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Seasonal Variation of Physicochemical Properties of Water in the Buriganga River, Bangladesh

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Abstract: The present study was lead within the Postogala Bridge to Amin Bazar Bridge of Buriganga River, Bangladesh to evaluate the water quality in the context of physical and chemical properties. Nine water quality parameters were monitored at nine stations during the winter and the rainy season within 2012-2013. The physico-chemical parameters such as Temperature, pH, TDS, Total TSS, Eh, DO, BOD, COD, Chloride (Cl^-) were tested as per EPA standard methods. A few parameters were found around DoE standard such as Temperature, pH, TDS etc. The water was found slightly alkali as the pH was above 7 in both season. The DO level is higher in the rainy season (5.50 mg/L) than the winter (2.88 mg/L). The BOD level in the winter (0.64 mg/L) is lower than that of the rainy season (1.97 mg/L); whereas COD (265.33 mg/L in the winter) was much higher than the BOD level that means the sample could be visualized as toxic. The negative value of Redox Potential (winter-67 mV, rainy-78.99 mV) described about the metal ions deposition in the river water. The value of Total Dissolve Solid was almost 5 mg/L in the both season. The analysis of the water quality parameters of the Buriganga River clearly indicated high pollution load on the river water. To maintain the sound environment and healthy ecosystem of the river and the surrounding areas, proper management and monitoring of water quality of the river is needed.

Key words: Buriganga River · Seasonal variation · Physicochemical parameters · Water quality · Pollution

INTRODUCTION

Buriganga is one of the most polluted rivers in Bangladesh. A big number of the industries and factories of Dhaka are situated on the banks of the Buriganga or very close to the river system. Extensive part of urban manure and wastes which are contributed from the domestic level of the Dhaka city is also thrown in the Buriganga River (Moniruzzaman *et al*. 2009)[1]. Although Bangladesh is predominantly a plain surface, it is criss-crossed by a very high density river system. Directly or indirectly Bangladesh depends on its river system for various purposes like as fishery, agriculture, sanitation, navigation, drainage, forestry and control of salinity. The river system of Bangladesh contribute to control settlement patterns, domestic water supply, communications and indirectly, in sanitation and health. However, a number of rivers in this country have become biologically and hydrologically dead due to the indiscriminate dumping of domestic and industrial wastes, intrusion by corrupt people (Moniruzzaman *et al*. 2009)[`1]. Several studies show that the Buriganga is severely polluted comparatively others rivers of the country (Ahmed *et al*. 2011)[2]. The pollution is the great and multifaceted problem in country because of its multidimensional nature. Pollution control is the involved multi phenomena such as social, economic and environmental magnitudes which are associated to water pollution management issues that need to be jointly addressed while seeking a sustainable solution (Rahman

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and Bakri 2010)[3]. Surface waters are more susceptible to contamination due to their easy convenience for dumping of wastewaters (Ahmed *et al.* 2011)[2].

Hydraulically, the Buriganga is not an inaccessible river. Total length of the Buriganga River is 27 km (banglapedia.org). Mean width of the river around Dhaka city is nearly 500 m. (Rahaman and Rana 1996). The Dhaka City is one of the most densely populated capitals in the world, home to approximately nine million people of which less than 25% are served by sewage treatment facility (Ahmad *et al*. 2010). Various activities to responsible for polluting Buriganga river most of them are natural and human activities compelled changes in the Buriganga river and the rivers around Dhaka city have in the winter seasons of the last decades caused a complete deterioration of water quality. Due to the dumping of huge volume toxic wastes of city's thousands of industrial units and sewerage lines, the river Buriganga is being polluted enormously day and night. This scenario increased unexpectedly day by day (Ahmad *et al*. 2010)[2]. The largest share of pollution consignment into the river Buriganga appears to be from about 200 tannery industries in the Hazaribagh and Rayer bazar area (about10,000 people's economic source directly involve on this industrial cluster) (Rahman *et al*. 2010). Most of the industries and factories of Dhaka are established on the banks of the Buriganga or nearby to the river system (Moniruzzaman *et al*. 2009). The river receives a large quantity of wastes (both solid waste and wastewater), by the surface runoff, untreated industrial effluents and treated sewage effluents directly or indirectly from the city of Dhaka. The wastewater comes from several numbers of sources along its way, which are discharged as industrial effluents without any treatment, municipal sewage, household wastes etc. (Rahman and Bakri 2010). These wastes and solid toxic contaminate the river water which are directly affecting on its aquatic life and indirectly to impact on human health (Ali *et al*. 2008). These industrial wastes are discharged in to the river especially effluents from tanneries located in Hazaribagh area, it is very regret matter any tanneries industries don't use ETP. They were thrown both solid wastes and liquid wastes directly to Buriganga river. The Department of Environment (DoE) identified 249 factories along the river Buriganga who are contributes to contaminate of the Buriganga river water (Moniruzzaman *et al*. 2009).

