities in Bangladesh (BBS, 2011). Geographically it is located on the northern outskirts of Dhaka with a total area of 280.12 sq km. Savar is around 24 km north of the capital city Dhaka. Kaliakair Upazila and Gazipur City Corporation border it on the north, Keraniganj Upazila on the south, Mirpur Mohammadpur Pallabi Thana and Uttara Thana on the east, and Dhamrai Upazila and Singair Upazila on the west. Savar upazila consists of twelve unions and a Paurashava (Hasan et al., 2016).

Figure 2: Study Area Map



Source: BCAS Data, 2018

The main rivers of Savar are Banshi (Bangshai), Turag and Dhaleshwari. The Bangshi and its southern course, the Dhaleswari, run along the western side of the study area, while the Turag runs along the eastern side. The Karanatali River, a watercourse that runs through the study region, begins near Savar purashava and flows toward Turag, southeast of the study area (Hasan et al., 2016). At present, the rivers are being severely polluted due to the hazardous wastes of numerous industries and tanneries and the existence of these rivers is under constant threat due to encroachment.

5. Contextual Background

The garment industry in Bangladesh is expanding since 1984 and now there are more than 4500 factories in operation (BBS,2019). After the acceleration of GDP growth in Bangladesh since the beginning of the 1990s, most of the garment industries are growing in Dhaka and in its surrounding areas (Abdin, 2016). Savar is an industrial zone covering hundreds of factories and manufacturing centers, the majority of which are readymade garments (RMG) and garment supporting industries.

- The first Export Processing Zone (EPZ) was founded in 1983 in the port city of Chittagong, while the second, known as the DEPZ, was established in 1993 near the river Bangshi in Savar, Dhaka. and in 1997 another expanded zone was added to it (BEPZA, 2020). In terms of export allotment, employment generation, and investment volume, particularly foreign direct investment, the Dhaka export-processing zone (DEPZ) is one of the greatest economic zones in Bangladesh. The Dhaka Export Processing Zone (DEPZ) is the country's second export processing zone, with 100 industrial units that are categorically the leading pollution creators (Khan et al., 2011; Khanam et al., 2011; BEPZA, 2020).
- In Bangladesh, the leather industry is a well-established industry that ranks second in terms of export revenues. In June 2009 by the order of the High Court, and with help of Bangladesh Small and Cottage Industries Corporation (BSCIC), on around 200 acres of land, the tanneries were relocated from Hazaribagh to Hemayetpur in Savar near the Dhalweshari river (Hossain and Abedin, 2019). Despite the fact that the tanneries were relocated from Hazaribagh in the heart of Dhaka to Savar with the sole goal of preventing effluent pollution of the Buriganaga, it appears that the same tragic story is being repeated, with the Dhalweshari River as the current victim. The Savar Tannery Industrial Estate will discharge a large amount of dissolved salt into the Dhalweshari River.
- In the Ashulia and Zirabo areas near the Turag river, a huge number of small and medium industries have established and developed rapidly. Besides, Tongi Heavy Industrial Area is very close to the river. The Tongi Heavy Industrial Area is home to about 240 industries.
- Biodiversity is an essential component for sustainable environment. However, economic growth and other human activities put strain on the environment, making it impossible to protect natural sectors large enough to accommodate entire ecosystems. According to present law to protect the environment, every industrial unit is required to have its own Effluent Treatment Plant (ETP) for wastewater treatment. However, just a few industries have followed the ETP guidelines thus far. The majority of industries with ETP facilities were discovered to rarely use their ETP to reduce production costs. As a result, most of these industries discharge untreated or inadequately treated industrial wastewater, effluent, and even sludge into the environment, lowering soil quality by increasing pollutant concentrations (Ahmed et al., 2009; Mortula and Rahman, 2002; Mahfuz et al., 2004; Rahman, 2008). Unfortunately, uncontrolled industrial waste releases from industries along the river's banks have considerably increased river water contamination to a highly unsafe level, and the river water has become visibly discolored. (Talha, 2007).

6. Result and Discussion

6.1 Environmental Legislation in Bangladesh

Rapid industrialization and lack of proper waste management are causing serious water pollution in the rivers of Bangladesh, threatening aquatic ecosystems and the people who rely on them for their livelihood. On the other hand, Bangladesh has a well-developed framework of environmental regulations, legislation, and guidelines in place to manage pollution of water, soil, and air. A quick summary of the policies and legislation is shown in the table.

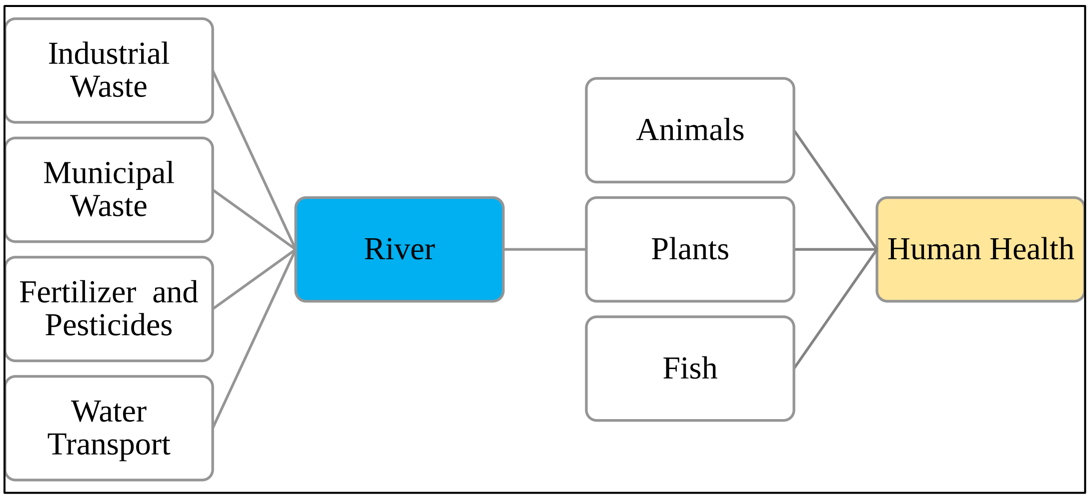


Figure 3: Pollutants impacts on river and human health

Source: Developed by Author, 2022

Table 1: Environmental Legislation in Bangladesh

Policy/Rule/Act	Main Features
National Environment Policy, 1992	• Ensure environmental balance and sustainable development of the country through environmental protection and conservation, as well as environmentally competent natural resource management; • Ensure environment- friendly development in all sectors and must conduct an IEE and EIA prior to project initiation.
National Environment Management Plan, 1995	• Identification of key environmental issues that creates environmental pollution and promote sustainable development; • Conservation of habitats and biodiversity.

Policy/Rule/Act	Main Features
Bangladesh Environment Conservation Act of 1995	• Environmental protection and enhancement; • Pollution control and mitigation by the establishment of a standard limit for waste discharge and emission.; • Industrial and other development discharge limitations and permits are regulated.
Environment Conservation Rules, 1997	• Determine criteria for ambient air, different types of water, industrial effluent, emission, and noise etc.; • Determine Environmental Clearance procedure and classified all the industrial units in 4 broad categories including the requirements for IEE / EIAs according to the categories.
The National Water Policy, 1999	• Water resource and quality protection and restoration, including strengthening rules on agro-chemicals and industrial wastewater.
The Environmental Conservation Act (Amendment 2000)	• Determine the financial obligation in the event of ecosystem damage.
The Environmental Conservation Act, 2010	• Dealing with disposal of hazardous wastes and managing ship braking industries & wetlands.
Bangladesh Water Act, 2013	• Water resource protection and conservation • The need of controlling all water sources was recognized in the context of natural surface water flow and groundwater recharge.
National River Protection Commission Act, 2013	• Preventive measures against illegal river occupants, river water pollution, and environmental pollution
National Environment policy, 2018	• Ensure long-term development by maintaining ecological balance and conserving natural resources. • Determine the responsible authority for specific sectors.

