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TEMPORAL AND SPATIAL VARIATION OF WATER QUALITY OF MAYUR RIVER, KHULNA, BANGLADESH

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ABSTRACT

Mayur River, locating north western side of Khulna, has enormous significance from numerous points of views like water reservoir, navigation etc. Unfortunately latrge scale water quality degradation took place due to pollution as a result of human interruption, unplanned and untreated crude dumping of domestic, industrial and household waste into it. The aim of this study are to carry out the temporal and spatial water quality assessment of selected locations of Mayur River. The water quality was found "Very Bad" in March-2019, April-2019 and May-2019 from station 1 to station 8 except station 4 in June-2019. From July-2019 to February-2020 the water quality was found "Bad" with some exception like station 6 in February-2020. For all the stations (S1 to S8) the regression equations indicate upward regression line and the R^2 values show the plotted data fits the regression model ranging 34.28% to 64.21%.

Keywords: Water Quality Parameter, Water Quality *Index, Mayur River, Khulna city.*

1. INTRODUCTION

In Bangladesh, rivers, their tributaries and distributaries are the prime source of fresh water for all forms of lives. The Mayur River, originated from Beel Pabla, contiguous to the northwestern boundary of Khulna City Corporation (KCC) passes through the urban and peri-urban areas of Khulna City. The length of Mayur River about 11.69 km and its width vary varies widely at different chains (Akber et al., 2010). This river has importantance from plentiful points of views: water reservoir, transportation, water source for irrigation, ground for fishing and the main wastewater route of the city. The Mayur River also plays a significant role in contributing to ground water table. The river and its connected canals are not functioning properly due to illegal encroachment and pollutants discharged by the city people. As a result, Khulna City faces serious water logging even with minimum rainfall. Mayur River makes available irrigation water for farmers living near the river and imperative ecosystem facilities such as water for domestic purposes e.g. drinking water, water for industrial, commercial purposes and production of fishes. Again the Mayur River attends other uses further than direct consumption: it has an effect on the values of land and property, offers recreation and tourism facilities, supports controlling of flood, biodiversity (e.g. bird habitat), reduces river bank erosion, climate regulation, nutrient and water cycling and most importantly is shared by both the urban and peri-urban residents for numerous uses. It was estimated that up to 725,732,265 US gallons of water can reserved by River Mayur (Rezaul et al., 2011). Few experts related to water and environment think that this river and the connected canals can be made use as a reservoir and sustainable water supply system by applying treatment facilities ensured for KCC.

Unfortunately the Mayur River water is often being contaminated by crude dumping of solid waste in Rajbandh as well as clinical and household waste from KCC discharge outlets in Chawk Ahsankhali. Khan (2011) found that the chemical composition of Mayur River has become so poor in quality and unusable. Kumar et al. (2011) found that the 22 drains of the KCC area that discharge wastewater directly into the Mayur River. Moreover, the clinical wastes and wastewater are discharged directly into the Mayur River system. (Rahman et al., 2014) undertook an Environmental study related water quality of Mayur River in case of suitability for irrigation. SaciWater (2011) and DoE (2015) in their report on water quality showed the graphical presentation of pH, DO, TDS, Chloride, Turbidity and SS of Mayur River in 2015. The water security of Mayur River is getting affected due to development projects built on the Mayur River in Khulna. All the above works focused mainly on the water quality parameters, water logging, security of water and influence of development projects on water quality of Mayur River. In most of the studies water quality was assessed on the basis of values water quality parameters and comparison of them with the standard values. Here is the reason why, the study on Water

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Quality Index (WQI) came from. The core objectives of this study are to find out the seasonal variation of selected Water Quality Parameter (WQP) and to assess the water quality of Mayur River on the basis of temporal Water Quality Index (WQI) of selected locations. After finding out the water quality parameters, they were compared with the standard values of Environmental Protection agency (EPA) and DoE. Then Water Quality Index WQI is calculated using National Sanitary Foundation (NSF) water quality index formula and water was assessed using the standard range of water quality index (WQI).

