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WATER QUALITY MODELLING AND ASSESSMENT OF THE BURIGANGA RIVER USING QUAL2K

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ABSTRACT
The Buriganga River runs through Dhaka's south and west sides. Due to the anthropogenic involvement of essential pollutants such as industrial effluents, urban sewage, and solid wastes in this area, the water quality of this river has been a source of worry. The Dissolved Oxygen of the river water showed a variation from 0.50 mg/L to 3.5 mg/l. The BOD of the river water was shown in a variation of 27.50 mg/L to 129.7 mg/L, where the mean value was 78.6 mg/L. Although Biochemical Oxygen Demand (BOD) is not a water quality parameter, it is the most widely utilized indicator of a surface water body's overall health. The COD of water from the river Buriganga was 65.29 mg/L to 279.8 mg/L. The concentration of Ammoniacal Nitrogen in the river water was found to vary from 1.8 mg/L to 6.9 mg/L. Suspended Solids of the Buriganga River Water ranged from 36 mg/L to 42 mg/L. The water quality test results have been used as input data in the Qual2k Software, and a produced Water Quality Model has been shown using the Qual2k software. The mean value of these physicochemical parameters has been summarised to calculate the River's Water Quality Index (WQI) using the DoE formula, which was found to be 27.77, classified as very polluted class V water.

Keywords: *Water Quality, Qual2k, Biochemical Oxygen Demand, Buriganga River, Water Quality Index, dissolved Oxygen*.

INTRODUCTION
Water is essential for human survival and the survival of plants, animals, and all other living species. Water bodies, including lakes, rivers, ponds, and estuaries, provide water for home, industrial, agricultural, and aquaculture applications. Water quality models (WQM) are decision-making aids that simulate the fate of pollutants in water columns and estimate the hazards that come with them (Chapra & Pelletier, 2003). Monitoring for pollutant estimation is a complex endeavour that necessitates updating existing models and developing new WQM to accurately measure solute transport in water bodies (Strokal et al., 2019). (Manoj & Padhy, 2014)conducted the first substantial research on water quality modeling in 1925, simulating BOD and DO in the river system. Simulation and optimization models are two types of WQM (Horn, Rueda, Hörmann, & Fohrer, 2004). All models that portray changes in water quality in any mathematical manner are called simulation models. This paper will cover the water quality modeling of the Buriganga River and assess the potential point sources of pollution affecting the water quality. Water samples will be taken from two sampling stations, and chemical tests will be conducted to get the observed values of water quality parameters. After getting the required input data, Qual2k software will be run, and the modeled data will be compared with the observed data, which was achieved from the chemical tests. This will provide more accurate values of the water quality parameters. Finally, WQI will be measured using the DoE formula to classify the river water. Potential sources of pollution can be identified from previous research papers related to it and from surveying the surrounding area of the sampling stations.

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PROBLEM STATEMENT

The Buriganga River is now suffering from a significant pollution problem. Some of the contaminants in Buriganga include mill and factory wastes, domestic wastes, medical wastes, sewage, dead animals, plastics, and oil (Ahammed, Tasfina, Rabbani, & Khaleque, 2016). Thousands of tons of solid trash are discharged daily in Dhaka, most of which end up in the Buriganga. Tanneries send 22,000 cubic liters of poisonous waste into the river every day, according to the Department of the Environment (DoE). Tongi, Tejgaon, Hazaribagh, Tarabo, Narayanganj, Savar, Gazipur, Dhaka export processing zone, and Ghorashal have been recognized as the fundamental causes of river pollution in and around the capital city (Ahammed et al., 2016). Most of these areas' industrial facilities have no sewage treatment or effluent treatment plants. The textile industry produces up to 56 million tons of garbage and 0.5 million tons of sludge per year, the most of which is dumped into the Buriganga. According to a report from 2004, up to 80% of Dhaka's sewage was untreated (Nath, Choudhury, & Sinha, 2017). The discharged waste materials transform the air, water, and soil into an extensive reservoir of harmful contaminants. Increased environmental impacts have resulted in acid rain, global warming, and health risks (Kroeze et al., 2016). Any artificial alteration of the environment's composition could have devastating implications and potentially jeopardize life's survival on the planet (Boye, Falconer, & Akande, 2015; Delpla, Jung, Baures, Clement, & Thomas, 2009; Strokal et al., 2019). As a result, this research aims to review the water quality parameters using QUAL2K modeling and assess the causes of pollution affecting water quality.