In addition to the pollution problems, the river Buriganga is going to be a dead river on account of continuously decreasing of biological diversity and other aquatic community. The channel are narrowing as influential people are continuously grabbing the riverbanks (Ali *et al*. 2008). Healthy environment and sufficient nutrients are essential for living and growth of aquatics organisms. Physicochemical characteristics of the water body helps to determine the productivity level of aquatics organisms. The highest productivity obtained when the physical and chemical parameters are at the ideal level. Water quality contribute to help decision making process for pollution control in environment protection purpose (Kamal *et al*. 2007)[4].

A number of studies on Buriganga river water quality has been carried out (for example kamal *et al*. 2007; Ali *et al*. 2008[5]; Moniruzzaman *et al*. 2009; Rahman and Bakri 2010; Ahmed *et al*. 2011). They have all stated apprehension about the deteriorating quality of Buriganga river. Nevertheless to date no study has been conducted especially seasonal variation of water quality along Buriganga river. The study was conducted within the Buriganga Bridge-1 (Postoghola Bridge) to Kholamhora Ghat, which is significant due to the existence of many tannery industries and urban sewage flash point situated at this portion of the Buriganga River. The study is very important to provide an up to dated report on the status of water quality of the Buriganga river.

This study carries great importance to deliver the information about present state of water quality of the Buriganga river. This is because the previous studies the data are agreeable still 2011, but next year data are not available till this study. Therefore, water quality is the continuous processes, so update data is more useful for maintaining water quality and monitoring. Subsequently this study could be used for creating continuous water quality database. Therefore a comprehensive experimental research was required to evaluate the present status of the water quality of Buriganga river. In this regard, this study aims to investigate seasonal variation of physiochemical water quality in terms of some selected parameters, which consists: Temperature, Total Dissolved Solid (TDS), Total Suspended Solids (TSS), pH, Redox Potential (Eh), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Chloride (Cl^-) ion along the Buriganga river for both winter (January-February) and rainy (August-September) seasons. The standard deviation of the water quality test results and mean values were compared in terms of the DoE standards and WHO guidelines. The acquired water quality results were summarized and presented through tabulated form and graphical analysis. The principal objectives of the present study implicate the following themes: a) to find out the spatial circulation of water quality of the Buriganga River with continuous data generation. b) to evaluate the seasonal deviation of physicochemical parameters. c) To recommend the approaching uses of water of the Buriganga river. Therefore it was very significant to examine the water quality parameters of the Buriganga River to investigate the source of pollutants and quantified its level of pollution [6-19].

MATERIALS AND METHODS

Study Area: The study has been conducted on Buriganga river which is consecutively by the side of the Dhaka city, the capital of Bangladesh, is one of the most polluted rivers in Bangladesh (Fig 1). The river Dhaleshwari is the source of the Buriganga river and near Kalatia it originated from the Dhaleshwari river. Its average width is 400m and its average and maximum depth 10m and 18 m respectively (Ahmed *et al*. 2011). The river is 27 km by length. Water samples were collected over the 7.5 km stretch on river Buriganga. It is located in the center of Bangladesh between latitude 23°41'16.26"N-23°42'42.22"N and longitude 90°21'36.97"E E to 90°25'39.54"E respectively. Sample was collected form 18 points. Which were A. The Buriganga Bridge-1(Postoghola Bridge), B. The Buriganga Bridge-2 (Naya Bazar Bridge), C. The Kholamhora Ghat, D. The Bosila Bridge E. The Ramchandrapur (sholmasi) and F. The Amin Bazar Bridge three substations under each location respectively north, mid and south points (Figure 1).

Sampling and Methods: Water samples were collected during rainy season from August-September 2012 and also during winter season from January-February 2013. Collected water samples were tested for physical qualities and chemical contents in the Buriganga River water. Sample collection was conducted in two times at an interval of four months. Water samples were collected during winter and rainy season at the following six strips across the river. Each strips contain 3 points each sampling points had three locations, two sides of the rivers and the middle part of the river (like as A1, A2, A3, B1, B2, B3 etc., Table 2). Total eighteen sampling points were selected for the collection of water samples. Prior to sample collection, all bottles were washed with dilute acid followed by distilled water and were dried in an oven. The sample bottles were labeled with date and sampling source eighteen sampling locations (GPS value are in Table 1) were selected for the collection of water samples. The water samples were collected in plastic bottles and preserved in refrigerator at room temperature for laboratory analysis.