2. METHODOLOGY

2.1 Selection of Strategic Water Sampling Stations

Total of 8 sampling stations were selected on the basis of reconnaissance survey conducted from Gallamari to Rayermahol including Boyra and Sonadanga. The reconnaissance survey was based on depth and flow of water, amount of physical pollution, climatic condition and number of connecting drains of Khulna City Corporation (KCC) to the Mayur River. Composite water samples was collected in 12 different months from March-2019 to February-2020 according to guidelines (UNEP/WHO, 1996). Water sample were collected at the station from a depth of 0.30 m - 0.45 m from the surface of water. The total length of the river in the study zone is about 5.5 kilometers. The reason of selecting that length is the variation of pollution and water flow at small distances. Water samples were then securely sealed with proper leveling and transported to the laboratory within the same day. Table-1 below shows the study area.

Table 1: Study Area of Mayur River.

Sample ID	Area and Location	Longitude	Latitude
S1	Rayermahal (out of sluice gate)	89°33′10″E	22°48′12″N
S2	Andirghat, Boyra	89°36′23″E	22°41′50″N
S3	Boyra (beside funeral place)	89°28′16″E	22°42′43″N
S4	Chakmathurabad	89°34′55″E	22°40′16″N
S5	Sonadanga (beside bus terminal)	89°27′10″E	22°43′36″N
S6	Sonadanga (beside truck terminal)	89°28′21″E	22°45′39″N
S7	Gallamari (Near Khulna University)	89°30′20″E	22°42′19″N
S8	Gallamari (Beneth the Bridge)	89°23′27″E	22°49′01″N

2.2 Laboratory testing and anaylytical approach

To investigate the water quality of the Mayur River water samples were collected. Experiments were conducted on the collected water sample to find out the physical, chemical and biological features of the water. Physical examination was conducted to find out Temperature, pH, Turbidity, Total Solids (TS). Chemical examination revealed the Phosphate, Nitrate, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) of the water. While biological examination Total Coliform (TC) of the water were determined. The methods outlined in the Standard Methods for the Examination of Water and Wastewater (APHA, 2005) was followed for the analysis of all the physico-chemical parameters.

An equation of NSF water quality index was established using weighted factor of specific parameter and sub-index of apiece water quality parameter depending on their respective obtained values that can be found by calculator for water quality index or water quality index curve of respective parameters. The water quality index of individual parameter was then calculated from water quality index calculator used by Environmental Engineering and Earth Sciences, Center of Environmental Quality, Wilkes University. According to NSF water quality index, Equation (1) was used for the calculation. (EEES, Wilkes).

$$WQI = 0.17\, I_{DO} + 0.16\, I_{FC} + 0.11\, (I_{pH} + I_{BOD}) + 0.10\, (I_{\Delta T} + I_{PO4} + I_{NO3}) + 0.08\, I_{T} + 0.07\, I_{TS} \quad (1)$$

Where I is considered as the water quality sub-index. Water quality parameters values were compared with the standards of DoE and EPA standards. Regression analysis were carried out on WQI values of all the stations and regression equation with R^2 values were obtained. Water quality was assessed on the basis of National Sanitary Foundation (NSF) Water Quality Index using the following Table.

Table 2: Quality of water according to National Sanitary Foundation (NSF) Water Quality Index (Mirzaie, 2016).

WQI Range	Quality
90-100	Excellent Water Quality
70-89	Good Water Quality
50-69	Medium Water Quality
25-49	Bad Water Quality
0-24	Very Bad Water Quality

3. RESULTS AND DICUSSIONS

3.1 Temporal Variation of WQP of Mayur River

Sessonal variation of temperature, pH, DO, BOD, turbidity, TS, phosphate, nitrate, faecal coliform respectvely has been shown in Table 3 and Table 4 resepctively where April to October has been taken as wet sesaon and November to March as dry season.

Table 3: Water Quality Parameter of Wet Season of Mayur River.

	Months							
WQP	**Apr-19**	**May-19**	**Jun-19**	**Jul-19**	**Aug-19**	**Sep-19**	**Oct-19**	**Avg.**
Temperature (^{o}C)	36.44	38.46	31.91	29.83	28.84	27.98	28.09	31.65
pH	7.54	7.18	7.31	7.1	7.35	8.16	7.44	7.44
DO (mg/L)	1.75	1.96	2.19	2.4	2.32	2.08	1.97	2.09
BOD (mg/L)	199	139	104	74	54	72	93	105
Turbidity (NTU)	1351	1706	2164	2582	2161	1961	1603	1932
TS(mg/L)	16081	8767	8883	6430	5798	5009	4236	7886
Phosphate (mg/L)	11.55	12.64	10.87	8.81	6.08	5.51	6.49	8.85
Nitrate (mg/L)	64.97	30.81	31.84	26.02	21.98	12.98	12.46	28.72
Faecal Coliform (N/100 ml)	28377	28552	27444	28817	25943	21365	19337	25691