Source: Compile by Author, 2023

6.2 Assessment of Water Quality in the Study Area

Entire area of the Savar is an agricultural and low-lying area. Although it is an agricultural area, various industrial zones and individual industrial units have developed in the region. All most all these industries discharge the untreated toxic industrial wastes on the low and wetland of the surrounding area and the river water which continuously contribute to pollute the river water. Polluted water is water that has an unsafe level of one or more chemicals that could harm humans, plants, or animals. When concentrations of contaminants at the surface become high enough to damage aquatic ecosystems and pose a health concern, especially when ingested in food or water, an invisible danger is created. The table shows the average concentrations of major and minor trace elements for each water application.

Table 2: Physicochemical and Heavy metal standards of water of different type of water sources. (Compile by Author)

Parameters	WHO guideline 2003	DoE Standard (Drinking Water) 1997	DoE Standard for industrial waste (Inland Surface Water) 1997	DoE Standard for industrial waste (Irrigated Land) 1997
pH	6.5-8.5	6.5-8.5	6-9	6-9
EC (µs/cm)	400	-	1200	1200
DO (mg/l)	4	6	4.5-8	4.5-8
BOD (mg/l)	6	0.2	50	100
COD (mg/l)	10	4	200	400
TDS (mg/l)	500	1000	2100	2100
Fe (mg/l)	0.3	0.3-1	100	100
Cu (mg/l)	2	1	0.5	3
Ni (mg/l)	0.02	0.1	1	1
Zn (mg/l)	5	5	5	10
Pb (mg/l)	0.01	0.05	0.1	0.1
Cr (mg/l)	0.05	0.05	0.5	1

Source: Compile by Author, 2023

Table 3: Physicochemical characteristics of water from different rivers in Savar Upazila

pH	EC (µs/cm)	DO (mg/l)	BOD (mg/l)	COD (mg/l)	TDS (mg/l)	Year	Sources
Turag River							
7.98	1107	**6.8**	**180**	220	580	2010	(Rahman et al.,2012)
8.1	251.8	0.47	22.33	139.21	465.23	2011	(MoEF,1997)
9.1	**2850**	3.20	179	177	**1510**	2012	(Islam et al.,2015)
7.46	-	0.74	31.97	131.07	527.23	2013	(MoEF, 2013)
7.28	488.8	5.2	55.92	181.7	536.8	2014	(Arefin et al.,2016)
8.2	1682	4.10	3.30	169	804	2015	(MoEF, 2015)
7.61	2277	3.66	0.86	-	1349	2016	(Mottalib, Roy and Khan, 2017)
7.5	1409	2.3	-	-	1348	2018	(Begum et al.,2018)
7.53	-	2.05	34.74	**240.95**	607.18	2019	(Rahman, Jahanara and Jolly, 2021)
Bangshi River							
9.97	**2710**	1.40	**148**	172	**1160**	2011	(Rahman, 2012)
9.17	1670	**4.43**	69.75	38	1035	2012	(Rahman,Saha and Molla, 2014)
8.5	860	1.5	7.6	87	444.4	2013	(Kabir,2014)
8.17	950	-	-	270	400	2014	(Akter, 2014)
8.18	324.84	-	1.09	6	207.02	2016	(Mottalib, Roy and Khan, 2017)
7.15	-	-	2.72	3.18	-	2017	(Siddique and Hassan, 2018)
6.70	-	-	15	18	255	2018	(Dipta and Akhie, 2018)
Dhalweshari River							
7.24	-	5.4	2.4	-	142	2011	(MoEF, 2011)
7.6	-	6	2.6	-	174	2012	(MoEF, 2012)
7.56	-	7.5	**24**	-	498	2013	(MoEF, 2013)
7.78	660	4.3	13.2	39	310	2014	(MoEF, 2014)
8.78	**992**	**20.4**	12	48	476	2015	(MoEF, 2015)
7.86	181.2	7.5	8.4	30	234	2016	(MoEF, 2016)
7.5	155	2.90	12	40	547	2018	(Hossain and Abedin, 2019)
8.04	189	4.61	20	2	**715**	2019	(Hasan, Ahmed and Adnan, 2020)
7.29	530.41	4.82	1.25	5.12	371.58	2020	(Hasan et al., 2020)

Source: Compile by Author, 2023

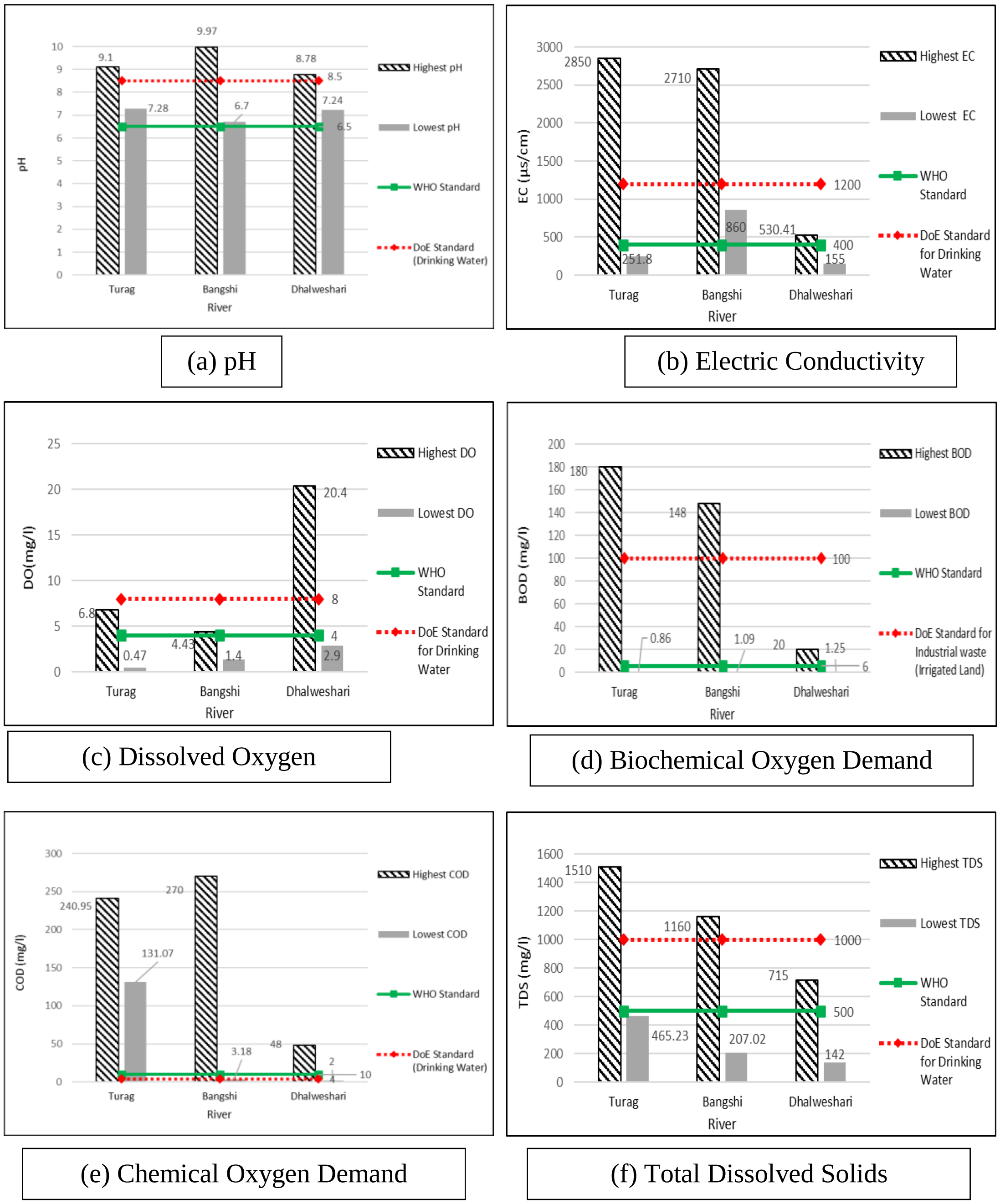


Figure 4: Profiles of water quality parameters (a) pH; (b) Electric Conductivity; (c) Dissolved Oxygen; (d) Biochemical Oxygen Demand; (e) Chemical Oxygen Demand and (f) Total Dissolved Solids

