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1 author:

A. A. Masrur Ahmed
Department of Climate Change, Energy, the Environment and Water

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Full Length Research Paper

A Canadian Water Quality Guideline-Water Quality Index (CCME-WQI) based assessment study of water quality in Surma River

G. M. Munna[1], M. M. I. Chowdhury[2], A. A. Masrur Ahmed[3]*, Sadia Chowdhury[1] and M. M. Alom[1]

[1]Shahjalal University of Science and Technology, Sylhet, Bangladesh.
[2]Civil and Environmental Engineering Department, P.O. Box 8275, King Fahd University of Petroleum and Minerals, Dhahran, Kingdom of Saudi Arabia 31261.
[3]Leading University, Sylhet 3100, Bangladesh.

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Water quality of Surma River is frequently deteriorating for the last few decades since ever-growing human activities, poor drainage facilities, and direct disposal of industrial and municipal waste. Along with poor structure, natural canals (local name *Chara*) are responsible for the conveyance of surface runoff from its urban catchments to the receiving Surma River. The purpose of this study is to assess the degree of pollution in context of CCME-WQI (Canadian Water Quality Guideline-Water Quality Index) in Surma River by determining various physico-chemical parameters. Data from sample analysis, the concentration of DO (Dissolved Oxygen), BOD (Biochemical Oxygen Demand), TSS (Total Suspended Solid), Turbidity and Fe (Iron) do not meet the satisfactory level. Particularly this study suggested that water quality of this river is affected for high turbidity and BOD due to soil erosion, runoff and municipal effluent discharge without any treatment. Beside these, concentration of heavy metals in Surma River is a bit high which poses another impact for the user of Sylhet city whom are mainly dependent on Surma River. Surma River is found to 15.78 according CCME-WQIs model which indicates that water quality of this river near Sylhet city is Poor and frequently impaired.

Key words: Natural canals, Surma River, pollution, solid waste, disposal.

INTRODUCTION

Water is well thought-out as a most imperative component to our earth surface. It is essential for all living beings, and man is no exemption. In today's world, river is considered one of the major sources for surface water and has significant contribution to carry water and nutrients to areas across the world. It plays a major role in water cycle, acting as a drainage channels for surface water. Near about 40% of the world's food supply is grown under irrigation, and a wide variety of industrial processes depends on water (BCAS, 2000). Oki and Kanae (2006) have introduced river is now an important source of safe water which globally serves about 2,000 km^3 freshwater. It is therefore a growing civilization with lots of human activities is seen to the banks of rivers. However, rising trend of civilization has put a great threat to the river water quality particularly in developing countries. It is noted that increasing scenario of population density, land development along river basin, urbanization and industrialization have been subjected for water pollution and environmental deterioration to the rivers water (Sumok, 2001). One of the reasons behind the deterioration of river water quality is demonstrated that most of the rivers are considered as the end point of urban effluent discharges without any prior treatment. It was also found that an extent of the industrial, agricultural

*Corresponding author. E-mail: masrur@mail.lus.ac.bd. Tel: +88 01912140065.

and other anthropogenic activities in the basin and reduced river discharges has introduced foremost problem for safe water (Sing et al., 2004).

Addressing a complex set of reasons that is, drinking water, irrigation, and transportation; river is considered a major sources of water supply in Bangladesh. Near about 230 rivers flow through the country including 53 international rivers (Sarwar, 2010). Of the part of Surma-Meghna river system, *Surma* is one of the major rivers in Bangladesh. Northeast Indian region of Assam is source point of *Surma*, flows through Sylhet city and goes on to joint with *Meghna* River, one of the three major rivers in Ganga delta. It is near about 515 km long (encyclopedia) and average 86 m depth (Wikipedia). It covers eastern parts of Bangladesh and contains at least eight million people making important river basin to the Bangladesh (Alam et al., 2007). Along with agricultural activities, Surma River has significantly take part on drinking or safe water supply. However, introduction of human activities and industrial effluents have put more threat to water quality of Surma River. It is therefore of vital importance to monitor and assess the water quality regardless if the water is still suitable for various uses.