The lowest average temperature was recorded 17.75 °C in December-2019 and the highest average was 38.46°C in the month of May-2019 exceeding the upper and lower limit of 30 ^{0}C and 25 ^{0}C accordng to Bangladesh standard (DoE) and EPA (2001) Standards. The average temperature is 31.65 °C and 22.586 °C in wet and dry season respectively.

The highest average pH value of 8.16 was recorded in September-2019 while the lowest average found 6.94 in December with an average of 7.44 and 7.40 in wet and dry season respectively. Temporal variation of pH is minor and close to each other and within the limit of standard value for surface water quality for pH (5.5-8.5) and (6.5-8.5) according to EPA-2001 and DoE standard.

Maximum average DO was 2.40 mg/L in July-2019 with lowest average of 1.53 mg/L in January-2020 where DO limit should be more than 5 mg/L according to DoE. The average DO slightly increased in wet sesaon due to dilution from 1.66 to 2.09 mg/L. The intensive lower DO value caused mainly the peak level value of BOD having the average highest of 199.25 mg/L in April-2019 and the lowest of 53.50 mg/L in August-2019. The water is a threat to the fisheries production and living. The frequent pollution, dumping of industrial waste and receiving waste from all KCC owned drains are the main reasons of fall of dissolved oxygen level in water of Mayur River.

The BOD level lowered a bit from 169.27 mg/L to 104.91 due to cosderable amount of rainfall and dilution of water in the river. The average highest BOD was 199.25 mg/L in April-2019 and the lowest one was 53.50 mg/L in August-2019 with an yearly average value of 131.73 mg/L that is so much alarming compared to the permissible limit of 5 mg/L (EPA, 2001) and less than 6 mg/L (DoE) resulting from sewage pollution and dumping of industrial waste into water. The more the BOD, the more rapidly oxygen is depleted in the river water. As a result aquatic organisms are getting stressed, suffocated and eventually dying.

Table 4: Water Quality Parameter of Dry Season of Mayur River.

	Months					
WQP	**Nov-19**	**Dec-19**	**Jan-20**	**Feb-20**	**Mar-19**	**Avg.**
Temperature (^oC)	22	17.75	18.65	22.2	32.33	22.58
pH	7.51	6.94	7.61	7.56	7.38	7.4
DO (mg/L)	1.83	1.7	1.53	1.56	1.69	1.66
BOD (mg/L)	126	169	181	181	189	169
Turbidity (NTU)	1230	1009	804	624.5	934	920
TS(mg/L)	3255	2630	2555	3354	6192	3597
Phosphate (mg/L)	7.38	6.03	8.54	10.69	10.43	8.61
Nitrate (mg/L)	12.29	16.83	22.87	25.49	97.27	34.95
Fecal Coliform (N/100 ml)	18850	23432	24689	24997	30416	24477

The amount of turbidity was almost double in wet season than that of dry sesaon due to clay particles, sewage solids from various drains of KCC, silt and sand washings during run-off, organic and biological sludges from hanging latrine over river Mayur. The highest average turbidity was 2582.12 NTU in July-2019 and lowest average was 624.5 NTU in February-2020. The yearly average turbidity for Mayur River water is 1510.76 NTU that is far higher than the DoE standard limit of 10 NTU only.

This huge amount of turbidity are creating hindrance of sublight to penetrate into river and as a result the plants and aquatic lives are unable to conduct photosynthesis and that causng the depletion of DO level in water.

The highest average value of total solids was 16081.45 mg/L in April-2019 and the lowest average was 1389.06 mg/L. The amount of total solids in wet season is almost double than that of dry season (Tabe 3 and Table 4). The excess amount of total dissolved solids and total suspended solids caused this huge amount of total solids in Mayur River in both the sesaons. Runoff from construction, chemicals from nearby factories, storm water, and agricultural runoff get mixed with river water through drain are main reasons of such increase of total solids in wet season in Mayur River water. Besides agricultural practices, logging activities, sewage treatment plant discharges, and other sources are responsible for high amount of total solids in river water of Mayur.