Source: Compile by Author, 2023

From the figure 4, it is observed that the level of pH in the water of the three rivers belongs almost in the safe range of 6-9 as compared to the standard level. The pH of Bangshi river water has changed more than other rivers in the last decade. During this period, the highest value of the Bangshi and the Turag rivers exceeded the DoE's industrial waste standard which is shown in the figure. Compared with the WHO standard level the presence of Electric Conductivity (EC) in the Turag and the Bangshi river is very high where the presence is lower in the Dhalweshari river. The highest value of the Electric Conductivity (EC) in all three rivers exceeded the WHO standard which is shown in the figure. As shown in figure, TDS levels are measured above standard of the WHO ranges at all instances where the highest value is 1510 mg/l in Turag River. But it is found that as compared with the DoE standard for drinking water the presence of TDS in the Turag and the Bangshi river is very high where the presence is lower in the Dhalweshari river which is 715 mg/l. DO of the river water was determined to be below the DoE approved criteria, which is incredibly detrimental to the river's flora and fauna. Concurring to DoE’s standard for drinking water and WHO standard, Dissolve Oxygen (DO) ought to be 4 mg/l and 8mg/l separately. More or less Turag and Bangshi rivers meet the standard level but the Dhalweshari stream is exceptionally distant from the guidelines with a 20.4 mg/l Dissolve Oxygen esteem during the study period. Biochemical Oxygen Demand should be very low according to DoE for industrial waste water which is 6mg/l. But WHO preferred it can be 100 mg/l.

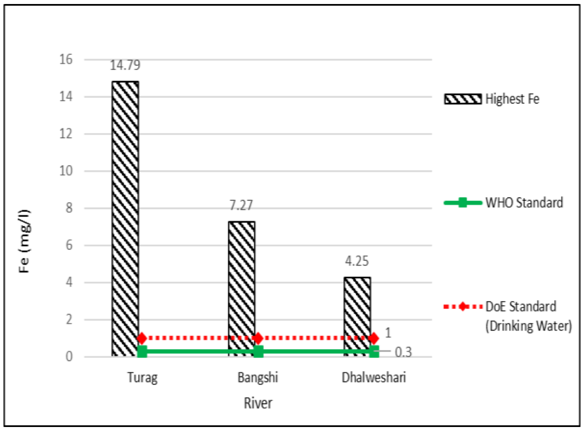
From collected data and compression table can be state that expect the Dhalweshari river’s the value of Biochemical Oxygen Demand (BOD) is very high for Turag and Bangshi streams. Highest value for Turag and Bangshi river is 180 and 148 respectively. During this period the most noteworthy Chemical Oxygen Demand (COD) of Turag, Bangshi and Dhalwashiri waterway are 240.95 mg/l, 270 mg/l and 48 mg/l individually. In spite of the fact that Turag scored 48 mg/l which is least among others but stills it isn't satisfying. Because the standard values for Chemical Oxygen Demand (COD) in drinking water are 4mg/l and 10mg/l, respectively, according to the DoE and the WHO.

Table 4: Heavy metals concentration in water from different rivers in Savar Upazila

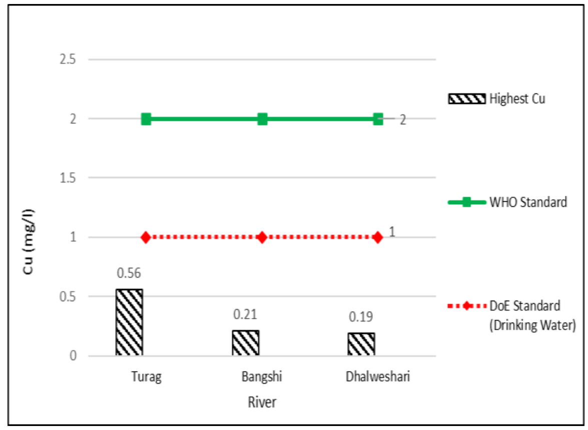
Turag River							
Fe (mg/l)	Cu (mg/l)	Ni (mg/l)	Zn (mg/l)	Pb (mg/l)	Cr (mg/l)	Year	Sources
3.29	0.01	-	0.02	0.09	-	2012	(Islam et al.,2015)
14.79	.09	0.028	.03	0.06	**0.47**	2014	(Arefin et al.,2016)
1.12	**0.56**	-	0.03	**0.06**	0.06	2015	(Mottalib, Roy and Khan, 2017)
-	-	-	**0.09**	0.01	0.01	2016	(Rabbi et al.,2016)
1.04	0.47	-	-	0.06	-	2017	(Hafizur, Hossain and

Turag River							
							Islam, 2017)
Bangshi River							
7.27	0.04	0.01	**0.24**	**3.65**	0.002	2011	(Khanam et al.,2011)
0.044	0.13	0.06	0.14	0.01	**0.055**	2012	(Momtaz et al.,2012)
0.077	0.004	0.007	0.027	0.02	0.008	2014	(Akter, 2014)
0.068	.014	-	0.028	.006	.04	2015	(Sikder et al.,2015)
2.16	**0.21**	**0.15**	0.098	0.69	0.41	2016	(Mottalib, Roy and Khan, 2017)
Dhalweshari River							
-	**0.19**	.01	-	0.04	0.50	2009	(Ahmed et al.,2009)
4.25	0.01	0.02	0.005	**0.39**	0.02	2017	(Ghosh and Hossain, 2019)
0.21	0.01	0.02	**0.09**	0.06	**1.2**	2018	(Hossain and Abedin, 2019)
2.44	0.08	**0.02**	0.01	0.05	0.94	2020	(Ahmed et al.,2020)
-	-	-	0.008	-	0.64	2021	(Whitehead et al., 2021)

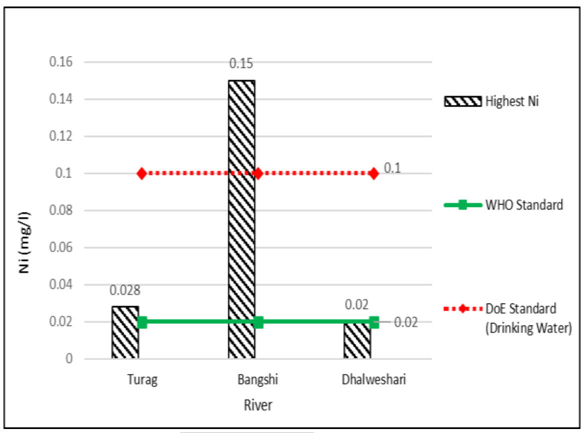
Source: Compile by Author, 2023



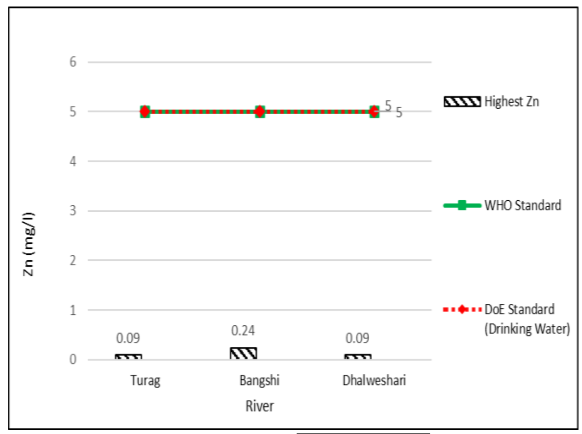
(a) Fe



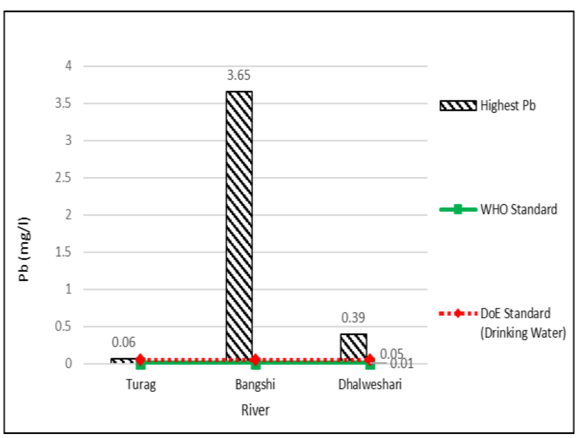
(b) Cu



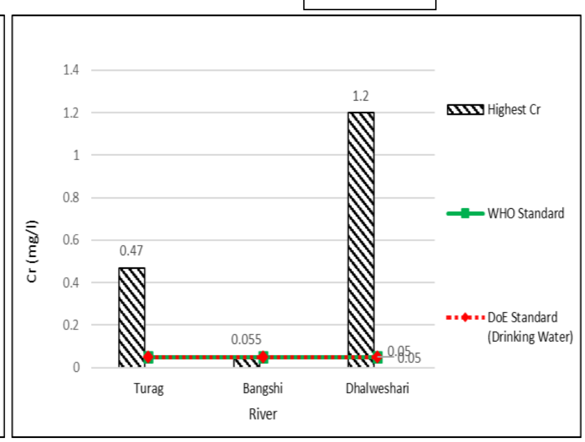
(c) Ni



(d) Zn



(e) Pb



(f) Cr

Figure 5: Profiles of water quality parameters (a) Fe ; (b) Cu; (c) Ni; (d) Zn; (e) Pb and (f) Cr