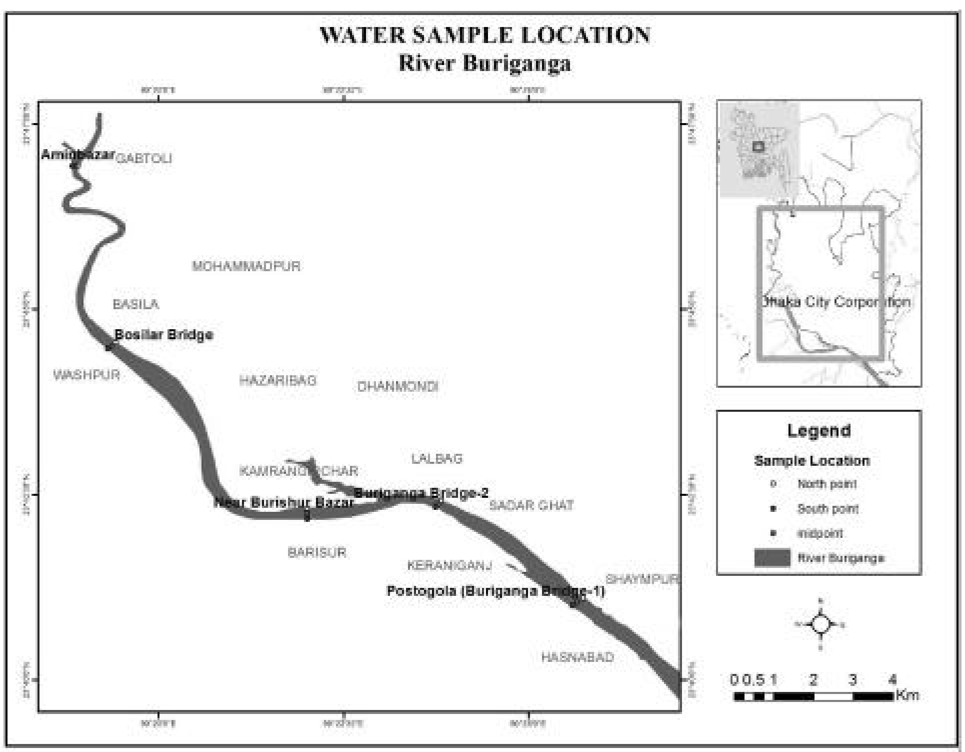

Fig. 1: Study area and sampling point in the Buriganga river

Table 1: Sampling location in the Buriganga River

Sampling Station	Location	Latitude and Longitude
A1	The Kholamhora Ghat south point	N 23°42'42.22" E 90°21'36.97"
A2	The Middle Point between the Kholamhora Ghat and the Kamragirchar Mid-point	N23°42'43.49" E90°21'39.60"
A3	Near the kamragirchar point	N 23°42'44.70" E 90°21'43.57"
B1	The Buriganga Bridge 2, near the Babu Bazar Piont	N 23°42'33.42" E 90°24'7.74"
B2	The Buriganga Bridge 2, Mid-Point	N 23°42'32.03" E 90°24'5.53"
B3	The Buriganga Bridge 2, Kathuria point	N 23°42'29.71" E 90°24'5.34"
C1	The Buriganga Bridge 1,Postogola bridge, south point	N 23°41'11.84" E 90°25'34.60"
C2	The Buriganga Bridge 1,Postogola bridge,Mid-point	N 23°41'13.11" E 90°25'37.81"
C3	The Buriganga Bridge 1,Postogola bridge, North point	N 23°41'16.26" E 90°25'39.54"
D1	The Bosila Bridge (north point)	N 23°44'.622" E 90°20'.772"
D2	The Bosila Bridge (Mid-point)	N 23°44'.583" E 90°20'.733"
D3	The Bosila Bridge (South point)	N 23°44'.562" E 90°20'.714"
E1	The Ramchandrapur (sholmasi) South point	N 23°45'.533" E 90°19'.992"
E2	The Ramchandrapur (sholmasi) Mid-point	N 23°45'.428" E 90°20'.045"
E3	The Ramchandrapur (sholmasi) north point	N 23°45'.531" E 90°20'.109"
F1	The Amin Bazar Bridge (west point)	N 23°47'.053" E 90°20'.095"
F2	The Amin Bazar Bridge (Mid-point)	N 23°47'.048" E 90°20'.108"
F3	The Amin Bazar Bridge (East point)	N 23°47'.047" E 90°20'.124"
Total = 18		