OBJECTIVES

The study's overall goals are to examine the current state of the Buriganga River's water quality and to analyze the effects of contaminants in the river using an existing water quality model. The following are the specific objectives:

- To evaluate the current water quality of the River Buriganga based on the physico-chemical water quality parameters.
- To determine the Water Quality Index (WQI) using the DoE formula
- To provide information regarding the level of pollution on each segment of the river based on the physicochemical parameters using Qual2K for future wastewater Management

SCOPE OF STUDY

The river Buriganga runs through Dhaka city. It's one of the world's most crowded cities. This city, which is only partially connected to the sewer pipeline, has a population of approximately twenty million people. In addition, over the last decade, a number of industries have been installed, with many more in the process. As a result, the volume of sewage (treated or untreated) and industrial wastes (mainly untreated) discharged into the river has skyrocketed. The research also focuses on the QUAL2K software's water quality model application. The QUAL2K water quality model is a one-dimensional, steady-flow stream model. It featured simulations of new water quality interactions such as algal death to BOD conversion, denitrification, and DO shifts generated by fixed plants. These new elements have the potential to overcome QUAL2E's limitations. It is free software that is beneficial in data-constrained situations. The primary goal of this research is to use the QUAL2K model to estimate water quality metrics such as DO and BOD5 along the lower Buriganga River and to construct hypothetical scenarios to keep the Buriganga River's DO concentration constant within the allowable limits.

LITERATURE REVIEW

The Department of Environment (DOE) maintains three monitoring stations along the Buriganga, where samples are taken as needed (Salman, Ahmed, Peas, & Khan, 2018). The selection of DOE sampling stations is based mainly on the placement of various industrial installations along river banks, with the goal of determining the effects of effluent discharges on water quality (Kamal, 1996). The study examined cumulative data for three metrics, namely TS, DO, and BOD, for the river Buriganga from 1984 to the present. The metrics are generally within acceptable ranges, although there is an apparent decline in water quality in very modest amounts (Kamal, 1996). The following observations are made about the Buriganga's river water quality: The Buriganga River's total solids (TS) content constantly increases in the wet and dry seasons. Because there was less dilution during the dry season, the pace of change was more pronounced. The concentration has increased from around 225 mg/1

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to about 275 mg/1. In both the dry and rainy seasons, BOD is reaching three mg/l. It's worth noting that seasonal variation in BOD isn't as pronounced as it was in the 1980s (Nath et al., 2017). In other words, dilution during the rainy season is insufficient to reduce the BOD burden. As a result, oxygen depletion has been relatively rapid. It has dropped below 5 mg/1 in the dry season for the previous two years; in the wet season, the pace of change is less fast but still below 6 mg/1. (Kamal, 1996).

The dissolved gaseous form of oxygen is known as D.O. It is required for fish and other aquatic species to breathe (Teurlincx et al., 2019). D.O. enters water as a by-product of photosynthesis by algae and plants and diffusion from the atmosphere (Anastasiadis et al., 2013). To maintain 100 percent D.O. saturation, the concentration of D.O. in epigenetic fluids constantly equilibrates with the attention of atmospheric oxygen (Anastasiadis et al., 2013; Chapra & Pelletier, 2003). When the rate of photosynthesis exceeds the rate of oxygen diffusion to the atmosphere, excessive algal growth can over-saturate (more than 100 percent saturation) the water with D.O. Because there is no mechanism to replace oxygen depleted by respiration and decomposition, hypolimnetic D.O. concentrations are often low. To survive, fish require at least 3-5 mg/L of D.O. (Gorde and Jadhav, 2013)

The QUAL2K model uses a finite difference (implicit backward approach) to solve the governing equation and is built up as a one-dimensional steady-state and totally mixed system. The model was calibrated to minimize the general error for DO and BOD (Mustafa, Sulaiman, & Shahooth, 2017). Horn et al. (2004) used the model to examine the impact of point and non-point source pollution on the Ghataprabha River in Karnataka, India. They found that the water quality in the river is excellent. Furthermore, increased river flow is associated with decreased dissolved oxygen (Olowe, 2018).