Source: Compile by Author, 2023

Fecontamination in river water could be the result of its long-term use in the manufacturing of machine tools, paints, pigments, and alloys in many sectors (Halim et al.,2009). The contamination of Fe is very high in all three rivers with the comparison with the DoE and WHO standards. When compared to the DoE and WHO standards, Fe pollution is extremely high in all three rivers. In all three rivers, Cu distribution was below WHO standards, however it was nearly two times higher in the Turag river than in the Bangshi river. Heavy metals Zn and Cr are commonly found in industrial settings, and their sources are mainly anthropogenic (Mondol et al.,2011). The non-ferric metal industry and agricultural practices are the main anthropogenic sources of Zn (Yaylalı-Abanuz,2011). Due to less number of non-ferric metal industry the presence of Zn is very low in all the three rivers. However, it is well known that Cr contamination of river water is increasing as a result of pollution from a wide range of sources, the most substantial of which are hazardous wastewater such as Cr pigment and tannery effluents, electroplating sludge, and leather production wastes, among others. Cr contamination is too high in the Dhalweshari and Turag rivers, but the rate in the Bangshi river is below the standard. Because of the pollutant from the Savar Tannary Estate, the Cr contamination in the Dhalweshari river is extremely high. Poorly treated wastewater released by ceramics, steel and alloys, and other metal processing sectors are major sources of Ni in the water. Only in the Bangshi River the range surpassed the DoE and WHO standards. Turag has a Ni pollution of 0.028 mg/l, which is greater than the WHO standard but less than the DoE standard. Pb contamination in water has received a lot of attention in recent years since this metal is extremely hazardous to both humans and animals. The primary sources of Pb pollution are battery manufacturing and scrap battery recovery facilities, thermal power plants, and the iron and steel sectors. The Bangshi River had the highest Pb contamination, at 3.65 mg/l. The Pb contamination values in the Turag and Dhalweshari rivers likewise exceed the standard values of 0.06 mg/l and 0.39 mg/l, respectively. Long-term Pb exposure could cause major neurological health problems if residents eat vegetables cultivated in this area on a regular basis.

6.3 Heavy Metal Risk on Human Health and Surrounding Environment

Heavy metal is one of the most harmful pollutants, threatening both individuals and the environment. As a result of unplanned urbanization and industrialisation, metal concentrations are rising at an alarming rate. While some metals are essential as micronutrients, excessive amounts have a substantial negative impact. Poisonous heavy metals in river water can cause major problems for all living things due to their long persistence and bioaccumulation in the food chain.

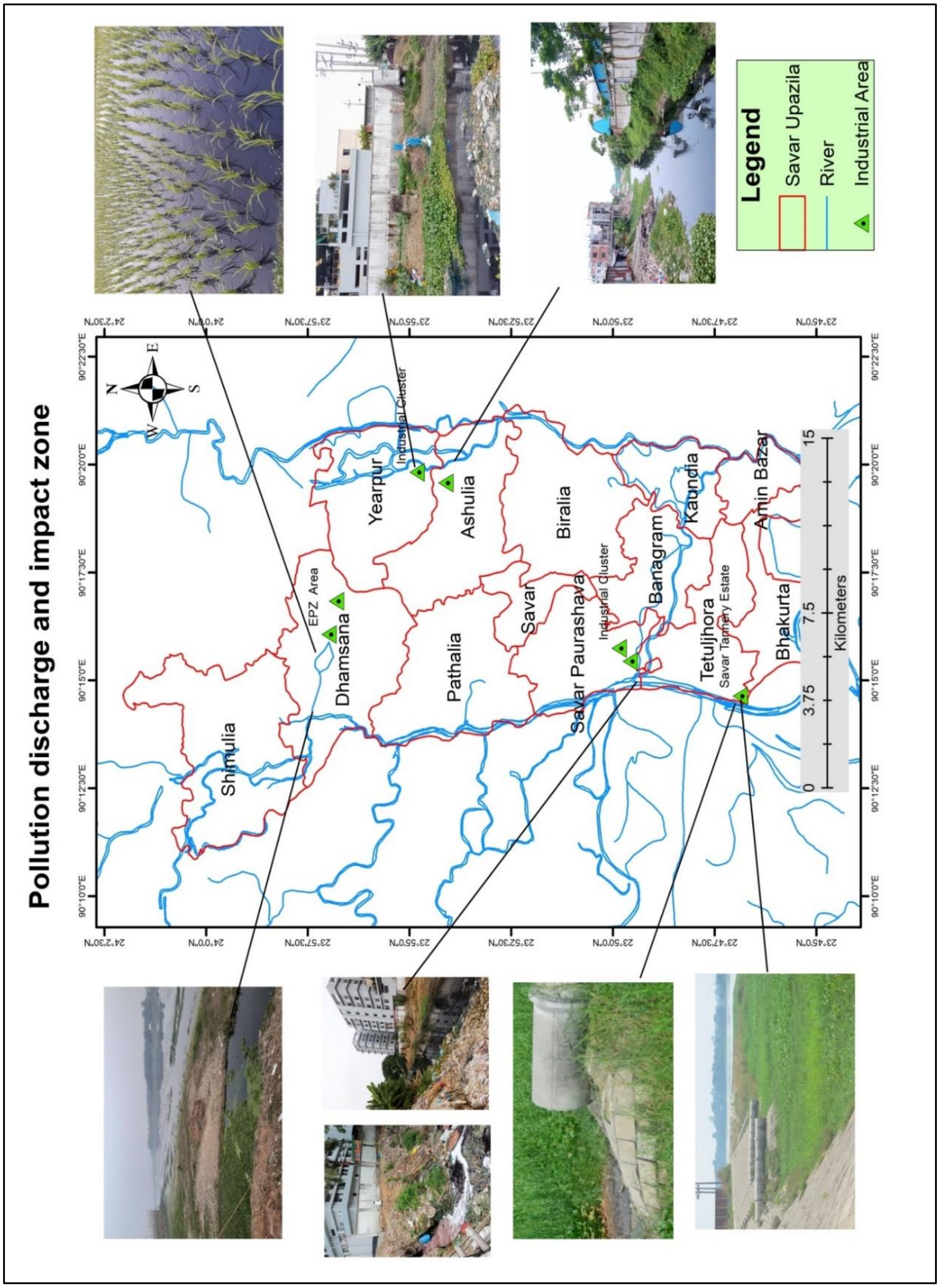


Figure 6: Pollution discharge and impact zone

Source: Field Survey,2022

Industrial waste pollution is organic, inorganic, and hazardous in nature, necessitating suitable treatment prior to disposal to avoid physical, chemical, and biological contamination of the receiving environment. The majority of our country's rivers are polluted by industrial trash. Rapid urbanization and development in the Savar area are increasing waste generation day by day (GoB,2007). Water is thought to be a transmitter of diseases like typhoid, para-typhoid, dysentery, cholera, hepatitis etc. The area's ground water and agricultural land have been contaminated as a result of the continuous chemical onslaught on the area's life line. However, the loss of aquatic vegetation and fauna, including fish resources, has already occurred in surface water. The majority of the time, river water is used for agriculture. As a result, when river water becomes contaminated and is used for irrigation, the land becomes contaminated. If the effluent release proceeds, the surrounding geo-environment will also suffer long-term damage.