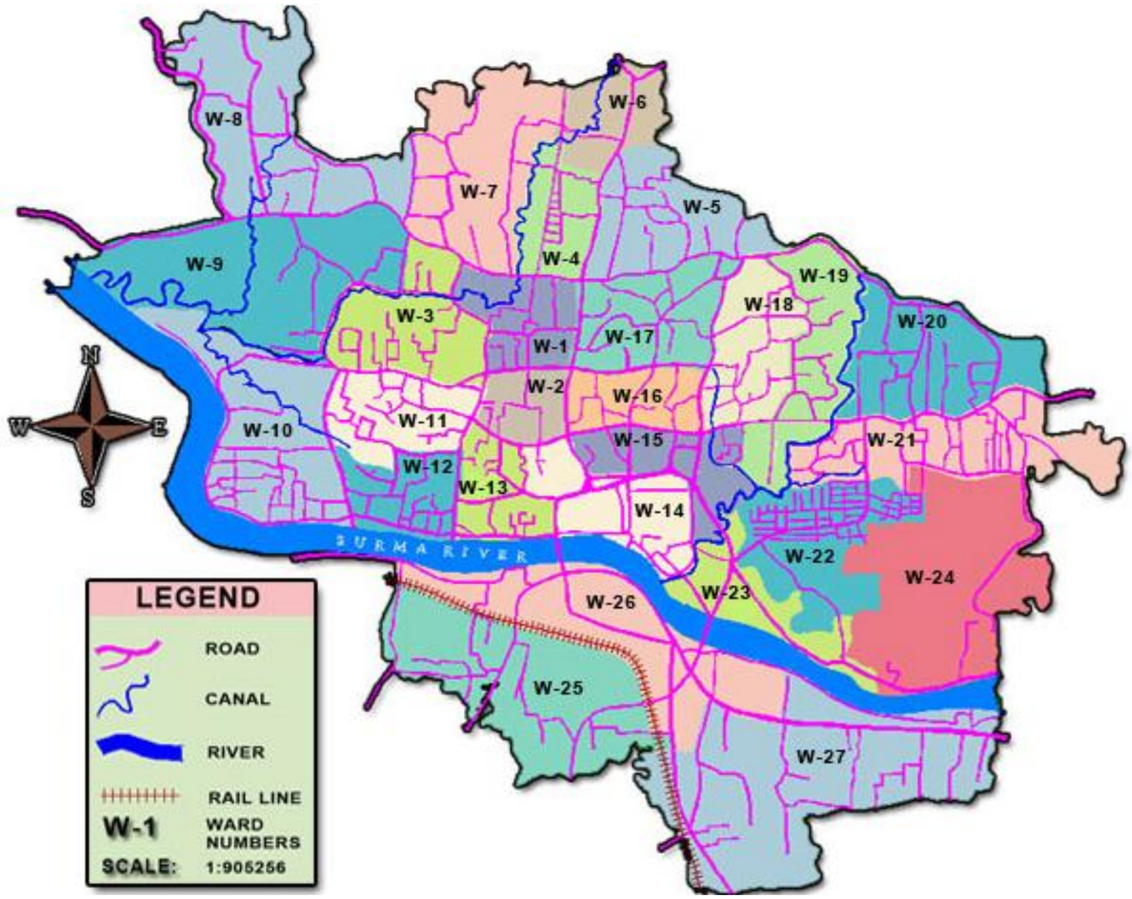
Like other six divisional cities in Bangladesh, Sylhet is heavily suffering for shortage of domestic water supply. At present, Sylhet City Corporation (SCC) is providing only 40% of domestic water demand from groundwater source in a total of 600,000 populations. Some portions of water demand are provided from water treatment plant in Sylhet and Sunamganj. The rest of the people still far away from SCC water supply services heavily depend on their own sources like tube well, or personal deep well. However, arsenic contamination in groundwater has post a great threat to the groundwater source in this area. It is therefore, water of Surma River that can play a vital role to meet the present water demand. Though Topkhana Water Treatment Plant uses Surma as a source of surface water and supply a very few amount, the water quality is seen far below the drinking water standard (Chowdhury et al., 2004). It is noted that water quality of this river is gradually deteriorated by direct or indirect disposal of municipal waste and surface run-off from agricultural field to river (Alam et al., 2007). Further poor management of solid waste has put another big challenge on water quality on *Surma* River. At present, a total of 180 to 200 tons of solid wastes are generated in Sylhet city and only 140 to 160 tons are collected (Amin and Baquee, 2005). Uncontrolled wastes are washed out to the roadside drains and natural canals. As such SCC is collecting only 56% of the total waste generated daily, while 44% remains uncollected (Alam et al., 2007). Thus without any waste water treatment unit, Surma River is receiving these pollution through a number of small and big canals. It is also found that a total of nine natural canals are identified for direct and indirect disposal of storm water from city to Surma River (Amin and Baquee, 2005). After compounding these factors, the study has undertaken with distinct aim by determining of water quality based on standard level to prepare a Water Quality Index (WQI) for *Surma* River.

Study area

Geographical location of Sylhet city is 24.8917°N and 91.8833°E in the north eastern region of Bangladesh. Total area of Sylhet City Corporation is 26.5 km^2 and it consists of 27 Wards and 210 mahallas (SCC data). It is a high densely populated area of nearly 0.5 million people which are living in this city. It is surrounded by a number of tea gardens along with some hilly areas from where natural channels (locally called ‘Chara’) are originated and fall into the Surma River. Total sewerage network of this city is built by many small drains which are connected with ‘Chara’. Among a number of Chara in Sylhet, Khushikhal, Gualichara, MongoliChara, Moragang, BolramChara, MalniChara, GoaliChara, JugniChara, Mira Chara, KalibariChara, BhubiChara are important. Our water samples are collected from the meeting points of six different Charas in Surma River. These are namely Khushikhal, Gualichara, BolramChara, MongoliChara, Malnichara and Moragang which make the whole city interconnected with the river Surma (Alam et al., 2006). Malnichara is the longest one among the six where some others of small length of Charas (Ansar Camp Chara, NorsignTilachara, GaviarKhal) are connected with it. Starting point of this Chara is Malnicherra tea garden and end point is Surma River. On the other hand, Khushikhal (flows from Shari River to Surma River) and MoragangCharas are out of Sylhet City Corporation area. Some other small length Chara like Sandabazarchara, Bhubichara, Subhanighatchara meet to GualiChara and then flow to Surma River. BolramChara and MongoliChara are small length but carry huge solid waste as they lay to the heart of the Sylhet city (Map 1).