The Department of the Environment (DOE) uses a water quality index (WQI) to classify the condition of rivers (Department of Environment, 2010). This index can be defined as a method for encapsulating large volumes of data about water quality in simple words so that it can be reported to management and the general public on a regular basis. Aside from that, a WQI enables comparisons between rivers (Sharma & Kansal, 2013). pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammoniacal Nitrogen (AN), Suspended Solids (SS), and Dissolved Oxygen (DO) are six chemical parameters that are assessed as a standard to estimate water quality using a WQI (DO) (Delpla et al., 2009; Kroeze et al., 2016; Strokal et al., 2019). Water quality data was also utilized to establish the status of water quality, whether it was classified as clean waters (80-100) (Gorde & Jadhav, 2013; Kroeze et al., 2016), mildly contaminated waters (60-80) (Boye et al., 2015; Rode et al., 2010; Teurlincx et al., 2019), or severely polluted waters (60) (Boye et al., 2015; Gao & Li, 2015; Sukereman & Suratman, 2016), and to classify rivers into Class I, II, III, IV, or V using the current Water Quality Index (WQI) (Sukereman & Suratman, 2016).

Every day, the tanneries pour 21,600 cubic meters (5.7 million US gallons) of poisonous waste into the river, according to the (Department of Environment, 2010). Seven critical places along the Buriganga River have been identified for monitoring the water quality: Mirpur Bridge, Boshila Bridge, Hazaribagh, Chandnighat, Sata Mosque Road, BD-China Friendship Bridge, and Fatullah (Salman et al., 2018). However, for this investigation, water samples were taken from two contaminated locations: Chandnighat and Fatullah. On November 8, 2016, the samples were taken. The pH concentration in Buriganga River water ranged from 7.4 to 7.6, although the typical pH range for inland surface water is 6.5 to 8.5, according to the analysis (Chen, Song, Liu, Yang, & Li, 2020). The dissolved oxygen (DO) concentration in the river water was higher than the Environmental Quality Standard (5 mg/l). In 2014, the highest DO (5.48 mg/I) was recorded in August at Mirpur Bridge, and the lowest (0.0 mg/l) was found in January at Sadar Ghat (Bangladesh Power Development Board, 2013).

METHODOLOGY

The goal of this study will be reached through a series of steps that make up the research technique. The phases that followed described the method used to accomplish the research's goals and objectives.

STUDY AREA

The research will be carried out in Bangladesh's Buriganga River. It is a tide-influenced river that flows west and south of Dhaka City and originates from the Dhaleshwari River. It's only 27 km long, with an average width of

400 meters and a depth of 10 meters (Boye et al., 2015). It is one of the country's and the world's most polluted rivers. The investigation includes the river area inside Dhaka city. Water samples were taken at Bosila Bridge, Kalunagar, Babubazar Ghat, Lalkuthi, Postogola, Pagla, and Fatullah. The river's water quality is degrading due to low DO levels, other harmful factors, and metal contamination.

Figure 1: Sampling Stations

Samplings

Samplings will be carried out period (November 2021) in sampling stations along the longitudinal axle of the Buriganga River. A multiparametric probe and turbidimeter will be used to determine the water temperature and pH. Dissolved oxygen (DO) can be measured using the Winkler method. Subsurface water can be used to collect samples (10 cm under the water level).

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Chemical Tests to be Performed

The following tests will be performed: Chemical oxygen demand (COD), Nessler test, Water pH determination Test, DO test using Winkler Method, and BOD5 Measurement using DO values. The Chemical oxygen demand (COD) and ammonia nitrogen test (Nessler Test) will be carried out with a Spectrophotometer Model 48000 DR 4000.

Application of Qual2k

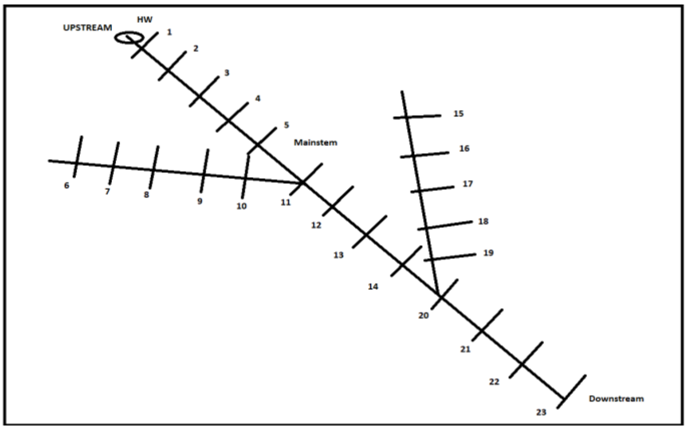
The information gathered was discussed, and recommendations were made based on the results of the data analysis performed with the QUAL2K software. The data collected from the spectrometer DR4000 test is then processed to produce the appropriate data.