Table 5: Impacts of various heavy metals on human health and plants

Heavy Metals	Effects on Human Health	Effects on Plants
Chromium (Cr)	- Dermatitis; - Lung diseases such as cancer, asthma; - Acute renal failure; - Gastrointestinal hemorrhage - Nervous system damage etc.	- Restricts plant growth and metabolism process (Sharma, Sharma and Tripathi, 2003). - Slow growth of the shoots and roots (Sharma, Sharma and Tripathi, 2003).
Copper (Cu)	- Liver and kidney damage; - Mental disorders; - Gastrointestinal hemorrhage; - Anemia; - Hypertension; - Death.	- Causes necrosis of the tip of the young leaves. Cereals and leguminous plants suffer from reclamation diseases (Cook et al.,1997). - Malformation and reduction of the roots (Cook et al.,1997). - Biomass and seed production have decreased (Kjaer and Elmegaard, 1996).
Iron (Fe)	- Anemia; - Cancer; - Diabetes; - Heart disease.	- Lower nutrient absorption and translocation (Martinez-Fernandez and Komarek, 2016). - Inhibited phyto-hormones (Gui et al.,2015). - Decreased root elongation (Liu, Zhang

		and Lal, 2016).
Lead (Pb)	- Memory loss and insomnia; - Joints weakness; - Vomiting and diarrhea; - Abdominal pain; - Anemia; - Cardiovascular diseases; - Gastrointestinal hemorrhage; - Coma and Death.	- Decrease in the number of leaves and plant height (Kabir, Iqbal and Shafiq, 2009). - Lower germination percentage, slower growth (Hussain et al,2013).
Nickel (Ni)	- Heart and liver damage; - Respiratory tract cancer.	- Lower chlorophyll content and stomatal conductance, as well as affecting the Calvin cycle and CO2 fixation (Sheoran, Singal and Singh, 1990). - Reduced nutrient uptake by plants (Pandolfini, Gabbrielli and Comparini, 1992). - Root growth inhibition (Lin and Kao, 2005).
Zinc (Zn)	- Gastrointestinal distress; - Damage to nervous system.	- Chlorosis of the older leaves. - Chlorophyll content decreases, chloroplast structure changes, photosystem II activity decreases, and plant development decreases. (Doncheva,2005).

Source: Compile by Author, 2023

7. Geospatial Inquiry of Industrial Water Pollution Impact

This study explores the impact of industrial water pollution on rivers in Savar Upazila. It uses advanced geospatial methodologies to understand and visualize the multifaceted dimensions of industrial water pollution. The geospatial analysis contributes to actionable strategies for sustainable waste management. It helps stakeholders and policymakers make informed decisions regarding industrial site selection, zoning regulations, and pollution control measures. Researchers have identified pollution levels and risk zones in three major rivers adjacent to Savar industrial area, which are compiled together in Figure 7 and 8.

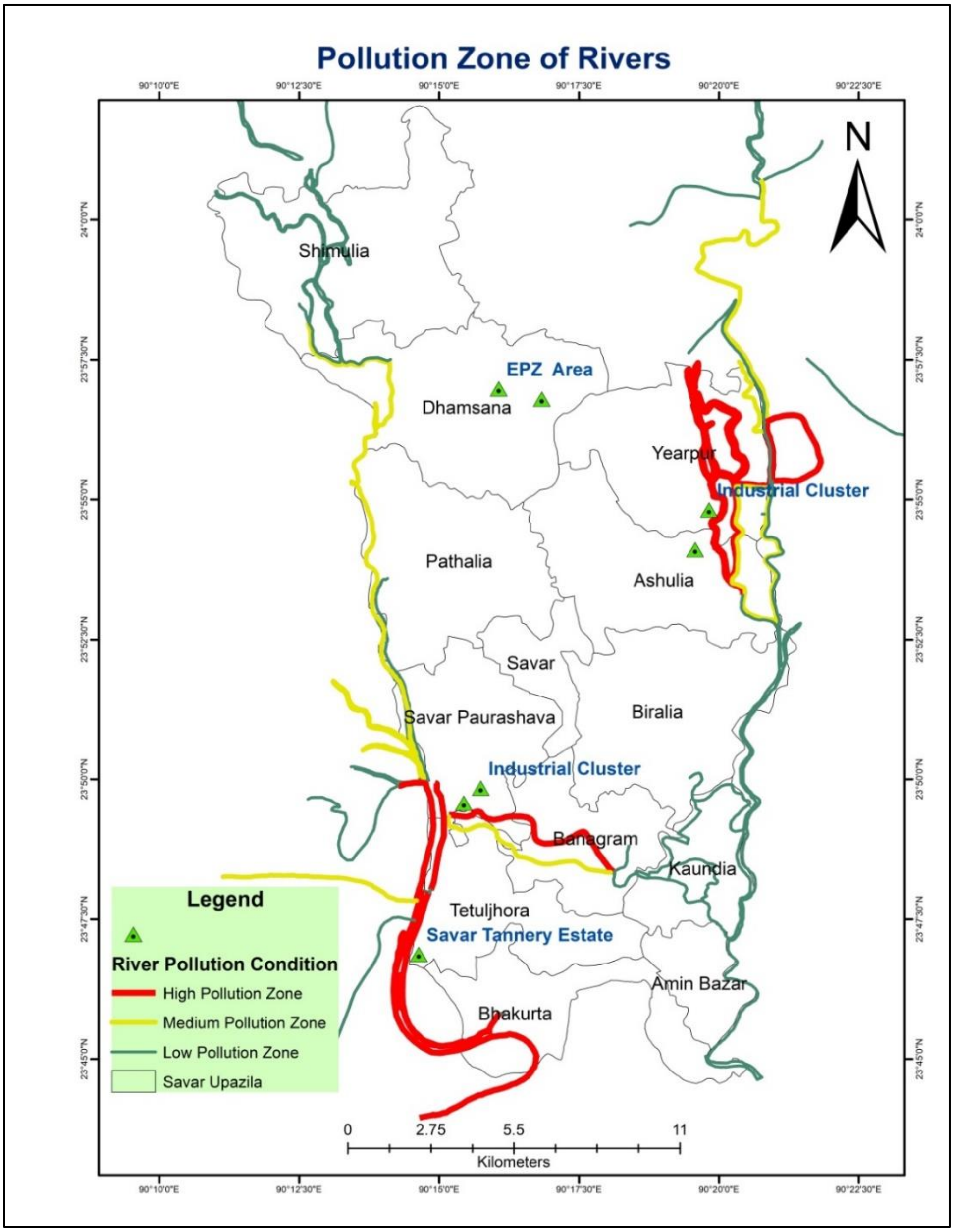


Figure 7: River Pollution Condition

Source: Developed By Author, 2023 (Arefin et al.,2016; Mottalib, Roy and Khan, 2017; Hossain and Abedin, 2019)

The area denoted by the red mark in the illustration is of particularly poor water quality and is therefore unfit for human consumption or agricultural use. In this area, several chemicals and heavy metals have polluted the water supply. The contamination spreads to the yellow mark areas as well. This water is not drinkable but is utilized for gardening and agricultural purposes. The areas highlighted in green are suitable for both drinking water and agricultural irrigation since the levels of chemical and heavy metal pollutants are well below the regulatory standards.