METHODOLOGY

Laboratory data are essential to design Water Quality Index (WQI) for Surma River. To obtain such data, six different sampling locations (at the meeting points of Surma River) were selected. These locations were chosen on the basis of maximum waste flow through the Chara to river. Water samples were collected at the first week of each month throughout a year from March, 2008 to February, 2009. A hard plastic bottle was used for sample collection and it was ensured that plastic bottles were properly closed with cap and tape to stop air contact. Wastewater characterization studies were conducted to determine pH, Total Solid (TS), Total Suspended and Dissolve Solid (TSS and TDS), Dissolved Oxygen (DO), Phosphate (PO_4^{3-}), Sulfate (SO_4^{2-}), Potasium (K^+), Nitrate (NO_3), CO_2, hardness as $CaCO_3$, Iron (Fe), Zinc (Zn), Chromium (Cr) by standard method (APHA-AWWA-WPCF, 1989). Even though five-day BOD has been chosen as the standard value for most wastewater analysis and for regulatory purposes, ultimate BOD is actually a better indicator of total waste strength (Davis and Cornwell, 1998).



Map 1. Location of Sylhet City Corporation.

Calculation of water quality index (WQI)

The Water Quality Index (WQI) is calculated using the Canadian Council of Ministers of the Environment Index method. Following expressions are used to determine the WQI for our study.

F_1 (scope) represents the percentage of variables that do not meet their objective at least once during the time period under consideration ("failed variables"), relative to the total number of variables measured:

$$F_1 = \left(\frac{\text{number of failed variables}}{\text{total number of variable}}\right)*100 \qquad (1)$$

F_2 (frequency) represents the percentage of individual tests that do not meet objective (failed tests):

$$F_2 = \left(\frac{\text{number of failed tests}}{\text{total number of tests}}\right)*100 \qquad (2)$$

F_3 (amplitude) represents the amount by which failed test values do not meet their objectives. F3 calculated in three steps:

i) The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an "excursion" and expressed as follows. When the test value must not exceed the objective:

$$\text{excursion}_i = ((\text{Failed test value i})/(\text{objective j}))-1 \qquad (3a)$$

For the cases in which the test value must not fall below the objective:

$$\text{excursion}_i = \left(\frac{\text{objective j}}{\text{Failed test value i}}\right)-1 \qquad (3b)$$

ii) The collective amount by which individual test are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of test (both those meeting objectives and those not meeting objectives). This variable, referred to as the normalized sum of excursions, or nse, is calculated as:

$$\text{nse} = \frac{\sum_{i=1}^{n} \text{excursion i}}{\text{\# of tests}} \qquad (4)$$

iii) F_3 is then calculated by an asymptotic function that scales the normalized sum of excursions from objectives (nse) to yield a range between 0 and 100.

$$F_3 = \left(\frac{\text{nse}}{0.01\text{nse}+0.01}\right) \qquad (5)$$

Table 1. Test result of different water quality parameters in Surma River.

Sampling points	Observation	P^H	CO_2 (mg/L)	Alka-linity (mg/L)	Hard-ness (mg/L)	TDS (mg/L)	DO (mg/L)	BOD_5 (mg/L)	Turbidity NTU	SO_4^{2-} (mg/L)	PO_4^{3-} (mg/L)	Potassium (mg/L)	Iron (mg/L)	Zinc (mg/L)	Chromium (mg/L)
Charar par	1st	6.73	25.17	55.33	134.83	215.6	6.23	4.59	6.85	6.05	0.40	3.00	0.29	0.18	0.08
	2nd	6.70	22.33	63.33	101.5	126.3	6.15	3.09	7.45	5.22	0.08	3.95	0.33	0.19	0.04
	3rd	7.92	29.67	63.83	77.67	120.0	4.95	4.95	18.91	3.92	0.95	4.40	0.27	0.19	0.04
Sheikh-ghat	1st	6.79	54.83	90.50	175.17	218.3	4.07	2.03	19.63	8.07	1.07	10.17	0.58	0.20	0.18
	2nd	6.77	30.00	33.33	105.17	65.83	11.10	11.1	6.92	4.07	0.16	2.94	0.39	0.22	0.06
	3rd	7.87	37.8	68.16	104.17	63.83	4.67	3.83	17.48	13.60	0.94	3.46	0.63	0.20	0.29
Kolapara	1st	6.87	35.33	31.33	144.17	202.5	4.05	4.05	7.77	22.52	0.04	6.5	0.60	0.17	0.11
	2nd	6.69	66.33	115.67	108.67	181.1	3.60	2.83	5.99	7.90	1.75	16.87	0.33	0.19	0.06
	3rd	7.29	20.27	77.00	108.33	51.50	5.65	2.54	20.31	10.03	0.27	6.63	0.40	0.20	0.06
Molla-para	1st	6.81	17.67	54.33	174.83	301.6	5.82	4.95	8.42	12.42	0.60	3.67	1.59	0.14	0.04
	2nd	6.74	18.00	30.67	89.50	33.33	4.80	1.67	6.96	19.82	0.05	2.41	0.36	0.24	0.05
	3rd	6.98	28.27	33.67	61.67	147.6	3.57	3.57	16.75	15.95	0.21	3.08	0.29	0.20	0.07