The range of phosphate in Mayur River water was 5.51 to 12.64 mg/L where in dry and wet season the average value were 8.61 and 8.85 respectively. The standard limit according to EPA, 2001 and DoE are 0.6 and 6 mg/L for surface water. The values are much higher from March-2019 to July-2019 and some fluctuations in middle time of the year. So the process eutrophication took place everywhere in the Mayur river. Run-off, use of fertilizers in adjacent crop lands and sewage discharges are some others reasons of higher phosphate content in river Mayur.

The yearly average nirate level is 31.32 mg/L that is within the prescribed range according to EPA, 2001 for surface water. Not much difference were found in nitrate content in wet and dry seasons. Much higher value was observed in March-2019 to April-2019 as because of mixing of city waste water and surface runoff.

Table 3 and Table 4 also show that the highest and lowest value of feacal coliform were obtained as 30416.00 (N/100 ml) in March-2019 and 18850.63 (N/100 ml) in November-2019 respectively. The yearly average value for the faecal coliform in Mayur river water is 25185 (N/100 ml) alarmingly crossing standard limit of 1000 (N/100 ml) (EPA, 2001). In wet season the value the amount of faecal coliform was 2569.71 and in in dry dry season it decreased to 24476.80 N/100 ml. As a result of the overflow of domestic sewage or nonpoint source pollution of human and animal waste, the total coliform was found higher in March, July and August-2019. It also indicates the sewage contamination and presence of other pathogenic organisms that is causing health risk to the adjacent inhabitants of Mayur River.

3.2 Spatial Variation of WQP of Mayur River

Table 5: Water Quality Parameter of Selected Stations of Mayur River.

WQP	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8
Temperature(^oC)	27.90	27.94	27.73	27.65	28.13	27.71	28.07	28.02
pH	7.29	7.50	7.50	7.70	7.30	7.81	6.91	7.24
DO (mg/L)	2.09	2.31	2.42	2.27	2.35	2.39	1.49	2.08
BOD (mg/L)	104	104	111	108	116	144	176	181
Turbidity (NTU)	1416	1887	1360	1324	1436	1506	1533	1625

WQP	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8
TS(mg/L)	5590	6387	6482	5472	6074	5184	5120	6744
Phosphate (mg/L)	9.38	9.60	10.67	13.57	9.49	10.59	6.69	7.92
Nitrate (mg/L)	23.69	31.49	32.00	25.86	31.55	38.66	34.78	32.50
Faecal Coliform (N/100 ml)	25437	26647	24437	29696	28877	32296	31570	29002

Table 5 shows the spatial variation of selected eight (8) locations of Mayur River during the study period. Here "S" indicates selected "Station" of Mayur River. The amount of DO is on the lower portion in case of all the stations and that caused the lower value of BOD. Station 8 that is located in Gallamari beneath the bridge contains most value of BOD (181 mg/L) due to crude dumping of market (kacha bazar) waste and slaughter house waste directly into the river. The highest amount of faecal coliform (32296 N/100 ml) was found in station 6 that is Sonadanga, beside the truck terminal indicates the amount of pollution in this river. Huge amount of turbidity and faecal coliform indicates presence of silt, clay, bacteria and other microorganisms.

3.3 Temporal Water Quality Index of Mayur River

Figure 1 shows the temporal variation of water quality index of Mayur River during dry season. It indicates the water quality index in March-2019 and April-2019 is much worse than that of other months. The WQI is April-2019, May-2019, June-2019, July-2019, August-2019, September-2019, and October-2019 were 19.14, 20.94, 23.03, 24.81, 25.8, 25.53 and 26.77 respectively. According to Table 2, it is evident that the water quality is "Very Bad" during April-2019, May-2019, June-2019 and in July-2019, August-2019, September-2019, October-2019 the water quality is "Bad".