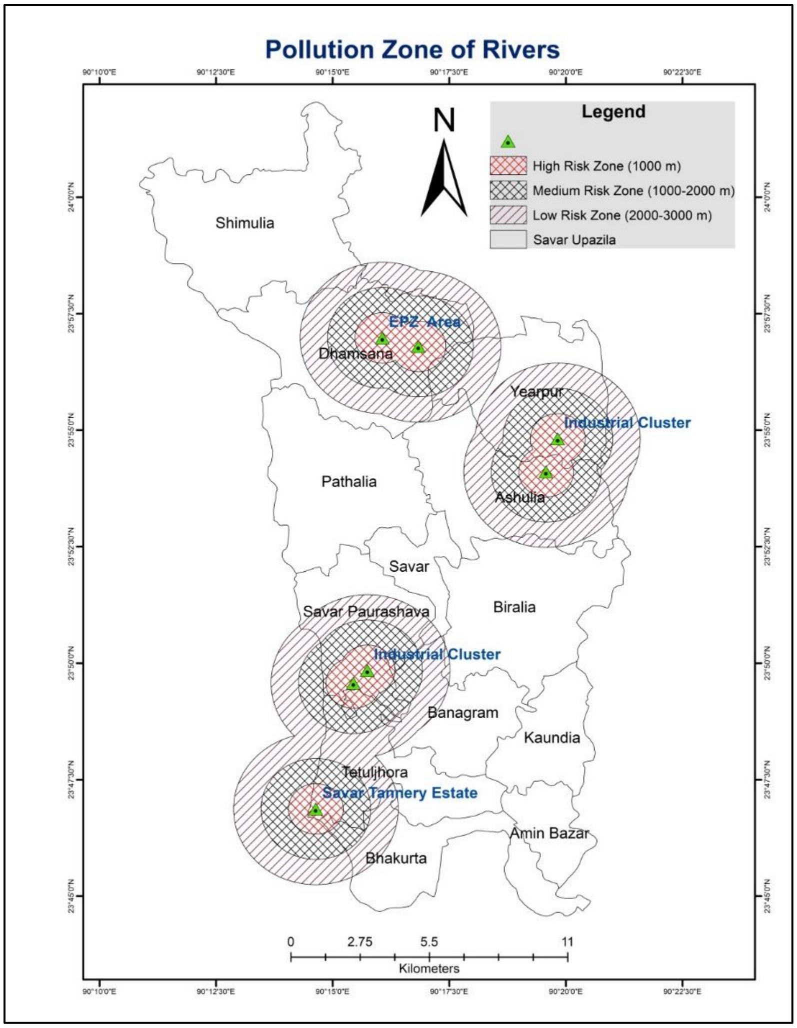


Figure 8: Influenced pollution risk zone of the industrial area

Source: Developed By Author, 2023 (Arefin et al.,2016; Mottalib, Roy and Khan, 2017; Hossain and Abedin, 2019)

As a result of direct industrial discharge, the surface water within a radius of one thousand meters from the industrial zone is heavily polluted. The 1000–2000 meter range indicates the medium risk zone, which is also contaminated due to the river's overflow during the monsoon season and the water logging issue of the area. The low risk zone indicates a distance of 2,000 to 3,000 meters from the industrial zone, which is where the river's irrigation is dispersing the industrial effluent.

8. Recommendations to Control River Pollution by Industries and It's Associated Impacts

Instead of the present DoE in-house review procedure, it is essential that the government establishes an independent EIA review board made up of specialists from research institutions, industrial associations, the media, and civil society as an initial step toward pollution reduction. The outcome of the EIA review, as well as the accepted EIA report, must be made public. It is also important that the project proponent's frequent post-development, environmental monitoring be subjected to third-party verification and that the information be made public. Industrial pollution mitigation would be necessary for all of the existing industrial clusters under consideration. Outside of these clusters, mitigation is also required for isolated individual enterprises. The mitigation strategy can be divided into four categories: Policy intervention; Management intervention; Technical option and Raising awareness. Better environmental performance in industrial clusters could be achieved through a combination of policy intervention, good management practices, technical control measures, and raising awareness among owners and the general public, recognizing the recent paradigm shift from expensive mitigation measures through treatment to cost-effective environmental management.

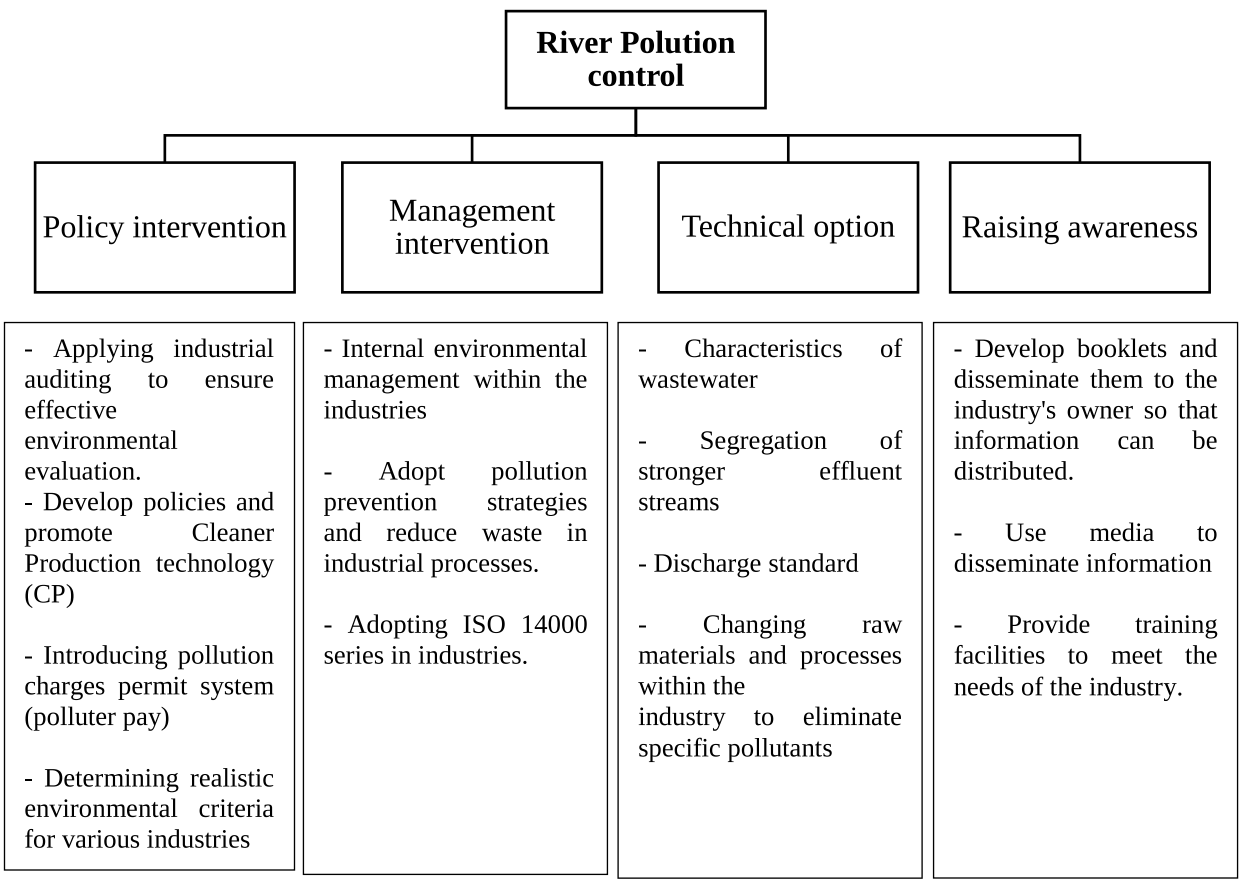


Figure 9: River pollution Control Strategy

9. Conclusion

River water pollution is a global problem and not peculiar to Bangladesh. However, rising pollution of rivers in Bangladesh is a significant concern for the government and population. Unfortunately, most rivers in Bangladesh are victims of pollution. Rising river water pollution of Bangladesh spares no area of life in this country. It impacts everyone. Based on different research data it is evident that river water is very much important for domestic, agriculture and industrial use in Bangladesh, but it is in critical condition from long time. Water is such an essential component of the human biosphere that any negative changes to this area of the environment have a significant impact on the entire quality of human life. This study looked at the effects of anthropogenic heavy metal contamination on the acuatic body in Savar area. All of the indices pointed to the fact that different metals had a significant impact on the study area. Agricultural crops contain toxic metals through polluted water irrigation. The consumption of the contaminated foodstuff can cause serious health injuries. Bioaccumulation of heavy metals in fish body is occurred in the polluted river, which causes toxic effects in fish body. Consumption of this contaminated fish might cause severe toxic effects in human body. Moreover, polluted water of the river causes serious damage to the aquatic ecosystem of the river. The damage of ecosystem creates different types of negative impacts in the entire environment of the study area. Unless urgent steps are taken to check the pollution of rivers and stringent environment safety rules are enforced strictly, the situation is likely to worsen further. There is an urgent need to look into the measures to control river water pollution. Damage to the environment as well as to ecology could be restricted only if zero discharge system ETP is implemented. The regulatory authorities should take immediate action on the study site in this regard. To prevent pollution of river water, legislation must be enacted that legally binds particular enterprises and prohibits the release of untreated or poorly treated industrial effluents. To assess the environmental quality, immediate steps must be taken, including routine monitoring of harmful metals in river water. Wastewater discharged by industrial units could be recycled for pollution mitigation in a sustainable and eco - friendly manner.