CCME Water Quality Index (CCMEWQI)

$$WQI = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right) \quad (6)$$

RESULT AND DISCUSSION

A routine laboratory analysis for different parameter in Surma River is performed for - physical, chemical and biological qualities following standard method. Our study was mainly conducted during the period of March, 2008 to February, 2009. The test result of varied parameters, showing seasonal variation with some fluctuation for Surma River are shown in Table 1 which presents the mean of all monitored values in each observation. To begin with the pH of surface water is an important indicator for the water quality and the degree of pollution in aquatic life. The results obtained for pH are varied between 6.69 and 7.92 which is shown in Table 1. Figure 1 graphically shows the pH data of four different locations. It is noted that maximum pH is found at Chararpar (pH=7.92) but this value still lies under the standard range and the variation of pH in different places is insignificant. However, all of observations are reported that pH concentration in the study area satisfied the allowable limits for surface water (World Health Organization, 1998). Meanwhile, four observations of our study for turbidity analysis (18.91, 19.63, 17.48 and 16.75) have exceeded the permissible limit (DoE, 1991). This may be because of the presence of organic matter pollution, other effluents, run-off with a high suspended matter content and heavy rain fall (Chapman, 1996).

Dissolve Oxygen (DO) is an important indicator for water quality assessment as well as water body's ability to support aquatic life. It is noted that standard for sustaining aquatic life is 4 mg/L and drinking purposes is 6 mg/L (Alam et al., 2007). Our particular value for DO in Surma river ranges between 3.57 to 11.1 mg/L which implies that all respective values of DO in water samples lies below the permissible limit for drinking purposes except Sheikhghat (20th May, 2011). Further, two observations from each location (Kolapara and Mollapara) shows less than 4 mg/L that demonstrated to the fact in particular period, water level goes below to the standard level for aquatic life. It means there are somewhat organic contaminants in the water, and the microbes are working to break it down. Lowering the water level may be one of other reasons to slow down the flow rate and reduce the DO level at this time. Addressing to this fact, higher values of BOD (> 2 mg/L) for all observation (except 2nd observation, Mollapara) also poses the threat of water quality in Surma River (Table 1). On the other hand, though the total dissolved solid in the Surma river water varies between 33.33 mg/L to 301.67 mg/L which is quite satisfactory regarding TDS (Figure 2a), suspended solids concentration (ranges from 85.83 mg/L to 310 mg/L) (Figure 2b) containing higher values than the permissible limit.

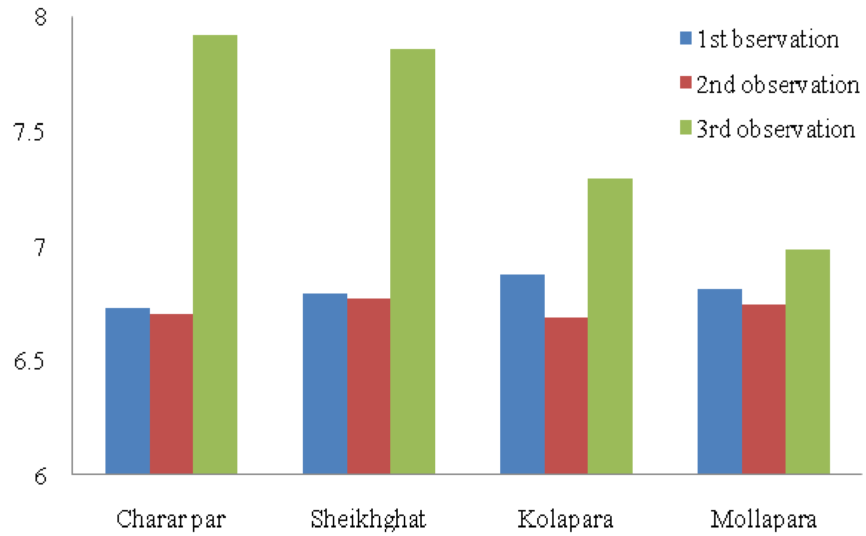


Figure 1. Data for pHon three observations at different locations and time.