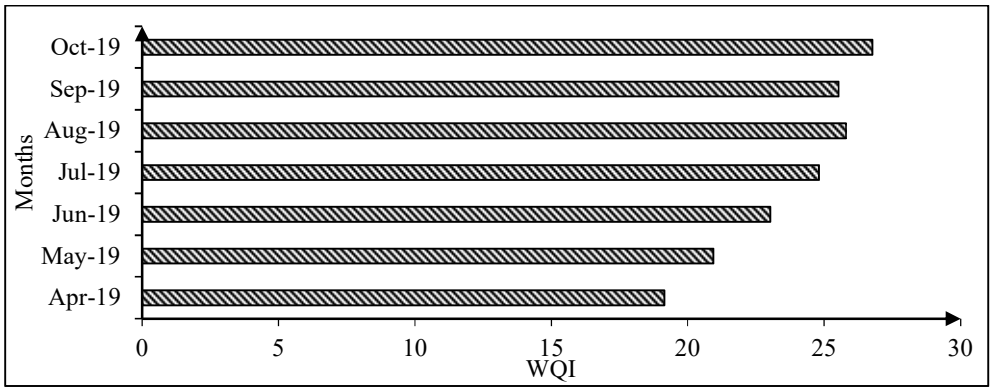

Figure 1: Water Quality Index of Mayur River in Dry Season.

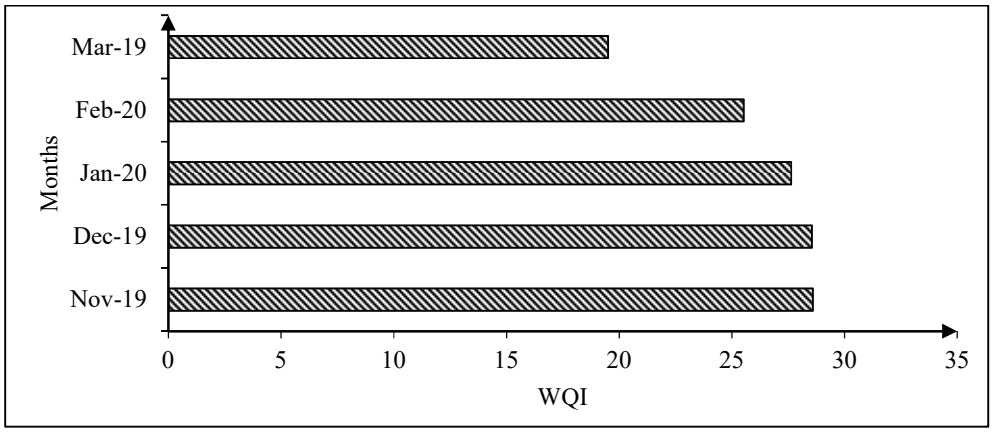

Figure 2: Water Quality Index of Mayur River in dry Season.

Figure 2 shows the WQI is November-2019, December-2019, January-2020, February-2020 and March-2019 were, 28.6, 28.54, 27.64, 25.52 and 19.51 respectively. So it is evident that the water quality is "Bad" during November-2019, December-2019, January-2020 and of "Very Bad" qaulity in March-2019. So it can be stated that the water quality degraded mostly in dry season than that of wet season.

3.4 Spatial Water Quality Index of Mayur River

Figure 3 shows the WQI for selected station of Mayur River indicating water quality of "Very Bad" and "Bad" form. The S1, S2, S3, S4, S5, S6, S7 and S8 possess the WQI value of 25.68, 25.06, 24.01, 25, 25.04, 22.96, 23.95 and 24.81 respectively. So according to Table 2 stations named S1, S2, S4 and S5 contain "Very Bad" quality of water whereas S3, S6, S7 and S8 contains "Bad" quality of water.

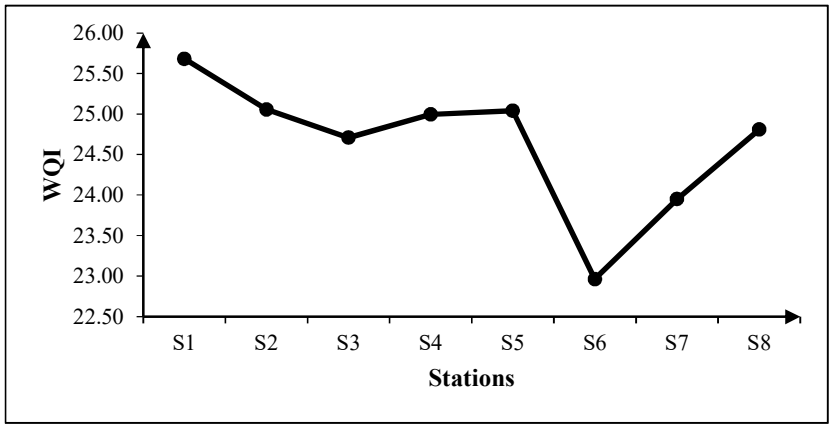

Figure 3: Spatial WQI of Selected Stations of Mayur River.