References

Abdin, M. (2016). For Sustainable Economic Development of Bangladesh. The Independent.

Ahmed, G., Uddin, M.K., Khan, G.M., Rahman, M.S., Chowdhury, D.A. (2009). Distribution of trace metal pollutants in surface water system connected to effluent disposal points of Dhaka Export Processing Zone (DEPZ), Bangladesh: A statistical approach. J. Nat. Sci. Sus. Technol. 3, 293–304.

Ahmed, M. K., S, A., Rahman, M., Haque, M., & Islam, M. (2009). Heavy metals concentration in water, sediments and their bioaccumulations in some freshwater fishes and mussel in Dhaleshwari River, Bangladesh. Terrestrial and Aquatic Environmental Toxicology, 3, 33-41.

Ahmed, R., Faruk, I., Ferdous, S., Chowdhury, M. R., & Mamtaz, R. (2020). Impacts of relocation of tannery industries on the river system of Dhaka. In 5th International Conference on Civil Engineering for Sustainable Development (ICCESD 2020). KUET, Khulna, Bangladesh.

Akter, M. (2014). Water quality assessment of an industrial zone polluted aquatic body in Dhaka, Bangladesh. American Journal of Environmental Protection, 3(5), 232. doi:10.11648/j.ajep.20140305.14

Arefin, M. T., Rahman, M. M., Wahid-U-Zzaman, M., & Kim, J. (2016). Heavy metal contamination in surface water used for irrigation: Functional assessment of the Turag River in Bangladesh. Journal of Applied Biological Chemistry, 59(1), 83-90. doi:10.3839/jabc.2016.015

Arefin, M., & Mallik, A. (2017). Sources and causes of water pollution in Bangladesh: A technical overview. BIBECHANA, 15, 97-112. doi: 10.3126/bibechana.v15i0.18688

Bangladesh Economic Review, (2017).

Bangladesh Export Processing Zones Authority, (2020). Retrieved 16 December 2020, from https://bepza.gov.bd/

BCAS, (2018).Bangladesh Centre for Advanced Studies.

Begum, T., Dey, S., Roy, K., Hena, M. K. A., Amin, K. R., & Sharmin, S. (2018). Assessment of surface water quality of the Turag River in Bangladesh. Research Journal of Chemistry and Environment, 22, 49-56.

Cook, C.M., Kostidou. A., Vardaka, E., & Lanaras,T. (1997) Effects of copper on the growth,photosynthesis and nutrient concentrations of Phaseolus plants. Photosynthetica 34(2):179–193

Dipta, I. A. & Akhie, A. A. (2018). Effects of water pollution insurrounding rivers of Dhaka city. International Conferenceon Research and Innovation in Civil Engineering (ICRICE2018). Southern University Bangladesh (SUB), Chittagong,Bangladesh, ISBN: 978-984-34-3576-7

Doncheva, S., Georgieva, K., Vassileva, V., Stoyanova, Z., Popov, N. & Ignatov, G. (2005) Effects ofsuccinate on manganese toxicity in pea plants. J Plant Nutr 28(1):47–62

FAO. (n.d.). Implementation of the Global Strategy in Bangladesh. Retrieved February 1, 2022, from https://www.fao.org/asiapacific/perspectives/agricultural-statistics/global-strategy/results-in-the-region/bangladesh/en/

GHOSH, P., & HOSSAIN, M. (2019). Assessment of Tannery Effluent: A Case Study on Dhaleshwari River in Bangladesh. Proceedings of International Conference on Planning, Architecture and Civil Engineering. Rajshahi University of Engineering & Technology, Rajshahi, Bangladesh.

GoB (2007). Environmental Quality Standards for Bangladesh. Department of Environment, Dhaka.

Gui, X., Deng, Y. Q., Rui, Y. K., Gao, B. B., Luo, W. H., Chen, S. L., Nhan, L. V., Li, X. G., Liu, S. T., Han, Y. N., et al., (2015). Response difference of transgenic and conventional rice (Oryza sativa) to nanoparticles (gamma Fe2O3). Environ. Sci. Pollut. Res. 22, 17716- 23.

Hafizur, R., Hossain, M., & Islam, M. R. (2017). Investigation of physicochemical parameter heavy metal in Turag river water and adjacent industrial effluent in Bangladesh. Journal BiNET, 05, 347-360. doi: 10.18801/jstei.050117.37

Halim, M., Islam, M., Safiullah, S., Waliul Hoque, S., & Saiful Islam, M. (2009). Heavy Metal (pb, cd, Zn, Cu, cr, Fe and Mn) content in textile sludge in Gazipur, Bangladesh. Research Journal of Environmental Sciences, 3(3), 311-315. doi:10.3923/rjes.2009.311.315

Hasan, M. M., Ahmed, M. S., Adnan, R., & Shafiquzzaman, M. (2020). Water quality indices to assess the spatiotemporal variations of Dhaleshwari River in central Bangladesh. Environmental and Sustainability Indicators, 8, 100068. doi:10.1016/j.indic.2020.100068

Hasan, M., Ahmed, M., & Adnan, R. (2020). Assessment of physico-chemical characteristics of river water emphasizing tannery industrial park: a case study of Dhaleshwari River, Bangladesh. Environmental Monitoring and Assessment, 192. doi: 10.1007/s10661-020-08750-z

Hasan, M., Islam, M. A., Aziz Hasan, M., Alam, M. J., & Peas, M. H. (2019). Groundwater vulnerability assessment in savar upazila of Dhaka District, Bangladesh — a GIS-based drastic modeling. Groundwater for Sustainable Development, 9, 100220. doi:10.1016/j.gsd.2019.100220

Hossain, S., & Abedin, A. B. M. S. (2019). Addressing the Impacts of Tannery Wastes on Soil Condition of Tetuljhora and Hazratpur Union: A Management Perspective. The Jahangirnagar Review Part II: Social Science, Vol. XLIII(1682-422), 211-225.

Hussain, A., Abbas, N., Arshad, F., et al (2013) Effects of diverse doses of lead (Pb) on differentgrowth attributes of Zea mays L. Agric Sci 4(5):262–265

Islam, M., Uddin, M., Tareq, S., Shammi, M., Kamal, A., & Sugano, T. et al. (2015). Alteration of Water Pollution Level with the Seasonal Changes in Mean Daily Discharge in Three Main Rivers around Dhaka City, Bangladesh. Environments, 2(4), 280-294. doi: 10.3390/environments2030280

Kabir, M. R. (2014). Social Impact Assessment Of Water Pollution: A Case Study On Bangshi River, Savar (Unpublished master's thesis). Brac University.

Kabir, M., Iqbal, M.Z., Shafiq, M. (2009). Effects of lead on seedling growth of Thespesia populnea L.Adv Environ Biol 3(2):184–190

Khan, M.K., Alam, A.M., Islam, M.S., Hassan, M.Q., and Al-Mansur, M.A. (2011). Environmental pollution around Dhaka EPZ and its impact on surface and groundwater. Bangladesh J. Sci. Ind. Res. 46, 153-162.

Khanam, D., Rahman, S., Islam, M., Ahsan, M., Saha, B., Akbor, M. A., Adyel, T. et al. (2011). Seasonal Implication of Heavy Metal Contamination of Surface Water around Dhaka Export Processing Zone (DEPZ), Savar, Bangladesh. Jahangirnagar University Journal of Science, 34, 21-35.