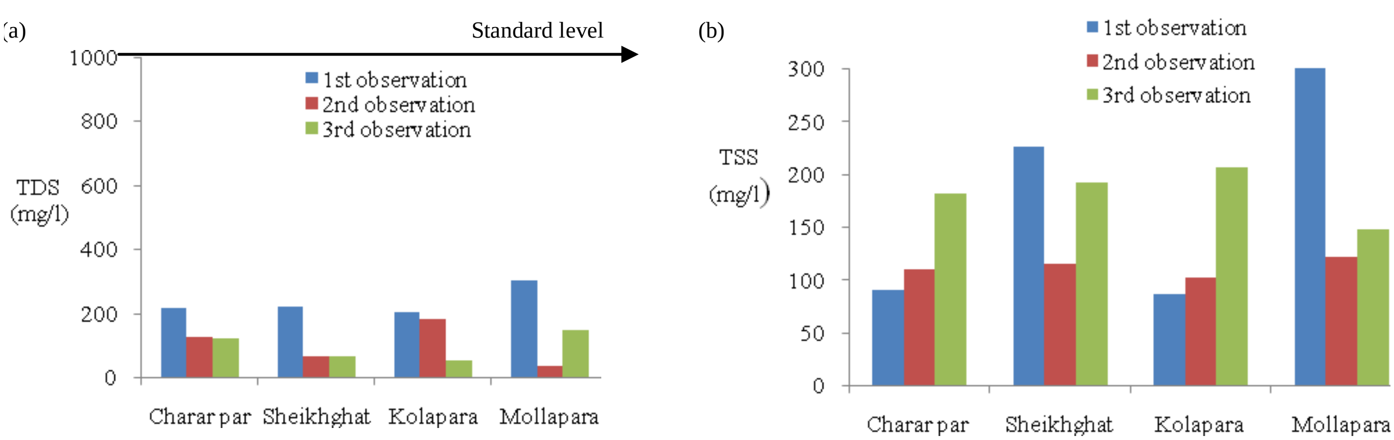


Figure 2. Data for two different parameter in Surma river at different location and time (a) Total dissolved solid (TDS) in mg/L (b) Total suspended solid (TSS) in mg/L.

Practically all natural waters' contain less or more dissolved carbon dioxide which plays an important role for water quality (WQC, 1972). It is reported that during the rain fall through the air, rain absorbs the CO_2 while air contains to a certain extent of 0.03% by volume (Rahman et al., 2012). Meanwhile, CO_2 combines with water and turned into carbonic acid. This carbonic acid sometime cause negative effect to the water bodiesif the water is slightly acidic. Seven of total observations show less than 7 pH which indicates the quality of the water is deteriorating regardless carbonic acid forming. Results of CO_2 (Table 1) is obtained from our study illustrates that 2 of our observations have crossed the maximum allowable limit (50 mg/L).According to the other standard limit, all values for CO_2do not satisfy the allowable limit (8 to 12 mg/L for fresh water (Rahman et al., 2012). However, if the water pH rise readily, dissolved CO_2 in water bodies may cause severe impact to the water quality. Higher value of CO_2 can cause the respiring problem and it becomes worse during summer when temperature goes up.

It is very important to the life of animals and plants regardless phosphorus which plays a vital role in fundamental process like cell respiration. Increasing uses of phosphates from human sources can have effect on stimulating plant growth in rivers, and sometimes 'blooms' of algae. Problem arises during the resulting blooms of algae and weed die and decomposition process strips oxygen from the river. The finding of phosphate results indicate that the amount of PO_4^{3-} in all sampling point lies between 0.04 to 1.75 mg/L (Table 1). Since all values satisfied the recommended level (6 mg/l