Standard methods based on Environmental Protection Authority (EPA) guidelines were used for the analysis of various water quality parameters. All water samples were collected, stored and analyzed according to EPA approved methods at the environmental lab of geography and environment department, Jagannath University, Dhaka. All experimental parameters were measured according to EPA standards methods. Water temperature was measured by the thermometer Celsius scale (Made in German, which measured 100°C) in the field. pH and Redox potential (Eh) were measured with an electronic digital instrument pH meter. Whereas, TS and TSS were measured by oven dried method (Radojevic and Bashkin, 1999) in the laboratory. TDS was measured by filtration and oven dried method (Radojevic and Bashkin, 1999). Chemical parameter such as Dissolved Oxygen (DO) was measured by Winkler titration method, Biological Oxygen Demand (BOD) was measured by 5 days BOD test (UEPA, 1986), Chemical Oxygen Demand (COD) measured by titration method (APHA, 1915) and chloride (Cl^-) ion was measured by the free or total chlorine test kits (0-3.4 mg/L Cl_2, model 223101CN-66, 223102 CN-66F). Three replicated analysis were done for each parameters in each sampling. Various software's used this study such as ArcGIS 10.0 was used to present sampling points on map, where water sample were collected in the Buriganga river. Microsoft Excel 2013, Sigmaplot 10.0 and SPSS 20.0 (Statistical Package for Social Science) were used for statistical analysis like as mean, standard deviation, maximum values and minimum values. Also, these softwares were used to analysis co-relation between two parameters.Moreover, adobe photoshop CS8 used to for graphical representration.

RESULTS AND DISCUSSION

Monitoring the river water quality is vital for managing the river ecosystem. The given following finding results in present study of Buriganga river water quality examining nine (9) parameters.

Temperature: Temperature is very important for water to manage quality. It is responsible for all change of physicochemical parameters of water. The rate of chemical reactions generally increases at higher temperature (Alam *et al*. 2007). In present study temperature of the river water was recorded ranged 18°C to 24°C during winter season (January, 2013). Mean temperature was recorded 21.22°C during Winter Season (Table 2). Relatively in the rainy season the mean temperature was recorded 21.56°C, (Fig 2b). Therefore, in the present study temperature was close to previous study (Moniruzzaman *et al*. 2009). River water temperature depends on a number of key components for example, wind magnitude, atmospheric temperature, solar radiation, salinity gradient and cloud coverage (Kamala *et al*. 2010). So, in the Buriganga river, water temperature was complimentary for the various chemical and biological processes in aquatic ecosystems. On the other hand, maximum temperature was recorded during rainy (August, 2012) season.