Qual2k calibration consists of the following steps:

- the model is run with available data and initial estimations of response rates, settling velocities, and other parameters;
- the co-located simulated and observed values are compared;
- the estimated calibration parameters are tweaked until the simulated and observed values are reasonably close.
- During calibration, values for chemical concentrations, flow rates, and water depths are frequently compared.
- In yellow "data" sheets, Qual2K records observed data for calibration.

It's also worth noting that the system's principal branches (the main stem and each of the tributaries) are referred to as segments. This distinction is important since the program plots model results on a segment-by-segment basis. In other words, the software creates separate plots for the main stem and each of the tributaries. In this report, we will show the physical-chemical parameters of the Mainstem.

Figure 2: Mainstem Headwater & Tributaries Reach Number



Here, in the first sheet, we input the experimented data on 12 December 2021. As per local time, hours +6 hours have been set. For the calculation step, we took 0.1 hours, as specified by the software. The final time for calculation was ten days. The solution methods for integration and pH were the Euler and Brent methods. On the basis of upstream and downstream location, we divided the river into several reach numbers and computed reach length and element numbers.

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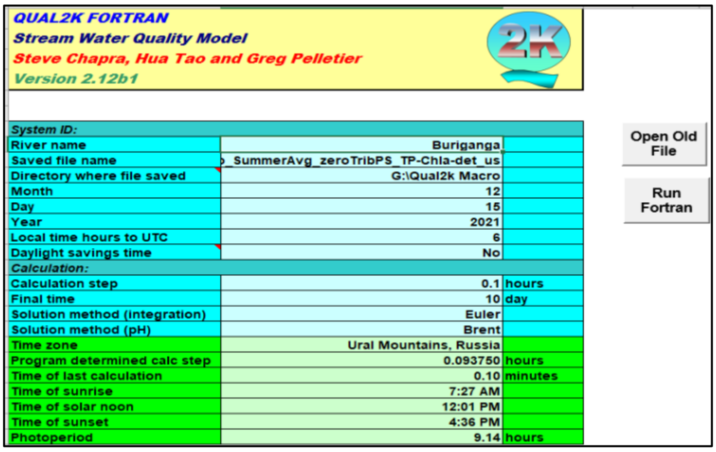
Figure 3: First Sheet Input



We input the experimented data for each physicochemical parameter (DO, COD, BOD5, NH3-N, SS) and pH in 6 different point sources in the water quality yellow data sheet.