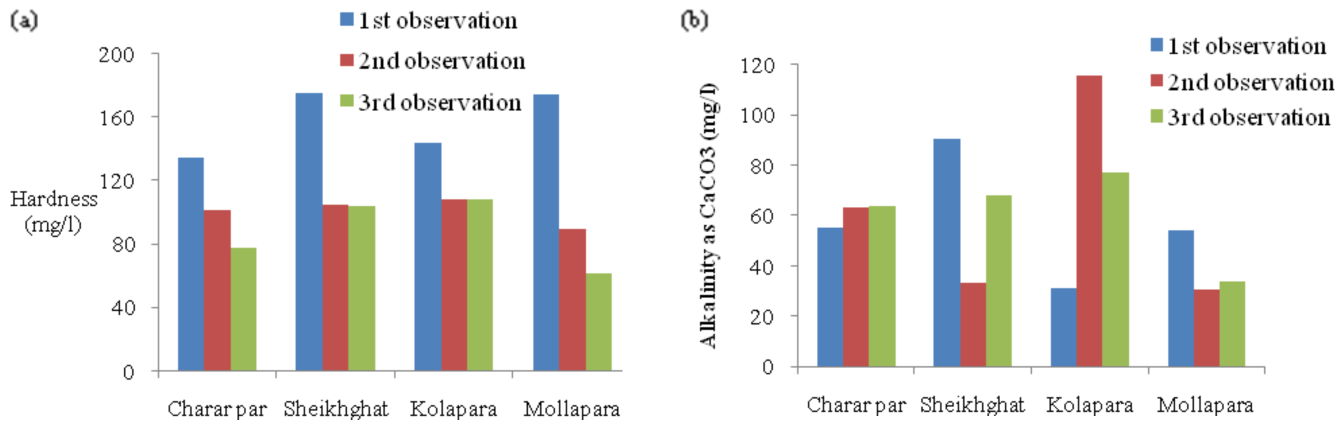


Figure 3. Two different water quality parameters (a) Hardness as $CaCO_3$in mg/l(b) Alkalinity as $CaCO_3$ in mg/L.

is recommended maximum for rivers and streams), still now no threat can be posed from phosphate. On the other side, naturally sulphates is present in surface water as SO_4^{2-} and it becomes high in surface water due to industrial discharges and atmospheric precipitation. However, results obtained from sulphate analysis also lies within the tolerable limitof 500 mg/L (Ikomi and Emuh, 2000; Egereonu, 2004) while concentration of SO_4^{2-} in all sampling point varied between 3.92 to 22.52 mg/L (Table 1).

Water hardness is commonly reported aspect of water quality and significant impact on fish culture. Generally, hardness of water is due to the presence of calcium, magnesium, chloride, sulfate, carbonate, bicarbonate etc. Figure 3a illustrates the water hardness as $CaCO_3$ (mg/L) for experimental areas (each observation indicates the average of six data). Obtaining result from our analysis, maximum hardness as $CaCO_3$ is found 175.17 mg/L while lowest value lies on 61.67 mg/L. It is reported that the permissible limit of Hardness of drinking water is 200 to 500 mg/l according to the DoE (Department of Environment), (EQS: Environmental Quality Standard for Bangladesh, PRB, 1991) standard. It is found from our study that 1st observation is showing somewhat higher value of hardness in compared to the 2nd and 3rd observation. However, all values lies within the permissible limit. On the other hand, one of the important findings is reported that all values of alkalinity in each observation do not satisfy the permissible limit (200 to 500 mg/L). The total alkalinity ranges lies from 30.67 to 115.67 mg/L (Figure 3b). It is apparent that alkalinity is not a self-pollutant but it is a total measure of the substances in water that have "acid-neutralizing" ability. It has significant impact on fish and aquatic life since it protects or buffers against pH changes (keeps the pH fairly constant) and makes water less vulnerable to acid rain. Thus it is clear that alkalinity of Surma River has already caused a threat to the protection of aquatic species.

As an important parameter for water quality; potassium (K^+), Iron (Fe), Zinc (Zn), and Chromium (Cr) are also analyzed for WQI. It is found that K^+ content of Surma River varies between 2.41 to 16.87 mg/L while one observation from Kolapara exceeded the maximum allowable limit (standard limit 12 mg/L, Bangladesh water quality standard). Similarly result obtained from iron (Fe) analysis, one of the observations also showed higher value than the permissible limit. The remaining results are quite satisfactory regarding water quality. However, most of the analysis from our study has shown the higher range of Chromium (Cr) concentration (standard level is 0.05 mg/L according WQI, Bangladesh) where maximum value is found 0.29 mg/L. On the other hand, all results for Zn analysis is found to be well within the allowable range.

A comparative study has done to evaluate our obtained results with previous works (Hossain, 2002; Alam et al., 2006). Table 2 shows the average data of different parameters in three particular years. Following to the Figure 4, it shows the variation of different water quality parameters for the last ten years. A steadily increasing trend is seen for higher pH and TS while no significant variation is seen for both in lower value from 2002 to 2012. But comparatively rapid rising scenario is observed for higher ranges of CO_2, DO, BOD, and Iron. Meanwhile, rate of rising pattern for minimum concentrations of all parameters: CO_2, DO, BOD, and Iron are comparatively low with maximum concentration. On the other hand, the maximum value of TS is increasing with time though the minimum value of TS is decreasing. However, Surma River is swelling for a while compared to previous time. Turning to TDS analysis, a decreasing scene is found while higher concentration of TS is gradually climbed up.

WQI measure

Appling the CCME equation on results of water quality

Table 2. Mean of minimum and maximum values for different water quality Parameters in Surma River during three particular year.