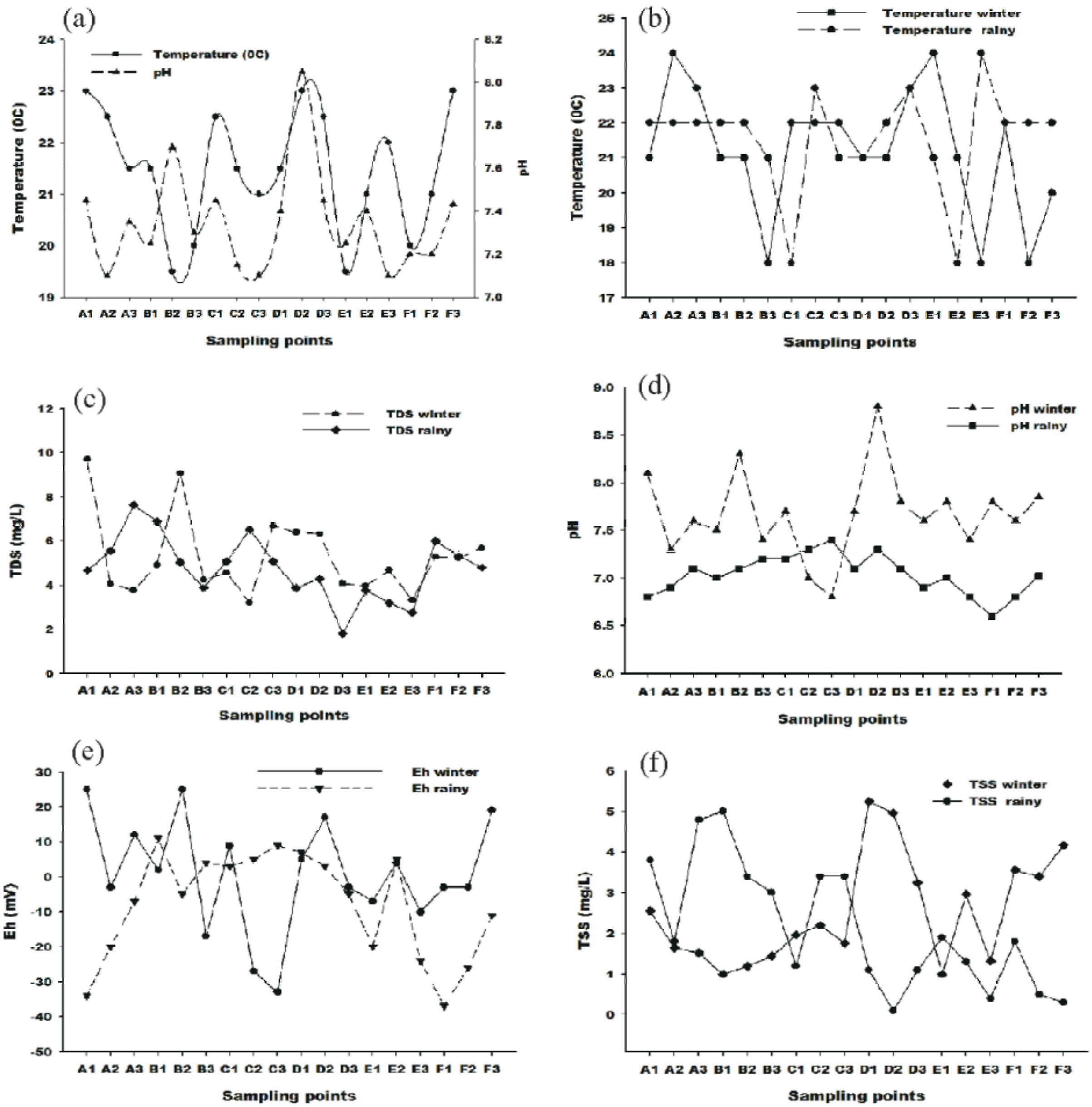

Fig. 2: Seasonal variation of water quality at different points of Buriganga River a. Relation between temperature and pH, b. Temperature, c. TDS, d. pH, e. Eh, f. TSS,

Comparatively, the present study recorded maximum temperature in during rainy Season, 21.19°C. Inclusive, mean (winter and rainy season) temperature was recorded 21.39° C in the Buriganga river, recorded temperature value to acceptable with DoE standard, where according to the DoE standard temperature have to be from 20°C to 30°C (Table 4). So, the study area water temperature was favorable for drinking water supply and managing aquatic ecosystem.

Total Dissolved Solid: TDS is the amount of total solids dissolved solids in the water (Afrin *et al*. 2011). High TDS influences the changing of natural taste and demonstrate the existance of toxic minerals (EC regulation, 2007). The Total Dissolved Solid (TDS) concentration of Buriganga river water was considerably high during the winter season (January, 2013). TDS ranged from 3.20-9.72 mg/L (Fig 2c) in the during the winter (January) season Mean TDS was found 5.29±1.81 mg/L (Table 6). Maximum TDS was measured 9.72 mg/L at the Kholamhora Ghat (Fig 2c),

Table 2: Concentration of physicochemical parameters of the Buriganga river in the winter (January) and rainy (August) season

Sampling Point	Temp. (0C)		TDS(mg/L)		TSS (mg/L)		pH		Eh (mV)		DO (mg/L)		BOD (mg/L)		COD (mg/L)		Cl-(mg/L)	
	winter	rainy	winter	rainy	winter	rainy	winter	rainy	winter	rainy	winter	rainy	winter	rainy	winter	rainy	winter	rainy
A1	21	22	9.72	4.68	2.56	3.8	8.1	6.8	25	-34	2.9	6	0.6	1	256	116.67	0.1	0.1
A2	24	22	4.04	5.56	1.64	1.8	7.3	6.9	-3	-20	4	6.4	1	1.8	256	320	0.3	0
A3	23	22	3.76	7.64	1.52	4.8	7.6	7.1	12	-7	3	5	0.3	1	336	280	0.1	0
B1	21	22	4.92	6.88	1	5	7.5	7	2	11	1.6	5.5	0.6	0.3	296	106.67	0.3	0
B2	21	22	9.08	5.04	1.2	3.4	8.3	7.1	25	-5	1.2	9.2	0.4	3.8	336	146.67	0.2	0.1
B3	18	21	4.24	3.88	1.44	3	7.4	7.2	-17	4	0.8	7.9	0.1	1.8	216	413.34	0.3	0.2
C1	22	18	4.56	5.08	1.96	1.2	7.7	7.2	9	3	3.3	6.7	0.5	2.3	296	186.67	0.1	0.1
C2	22	23	3.2	6.52	2.2	3.4	7	7.3	-27	5	2	5.2	0.3	2.6	240	126.67	0.3	0
C3	22	21	6.68	5.08	1.76	3.4	6.8	7.4	-33	9	3.2	5.5	0.5	0.6	280	247.62	0.2	0
D1	21	21	6.4	3.88	5.24	1.1	7.7	7.1	5	7	1.8	5.5	0.6	0.6	248	325.67	0	0.1
D2	21	22	6.32	4.28	4.96	0.1	8.8	7.3	17	3	2	4.4	0.3	3	296	78.75	0	0
D3	23	23	4.08	1.8	3.24	1.1	7.8	7.1	-3	-5	4.2	5.4	1.9	4.2	248	134.57	0.3	0.1
E1	24	21	3.96	3.76	1	1.9	7.6	6.9	-7	-20	3.1	3.5	0.5	1.7	256	192.85	0	0.3
E2	21	18	4.68	3.2	2.96	1.3	7.8	7	4	5	3.8	4.6	0.6	2.2	248	112.5	0.1	0.3
E3	18	24	3.32	2.76	1.32	0.4	7.4	6.8	-10	-24	3.4	4.5	0.6	2.5	272	268.58	0	0.2
F1	22	22	5.28	6	3.56	1.8	7.8	6.6	-3	-37	3.8	3.9	0.6	1.1	216	126.67	0	0
F2	18	22	5.24	5.32	3.4	0.5	7.6	6.8	-3	-26	4.8	4.8	0.4	1	264	47.85	0	0.1
F3	20	22	5.68	4.8	4.16	0.3	7.85	7.02	19	-11	3	5	1.7	3.9	216	163	0.1	0.4
SD	1.83	1.5	1.81	1.47	1.34	1.55	0.46	0.2	16.18	15.36	1.1	1.39	0.47	1.2	36.12	99.6	0.11	0.12
DoE	20 to 30°C		1000		≤ 30.0	-	6.5 to 8.5		5		>2.00		4	0.05				