Table 6: Temporal and Spatial Water Quality based on WQI of Mayur River.

Stations / Months	S1	S2	S3	S4	S5	S6	S7	S8	Temporal Avg.
March-2019	VBQ	VBQ	VBQ	VBQ	VBQ	VBQ	VBQ	VBQ	VBQ
April-2019	VBQ	VBQ	VBQ	VBQ	VBQ	VBQ	VBQ	VBQ	VBQ
May-2019	VBQ	VBQ	VBQ	VBQ	VBQ	VBQ	VBQ	VBQ	VBQ
June-2019	VBQ	VBQ	VBQ	BQ	VBQ	VBQ	VBQ	VBQ	VBQ
July-2019	BQ	BQ	BQ	BQ	BQ	BQ	VBQ	BQ	BQ
August-2019	BQ	BQ	BQ	BQ	BQ	VBQ	BQ	BQ	BQ
September-2019	BQ	BQ	BQ	VBQ	BQ	VBQ	BQ	BQ	BQ
October-2019	BQ	BQ	BQ	BQ	BQ	BQ	BQ	BQ	BQ
November-2019	BQ	BQ	BQ	BQ	BQ	BQ	BQ	BQ	BQ
December-2019	BQ	BQ	BQ	BQ	BQ	BQ	BQ	BQ	BQ
January-2020	BQ	BQ	BQ	BQ	BQ	BQ	BQ	BQ	BQ
February-2020	BQ	BQ	BQ	BQ	BQ	VBQ	BQ	BQ	BQ
Spatial Avg.	BQ	BQ	BQ	BQ	BQ	VBQ	VBQ	BQ	

BQ= Bad Quality and VBQ= Very Bad Quality

Table 6 shows the overall water quality both temporal and spatial. Here BQ indicating Bad Quality and VBQ indicating Very bad Quality of water in Mayur River during the study period form March-2019 to February-2020.

3.5 Regression Analysis of WQI

Regression Analysis was carried out on the WQI values of each stations using Microsoft excel. The related regression equation and regression coefficient (R^2) is tabulated as below-

Table 7 shows the regression analysis and related regression coefficient value for all the station from S1 to S8 during the study period of March-2019 to February-2020.
For all the stations (S1 to S8) the regression equations indicate upward regression line and the R^2 values show the plotted data fits the regression model ranging 34.28% to 64.21%.

Table 7: Regression Model of Temporal and Spatial WQI Trend Analysis.

Station	Regression Equation	R^2
S1	y= 0.7467x + 20.454	0.5502
S2	y= 0.6582x + 20.45	0.5964
S3	y= 0.5545x + 20.827	0.5466
S4	y= 0.6034x + 20.772	0.4815
S5	y= 0.6693x + 20.356	0.5560
S6	y= 0.3742x + 20.344	0.3428
S7	y= 0.738x + 18.784	0.6098
S8	y= 0.6947x + 19.947	0.6421

4. CONCLUSIONS

Mayur River is important to Khulna City from enorous purposes but the water quality is getting deteroriated by huge polluton and neglegence of the authority. Almost all the WQP values exceeded the limit set by the standards. DO concentration was much lower and unacceptable for aquatic life. Additionally BOD, turbidity, nitrate and faecal coliform concentration were much higher than the usual standards of DoE and EPA-2001. A considerable and sometimes abrupt variations of DO, nitrate and phosphate concentration were observed in Mayur River water. Water quality of Mayur River is in the category of "Bad" and "Very Bad" all through the year. Water quality degraded mostly in dry season than that of wet season. To counteract this amount of pollution of river water, inhouse water treatment plant may be introduced in Mayur River so that water can be purified easily. Khulna City Corporation (KCC) can play a vital role here by ensuring proper waste dumping facilty so that wastes are dumped into river water. Overall mass conciousness must be created so that the pollution can be kept under control and make river water habitable for fish and other aquatic lives.

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