Parameter	2002		2006		2011	
	Min	Max	Min	Max	Min	Max
pH	6.55	7.18	6.09	6.13	6.69	7.92
TS (mg/L)	200	500	145.7	149.4	155.33	611.67
TDS (mg/L)	100	400	129.5	139.3	33.33	301.67
DO (mg/L)	2.8	6.8	5.52	5.72	3.57	11.1
BOD (mg/L)	-	-	0.88	1.00	1.67	11.1
CO_2 (mg/L)	10	30	-	-	17.67	66.33
TSS (mg/L)	50	200	-	-	85.83	310
Fe (mg/L)	0.05	0.5	0.28	0.9	0.27	1.59
Zn (mg/L)	-	-	2.59	6.77	0.14	0.24

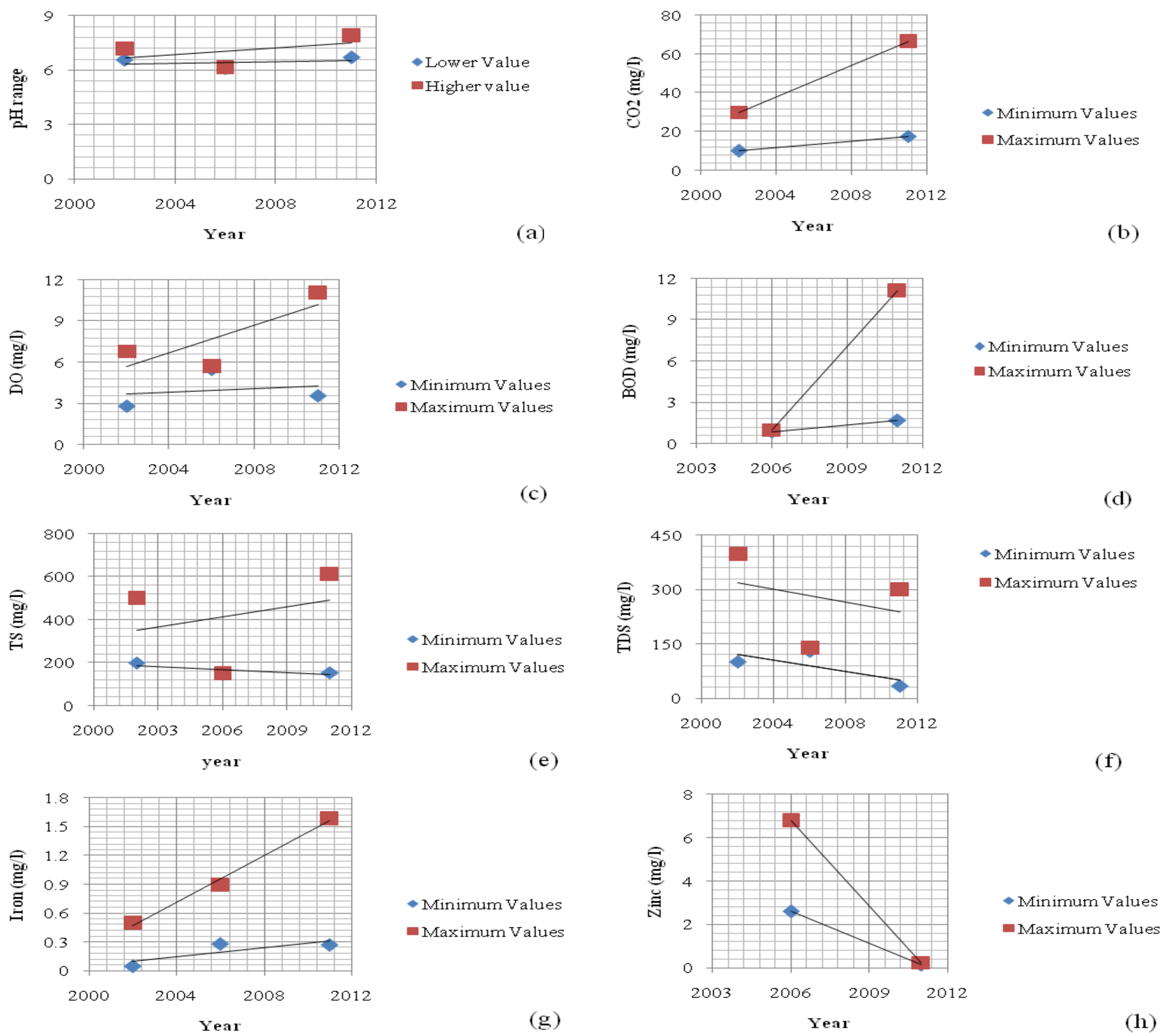


Figure 4. Variation of water quality parameter for the last ten years (a) pH (b) CO_2 in mg/l (c) DO in mg/l (d) BOD in mg/l (e) TS in mg/l (f) TDS in mg/l (g) Iron in mg/l (h) Zinc in mg/l.

Table 3. Variation of WQI of Surma River with different sampling points.