Table 3: Compliance of Buriganga river water quality parameters with DOE guidelines, compliance with standards (Yes/No)

Parameters	DOE standards to maintain the aquatic ecosystem	Winter season	Rainy season
Temperature	20 to 30°C	Y	Y
pH	6.5 to 8.5	Y	Y
DO	5 mg/L	N	Y
BOD_5	2 mg/L	N	N
COD	4 mg/L	N	N
TDS	450-2000 mg/L	Y	Y
Cl^- ion	5 mg/L	Y	Y

Table 4: The correlation coefficient (r) and t-value among different physicochemical water quality parameters in Buriganga river

Parameters	DO		BOD		COD		pH		Temperature		TDS		TSS	
	t	r	t	r	t	r	t	r	t	r	t	r	t	r
COD	0.86	0.04	0.72	-0.07	-	-	0.33	-0.16	0.19	0.26	0.85	-0.04	0.87	-0.03
TSS	0.76	0.06	0.72	0.07	0.87	-0.03	0.62	0.10	0.20	-0.25	0.00	0.91	-	-
DO	-	-	0.00	0.57	0.86	0.04	0.76	-0.06	0.20	0.25	0.89	-0.03	0.76	0.06
BOD	0.00	0.57	-	-	0.72	-0.07	0.75	0.07	0.49	0.14	0.11	-0.31	0.72	0.07
TDS	0.89	-0.03	0.61	-0.31	0.85	-0.04	0.53	0.13	0.33	-0.19	-	-	0.00	0.91
pH	0.76	-0.06	0.75	0.07	0.33	-0.20	-	-	0.04	-0.40	0.53	0.13	0.62	0.10
Temperature	0.20	0.25	0.49	0.14	0.19	0.26	0.04	-0.40	-	-	0.33	-0.19	0.20	-0.25

Table value of at 5% level of significance at 5 degree of freedom

south point (N 23°42'42.22" E 90°21'36.97"), because of showed high TDS of water due to huge urban and industrial activities around river and comparatively the lowest TDS 3.20 mg/L was found at the Buriganga Bridge-1(Postoghola bridge), mid-point (N 23°41'13.11" E 90°25'37.81"). TDS was moderately low during the rainy (August, 2013) season (ranged from 1.80 to 7.64 mg/L, Fig 2c) in the Buriganga river. Mean TDS was found 4.79±1.47 mg/L (Table 6). The highest TDS was recorded 7.64 mg/L at near the kamragirchar point (N 23°42'44.70" E 90°21'43.57") and the lowest TDS was found 1.80 mg/L at the Bosila Bridge, South point (23°44’.562’’N and 90°20’.714’’E, Fig 1c) in Buriganga river through the rainy season during study session (Table 3). The present study to signify the Buriganga river water TDS was controlled by the DoE Satandards (Table 4).Where, DOE guidline to denote for river water TDS is 1000 mg/L.But all these TDS values at different times of year were within the permissible limit (Table 4).

Total Suspended Solids (TSS): Sophisticated concentrations of suspended solids can assist as carriers of toxics, which readily cling to suspended elements (Ahmed *et al*. 2011). In present study recorded TSS ranged from 1.00-5.24 mg/L and mean TSS was recorded 2.51±1.34 mg/L during the winter season (January, 2013). The highest TSS was recorded 5.24 mg/L at the Bosila Bridge, Mid-point (N 23°44'.583" E 90°20'.733") and the minimum TSS was recorded 1.00 mg/L (Fig 2f). TSS was recorded very low in the rainy (August, 2012) season. The TSS was ranged from 0.10-5.00 mg/L. The mean TSS was recorded 2.13±1.55 mg/L in the rainy season and maximum TSS was recorded 5.00 mg/L at Buriganga bridge 2 (Fig 2f), near the Babu bazar point (N 23°42'33.42" E 90°24'7.74").The minimum TSS was recorded 0.10 mg/L (Fig 2f) at the Bosila Bridge, South point (N 23°44'.562" E 90°20'.714"). The concentration of TSS in effluents in all the seasons was less than according to WHO and EQS standards (Table 3). The study area TSS was permissible limit to maintained (DoE 1993; WHO 2006; UNEP 2008) standard both winter and rainy Season.