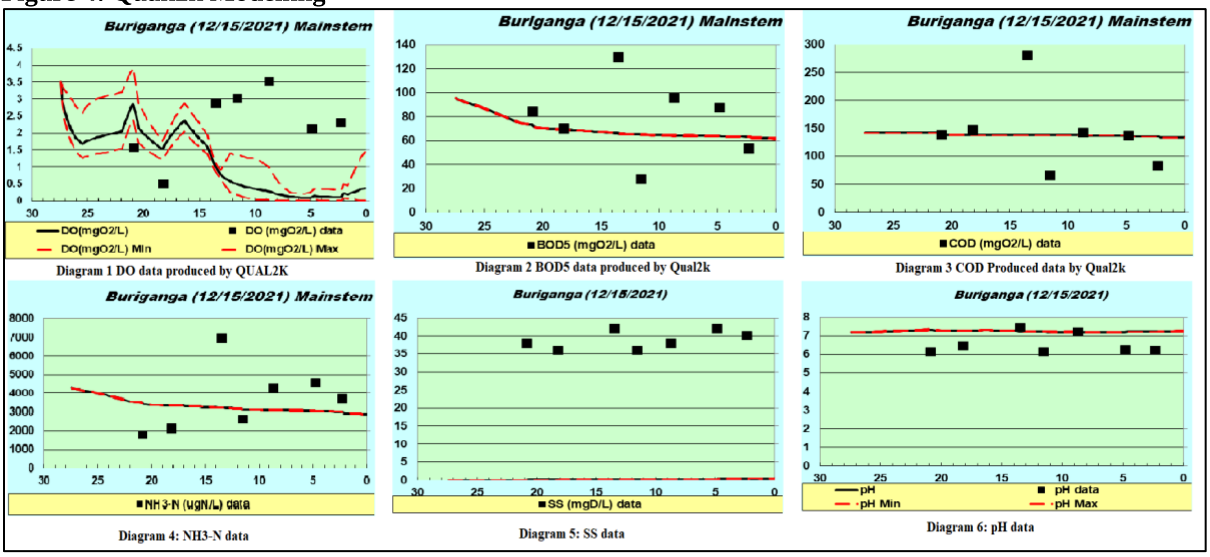
RESULTS AND DISCUSSION

In this section, the result will be discussed, as well as the outcome of the chemical experiment and Qual2k Modelling. The result is by comparing the lab's experimented data and the software's simulated data. The input parameters involved in QUAL2K were BOD5, COD, dissolved oxygen, ammonia nitrogen, nitrate nitrogen, and phosphate-phosphorus. The tests have been conducted in the dry season (winter).

Table 1: Water Quality Parameters at Various Stations Along the Buriganga River

Stations	pH	Temp.	DO	BOD	COD	NH3-N	SS
Bosila Bridge	6.11	18.30	1.57	84.00	137.80	1.80	38
Kalunagar	6.45	19.50	0.50	69.80	146.80	2.10	36
Babubazar	7.40	19.70	2.86	129.70	279.82	6.90	42
Lalkuthi	6.10	20.70	3.00	27.50	65.29	2.60	36
Postogola	7.20	21.60	3.50	95.60	142.40	4.30	38
Pagla	6.23	19.50	2.13	87.37	136.30	4.58	42
Fatullah	6.21	18.90	2.29	53.00	81.70	3.71	40

Figure 4: Quak2k Modelling



The simulated result will be produced after inputting the measured values in the water quality yellow sheet. In this Diagram 1, The black square boxes represent the estimated value of the DO from the experiment and the line shows our model produced by Qual2k. From this diagram, we can see the paid value of DO modeling at the upstream level is 3.5 mg/L and at the downstream level is 0.35 mg/L.
Diagram 2 shows the validated results of BOD5 by the Qual2k software. The BOD level gradually increases from the downstream to the upstream. In this diagram, the modelled value of BOD at the upstream is 94.62 mg/L whereas at the downstream, the value is 60.93 mg/L. Compared with the experimented data, the modeled data looks more precise after the validation.
The produced COD data by the Qual2k in Diagram 3 has been shown, ranging from 142.4 mg/L to 133.43 mg/L (Upstream to Downstream) which is quite acceptable compared with the mean value of the experimented data (141.44 mg/L).
Diagram 4 shows the validated result of Ammoniacal Nitrogen data produced by Qual2k, where the value of NH3-N upstream is 4.27 mg/L, and downstream, the value is 2.90 mg/L.
Diagram 5 shows the amount of suspended solids contained in different point sources. The validation has not been done perfectly in this case, as a vast difference exists between the modeled and input data. This could happen due to a technical error in the software. The modeled data is not acceptable in this case.
Diagram 4.6 illustrates the modeling of pH data of the Buriganga River. pH modeled value is the same upstream and downstream based on this diagram, which is 7.2. The black rectangular squares represent the input pH data in several different locations of the river. Analyzing the diagram, it can be said that the validation was smooth in terms of pH data.

Water Quality Index (WQI)
After analyzing the water quality model, the physicochemical properties will be used to measure the WQI using the DoE formula. The parameters chosen for the WQI based on the DoE's procedure are DO, BOD, COD, SS, AN, and pH. The system used in the calculation of the DoE's WQI is

$$WQI = 0.22*SIDO + 0.19*SIBOD + 0.16*SICOD + 0.15*SIAN + 0.16*SISS + 0.12*SIpH$$

Where SI is the Sub Index of each parameter.

DO – Dissolved Oxygen
BOD – Biochemical Oxygen Demand
COD – Chemical Oxygen Demand
AN – Ammoniacal Nitrogen
SS – Suspended Solid
pH – Acidity/Alkalinity

Table 2: Physicochemical properties and calculation of Water Quality Index of Buriganga River

Parameter	Min.	Max.	Mean
pH	6.11	7.40	6.76
DO	0.50	3.50	2.00
BOD	27.50	129.70	78.60
COD	65.29	279.80	172.55
AN	1.80	6.90	4.35
SS	36.00	42.00	39.00

Note: All units are in mg/L except pH.