Sampling points	Points Name	Level	Status
01	Charar par**	32.90	Poor
02	Sheikhghat	7.11	Very Poor
03	Kolapara	33.09	Poor
04	Mollapara	41.93	Poor
Overall WQI in Surma river considering all sampling points		15.78	Very Poor

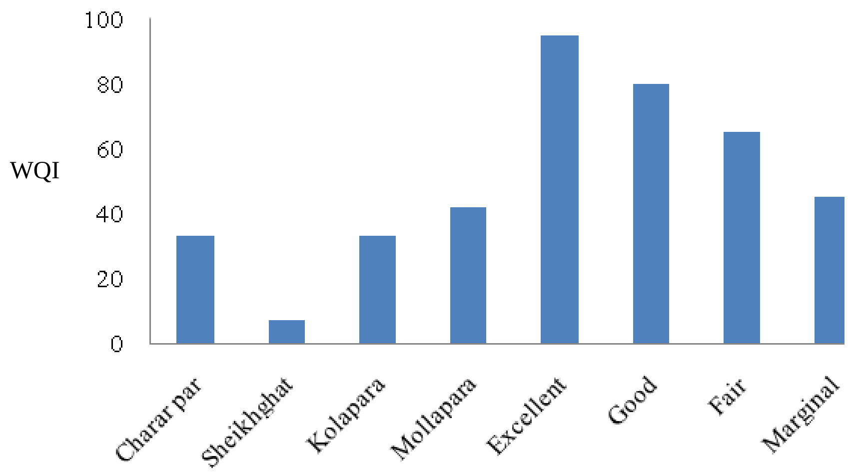


Figure 5. Variation of WQI in Surma River at 4 different locations.

analysis in Surma River, Table 3 shows the WQI level of each location. Considering all observation in each location, WQI for Surma River is equals to 15.78 which indicates that water quality of this river near Sylhet city is Poor and frequently impaired. Further, condition often departs from natural or desirable levels. This low level of WQI in Surma River can be attributed by 14 numbers of variables and 168 number of test along the period of study. Figure 5 shows the variation of WQI with CCME standard level to evaluate the status of existing water quality in this river. Calculated results obtained from all location are showing poor considering CCME Water Quality Index (Table 4). Considering all points, Sheikhghat has shown worst quality in context of CCME-WQI. The reasons may include direct discharge of effluent from fish market which lies within few yards from the sampling points. However, value for WQI obtained from CCME-WQI calculation indicates that the water must be treated to remove the physical and chemical impurities. Furthermore, to draw the water for drinking purposes there is need to boil and filter the water. In context of aquatic life, high turbidity sometimes has seen main culprit. The reasons may include heavy rainfall which causes soil erosion and upstream flow increases the turbidity. Thus soil erosion may be reduced by watershed management techniques, which will lessen the turbidity in water that threaten aquatic life (Lumb et al., 2006). On the other hand, higher CO_2 also poses poor water quality for aquatic life. It may occur due to varied temperature and sunshine duration from season to season where as temperature associated with sunshine has less decay of organic matter present in the water and cause a rise in the carbon dioxide content (Munawar, 1970; Hosmani, 1975).

Conclusion

The results of the present study are in conformity with the previous study findings that water quality of the Surma River is deteriorating at an alarming rate. Data from sample analysis, reveal that even pH, CO_2, TDS, SO_4^{2-}, PO_4^{3-}, Zn values lies under permissible range but the concentration of DO, BOD, TSS, Turbidity and Fe do not meet the satisfactory level. Particularly this study suggested that water quality of this river is affected for high turbidity and BOD due to soil erosion, runoff and municipal effluent discharge without any treatment. Along with Higher turbidity and BOD level, pollutants from untreated waste water constantly deplete DO which is one of the major parameters for the survival of aquatic life. Beside these, concentration of heavy metals in

Table 4. Range of CCME-WQI (Canadian Environmental Quality Guidelines, 1999, Winnipeg).

CCME-WQI Value	Rating	Remarks
95-100	Excellent	Water quality is intact; conditions are very close to natural or desired levels
80-94.9	Good	Water quality is intact; and only one minor threat or deterioration is observed, conditions rarely differed from the natural or desirable level.
65-79.9	Fair	Water quality is usually intact, but occasionally endangered or deteriorated; conditions sometimes deviate from natural or desirable levels.
45-64.9	Marginal	Water quality is frequently endangered or deteriorated. Conditions often deviate from natural or desirable levels.
0-44.9	Poor	Water quality is always endangered or deteriorated; conditions usually deviate from natural or desirable levels.

Surma River is a bit high which poses another impact for the user of Sylhet city who are mainly dependent on Surma River.

Based on CCME-WQIs model, WQI for Surma River is found to 15.78 which indicate that water quality of this river near Sylhet city is Poor and frequently impaired. Further, condition often departs from natural or desirable levels. This low level of WQI in Surma River can be attributed by 14 numbers of variables and 168 number of test along the period of study. Applying the CCME equation on results of water quality analysis, Sheikhghat sampling point has shown worst quality (WQI = 7.11) comparing to all locations. However, it is needed to assess the water quality for a large scale while this study has conducted on a limited scale in some selected locations. Additionally, due to lack of laboratory facilities, all parameter of water quality are not tested for and it is recommended for further study to get more accurate result for the large scale investigation.

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