pH: pH plays vital role to examine the water quality assessment as it has great influence on biological and chemical processes in the water body (Ahmed *et al*. 2011). In the study area the pH of water collected at different points and at different times of year ranged from 6.80 to 8.82 and the mean pH of water was found 7.67 ± 0.46 (Fig 2d) in the winter season (Table 6). The highest pH was found 8.82 at the Bosila Bridge, South point, (N 23044'.562" E 90°20'.714") and the lowest pH was found 6.80 (at the Bosila Bridge (north point), N 23044'.622" E 90°20'.772") in the Buriganga river during the winter season (Fig 2d).

On the other hand, the pH of water was slightly low during the rainy (August) season pH ranged from 6.63 to 7.35 in the Buriganga river. The mean pH value was found 7.03± 0.17. The highest pH was found 7.35 (at the Bosila Bridge(Fig 2d, north point, N 23°44'.622" E 90°20'.772", Table 6) and the lowest pH was found 6.63 (at the Amin Bazar Bridge, west point) in the rainy season (Table 2). Therefore, the study area mean water pH during the winter and rainy both season respectively 7.67 and 7.03 (Fig 2d). It's express the Buriganga river water pH was moral, pH = >7 (Accordance to DoE, Table 3).

But all these pH values at different times of year were within the permissible limit. There were not significan variation in pH values in this analysis. Reaction involving carbonate system control most of the natural water Ph. pH change quickly due to loss or gain of dissolved gases such as CO_2 and O_2. pH measure of the alkanity or acidity of water sample (Afrin *et al*. 2011). So the study area water was weak alkaline.

Redox-potential (Eh): Oxidation-reduction (Eh) reactions are significant in natural hydrological systems. Generally, redox reactions contribute to all aquatic creatures to achieve their energy for metabolic processes. It's refers to the concentration of oxidants and unwilling in the environment (Delaune *et al.* 2005). The oxidation reduction potential (ORP or Eh) values indicate the environment of deposition of aquifer materials. The values of Eh of the sample of the study area show both positive and negative potential. In present study redox potential (Eh) ranged-33.00 to +25.00 mV during the winter (January, 2013) season in the Buriganga river. The mean Eh was recorded +67.00 ± 16.17 mV and the maximum Eh was recorded ±25 mV at the Kholamhora Ghat south point, which samples were collected from the surface and the minimum Eh value was recorded-33.00 mV at Buriganga Bridge-1(Figure 2e), the Postoghola bridge, North point, in the Buriganga river during the winter season. Relatively redox potential (Eh) were recorded ranged-37.00 to +11.00 mV during the rainy (August,2012) season in and the mean Eh was found-7.89 ±15.36 mV in rainy and the maximum Eh was recorded +11.00 mv at the Buriganga Bridge-2(Figure 2e), near the Babu Bazar point (N 23°42'33.42" E 90°24'7.74") and the minimum Eh was recorded-37.00 mV at the Amin bazar bridge, west point.(N 23°472'.053" E 90°20'.095",F1,Table 6) during the rainy season (Figure 2e).

Dissolved Oxygen: Dissolved oxygen is essential for good water quality. Any forms of life cannot sustain without oxygen. Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. Dissolved oxygen concentration of the Buriganga river water was significantly low during winter (January, 2013) season (value in the ranged of 0.80 to 4.80 mg/L, Table 1). Mean dissolved oxygen was found 2.89 mg/L. The lowest dissolved oxygen of water was found 0.80 mg/L (Figure 3a) at the Buriganga Bridge 2, the Kathuria point (23°42'29.71"N to 90°24'5.34"E) and the highest dissolved oxygen was found 4.80 mg/L (Fig 3a) at the Amin Bazar Bridge, mid-point,(N 23°47'.048" E 90°20'.108"). Dissolved oxygen concentration of the Buriganga river water was significantly high during rainy (August, 2012) season. Dissolved oxygen ranged from 3.60 to 9.2 mg/L, Table 2) and the highest dissolved oxygen was found 9.2 mg/L (at the point of mid-Point, N 23°42'32.03" E 90°24'5.53" at the Buriganga Bridge-2). During rainy season mean dissolved oxygen was found 5.50 ± 1.39 mg/L.