Khanam, D., Rahman, S.H., Islam, M.S., Ahsan, M.A., Shaha, B., Akbor, M.A., Beg, R.U., and Adyel, T.M. (2011). Seasonal implication of heavy metal contamination of surface water around Dhaka Export Processing Zone (DEPZ), Savar, Bangladesh. Jahangirnagar University. Journal of Science, 34, 21-35.

Kjær, C., & Elmegaard, N. (1996) Effects of copper sulfate on black bindweed (Polygonumconvolvulus L.). Ecotoxicol Environ Saf 33(2):110–117

Lin, Y.C. & Kao, C.H. (2005). Nickel toxicity of rice seedlings: cell wall peroxidase, lignin, and NiSO4-inhibited root growth. Crop Environ Bioinform 2:131–136.

Liu, R. Q., Zhang, H. Y., Lal, R. (2016). Effects of stabilized nanoparticles of copper, zinc, manganese, and iron oxides in low concentrations on lettuce (Lactuca sativa) seed germination: nanotoxicants or nanonutrients? Water, Air, & Soil Pollution. 227, 1-14.

Lutfor Rahman, A., Islam, M., Hossain, M., & Ahsan, M. (2012). Study of the seasonal variations in Turag River water quality parameters. African Journal of Pure and Applied Chemistry, 6(10). doi:10.5897/ajpac12.023

Mahfuz, M.A., Ahmad, J.U., Sultana, M.S., Rahman, M.M., Goni, M.A., Rahman, M.S. (2004). Status of physicochemical properties of wastewater in Bangladesh: A cash studies in Dhalai Beel of DEPZ. Bangladesh J. Environ. Res. 2, 9–15.

Martinez-Fernandez, D., Komarek, M. (2016). Comparative effects of nanoscale zero-valent iron (nZVI) and Fe2O3 nanoparticles on root hydraulic conductivity of Solanum lycopersicum L. Environ. Exp. Bot. 131, 128-36.

MoEF (1997) Environmental Conservation Rules, 1997, Ministry of Environment and Forests, Dhaka

MoEF (2011) Water quality report, 2011, Ministry of Environment and Forests, Dhaka.

MoEF (2012) Water quality report, 2012, Ministry of Environment and Forests, Dhaka.

MoEF (2013) Water quality report, 2013, Ministry of Environment and Forests, Dhaka.

MoEF (2014) Water quality report, 2014, Ministry of Environment and Forests, Dhaka.

MoEF (2015) Water quality report, 2015, Ministry of Environment and Forests, Dhaka.

MoEF (2016) Water quality report, 2016, Ministry of Environment and Forests, Dhaka.

Momtaz, H., Alam, F., Ahsan, M., Akbor, M. A., & Rashid, M. M. (2012). Surface water quality around DEPZ industrial area, Savar, Dhaka. Bangladesh Journal of Scientific and Industrial Research, 47. doi: 10.3329/bjsir.v47i3.13061

Mondol, M., Chamon, A., Faiz, B., & Elahi, S. (2011). Seasonal variation of heavy metal concentrations in water and plant samples around Tejgaon Industrial Area of Bangladesh. Journal of Bangladesh Academy of Sciences, 35(1), 19-41. doi:10.3329/jbas.v35i1.7968

Mortula, M., and Rahaman, M. (2002). Study on Waste Disposal at DEPZ. Bangladesh Environment (BAPA). 2. 807-817.

Mottalib, A., Roy, S., & Khan, M. (2017). Comparative Study Of Water Quality Of Buriganga And Balu River, Dhaka Bangladesh. International Journal of Current Research, 9, 59132-59137.

Pandolfini, T., Gabbrielli, R., Comparini, C. (1992) Nickel toxicity and peroxidase activity inseedlings of Triticum aestivum L. Plant Cell Environ 15(6):719–725

Rabbi, F., Uddin, Z., Ahmed, M., & Majed, N. (2016). Pollution status of turag river: spatial and temporal variation of water quality. In Proceedings of 3rd International Conference on Advances in Civil Engineering (pp. 31-36).

Rahman, A., Jahanara, I., & Jolly, Y. N. (2021). Assessment of physicochemical properties of water and their seasonal variation in an urban river in Bangladesh. Water Science and Engineering, 14(2), 139-148. doi:10.1016/j.wse.2021.06.006

Rahman, M. M. (2012). Present Status of Water Quality of The Bangshi River, Savar, Dhaka, Bangladesh. Bangladesh journal of Environmental research.

Rahman, M., Saha, N., & Molla, A. (2014). Potential ecological risk assessment of heavy metal contamination in sediment and water body around Dhaka export processing zone, Bangladesh. Environmental Earth Sciences, 71. doi: 10.1007/s12665-013-2631-5

Rahman, S.H., Neelormi, S., Tareq, S.M. (2008). Environmental impact assessments of textile and dyeing industries on ecosystem of Karnopara canal at Savar, Bangladesh. Jahangirnagar Univ. J. Sci. 31, 19–32.

Reza, A. and Yousuf, T.B. (2016) Impacts of Waste Dumping on Water Quality in the Buriganga River, Bangladesh and Possible Mitigation Measures. Journal of the Environment, 11, 35-40.

Reza,A. and Yousuf, T.B. (2016) Impacts of waste dumping on water quality in the Buriganga River,Bangladesh and possible mitigation measures. Journal of the Environment 11(1): 35–40.

Sharma, D.M., Sharma, C.P., & Tripathi, R.D. (2003). Phytotoxic lesions of chromium in maize. Chemosphere 51:63–68

Sheoran, I.S., Singal, H.R., Singh, R. (1990). Effect of cadmium and nickel on photosynthesis and theenzymes of the photosynthetic carbon reduction cycle in pigeonpea (Cajanus cajan L.). Photosynth Res 23(3):345–351.

Siddique, S., & Hassan, K. (2018). Scenario of Bangshi River Water of Savar Pourashava and Planning for a Sustainable Management. In 4 th International Conference on Civil Engineering for Sustainable Development (ICCESD 2018). KUET, Khulna, Bangladesh., ISBN-978-984-34-3502-6.

Sikder, D. M., S, T., Saito, T., Hosokawa, T., Gumiri, S., Ardianor, Kurasaki, M. et al. (2015). Vulnerability assessment of surface water quality with an innovative integrated multi-parameter water quality index (IMWQI). Pollution, 1, 333-346.

Sultana N, Alam AKMR, HoqueS, 2017. Some physical and chemical characteristics of soil in selected wetlands at Savar, Bangladesh. Jahangirnagar University Environ Bull 6:13-26. Available from:https://www.researchgate.net/publication/324419470_Some_Physical_and_Chemical_Characteristi cs_of_Soil_in_Selected_Wetlands_at_Savar_Bangladesh Accessed: 20 January 2021.

Talha, B.H.(2007). Pollution Sounds the Death Knell of Turag. The Independent.

The Daily Star. (2022). Revitalising Bangladesh's Agriculture Sector. Retrieved 23 January 2022, from https://www.thedailystar.net/supplements/30th-anniversary supplements/news/revitalising-bangladeshs-agriculture-sector-2042629.

Uddin, M., Parveen, Z., & Hossain, M. (2016). Status of Heavy Metals in Water and Sediments of Canals and Rivers around the Dhaka City of Bangladesh and their Subsequent Transfer to Crops. Advances In Plants & Agriculture Research, 5(4). doi: 10.15406/apar.2016.05.00189

Uddin, M.J., & Rajonee, A.A. (2016). Present Environmental Condition and Its Impact on Livelihood – A Case Study of Two Villages around the University of Barisal. Developing Country Studies, 6, 121-128.

Whitehead, P., Mimouni, Z., Butterfield, D., Bussi, G., Hossain, M., & Peters, R. et al. (2021). A New Multibranch Model for Metals in River Systems: Impacts and Control of Tannery Wastes in Bangladesh. Sustainability, 13(6), 3556. doi: 10.3390/su13063556

WHO. (2003). Guidelines for drinking-water quality (3rd ed., Vol. 1). Geneva: World Health Organization.

Yaylalı-Abanuz, G. (2011). Heavy metal contamination of surface soil around gebze Industrial Area, Turkey. Microchemical Journal, 99(1), 82-92. doi:10.1016/j.microc.2011.04.004