Determine the WQI,

1. **Calculate the Sub-Indices:**
   - $SICOD = 103 \times e^{-0.0157 \times 172.55} = 103 \times e^{-2.71} \approx 6.85$
   - $SIBOD = 108 \times e^{-0.055 \times 78.60} - 0.1 \times 78.60 = 108 \times e^{-4.323} - 7.86 \approx -6.43$
   - $SIAN = 0$ (since AN ≥ 4)
   - $SISS = 97.5 \times e^{-0.00676 \times 39} + 0.1 \times 39 = 97.5 \times e^{-0.26364} + 3.9 \approx 78.80$
   - $SIpH = -242 + 95.5 \times 6.76 - 6.67 \times 6.76^2 = -242 + 645.42 - 306.63 \approx 98.78$
2. **Calculate the DO Index:**
   - $X = DO \times 12.6577 = 2 \times 12.6577 = 25.3154$
   - $SIDO = -0.395 + 0.03 \times 25.3154^2 - 0.000198 \times 25.3154^3 = -0.395 + 19.22 - 3.21 \approx 15.62$
3. **Calculate WQI:**
   - $WQI = 0.22 \times 15.62 + 0.19 \times (-6.43) + 0.16 \times 6.85 + 0.15 \times 0 + 0.16 \times 78.80 + 0.12 \times 98.78$
   - $WQI \approx 3.43 - 1.22 + 1.10 + 0 + 12.61 + 11.85$
   - $WQI \approx 27.77$

Table 3: General Rating Scale for the Water Quality Index (WQI)

WQI	10	20	30	40	50	60	70	80	90	100
General			Very Polluted				Slightly Polluted		Clean	
Water Classes	V				IV	III			II	I
Public Water Supply		Not Acceptable			Doubtful	Necessary Treatment becoming more Expensive			Minor Purification Require	Purification not Necessary
Recreation	Not Acceptable	Obvious Pollution Appear		Only for Boating	Doubtful for Water Contact	Becoming Polluted still Acceptable Bacterial Count			Acceptable for All Sports	
Marginal for Trout		Acceptable for All Fish		Course Fish Only	Hardy Fish Only	Doubtful for Sensitive Fish				
Navigation		Not Acceptable		Obvious Pollution Appear	Acceptable					
Treated Water Transportation		Not Acceptable		Acceptable						

Table 4: Assessment of Water Quality in the Buriganga River Based on Water Quality Index (WQI) Ratings

WQI	General Rating	Water Class	Public Water Supply	Recreation	Marginal for Trout	Navigation	Treated Water Transportation
27.77	Very Polluted	V	Not Acceptable	Not Acceptable	Acceptable for all fish	Not Acceptable	Not Acceptable

CONCLUSION & RECOMMENDATION

The research on the Burigranga River's physicochemical parameters shows that the river's water quality is very polluted and mostly unacceptable in most of the factors of the General Rating Scale for Water Quality Index. The water class of Buriganga River is defined as Class V in terms of Water Quality, and the value of WQI is 27.7 (very polluted). The BOD (Mean 78mg/L) and COD (Mean 172mg/L) values are significantly higher than the standard values. Due to Bangladesh's fast population growth rate, which is expected to reach more than 300 million people by 2050, land grabbing has become common. As a result, the major rivers are narrowing daily, putting a massive strain on most of them because most drainage outlets and wastewater from Dhaka's megacity drain into the Buriganga River (Peas, 2021). According to scientists, several enterprises have sprung up along the riverbank, each of which discharges 1.5 to 2 million cubic meters of untreated effluent daily.

The following are a few proposals for protecting the existing river:

- To ensure that all pollution-related rules and regulations are carefully enforced and adhered to. People should be aware that adherence to water laws is their responsibility.
- Dredge the existing river and remove non-biodegradable materials from the riverbed and banks.
- Destroy illegal structures on the riverbank and maintain a consistent monitoring system for land grabbers.
- Where adequate urban runoff (polluted stormwater flow into the river) occurs, mitigating systems such as retention basins, infiltration basins, and so on should be in place. People should not be allowed to put garbage into rivers.
- To make Effluent Treatment Plants available to all industrial units to reduce the river's polluting load. Industrial entities are expected to treat their effluent wastes before releasing them. Toxic materials must be chemically treated and transformed into non-toxic materials. Factory owners should endeavor to recycle treated water if at all practicable.
- To filter dangerous contaminants out of water flowing through the city drainage system before it enters reservoirs. If this water is allowed to enter water reservoirs without being treated, it will contaminate them.
- To reduce the risk of urban contaminants entering rivers, municipalities in most metropolitan areas should implement a robust wastewater management system.

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