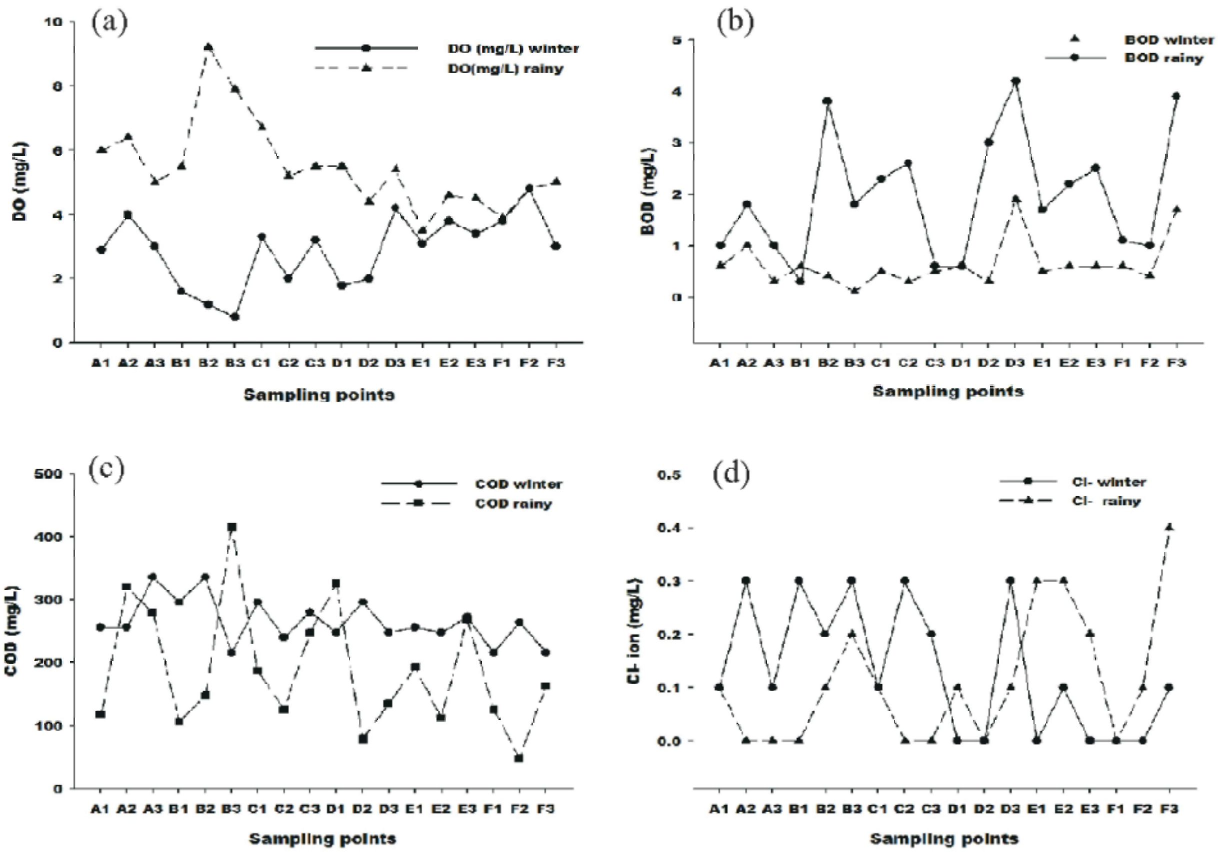

Fig. 3: Seasonal variation of water quality at different points of Buriganga River a. DO, b. BOD, c. COD, d. Cl-ion

In study areas water moderately-polluted (DO = 2.0~4.5) during winter season and lightly polluted (4.6~6.5) during rainy season (Fig 3a), accordance to river pollution Index (UNEP, 2008) and water and effluent quality guidelines (standards) of selected parameters for different uses as set by DoE 1997 in Bangladesh. The guideline dissolved oxygen is 5 mg/L of dissolved oxygen is recommended for optimum fish health, below this level harmful effects have been recorded. Low level of dissolved oxygen less than 2 mg/L has been reported in fish mortality So the water of the Buriganga river was relatively safe during rainy season. But in winter season, water was not adopt within the safe perimeter for drinking purpose, fisheries, irrigation and other activities in respect of dissolved oxygen concentration. The dissolved oxygen concentration of water of the Buriganga river indicated an unfavorable environment for aquatic lives during winter season.

Biological Oxygen Demand: Biochemical oxygen demand ranged from 0.10 mg/L to 1.9 mg/L in the Buriganga river during winter (January, 2013) season (Table 2). The lowest BOD level was recorded 0.10 mg/L in the station A1 and C3 and relatively the highest BOD level was recorded 1.9 mg/L in the station E1 (Figure 3b), which station was located at Bosila Bridge, South point, (N 23°44’.562" E 90°20’.714"). The mean BOD level was recorded 0.64 ± 0.46 mg/L in the Buriganga river during winter season.

On the other hand, during rainy (August, 2012) season the BOD value was ranged from 0.30 mg/L to 4.2 mg/L and mean BOD was found 1.97 ± 0.20 mg/L in the Buriganga river. Maximum BOD value recorded 4.2 mg/L in the D3 station (Figure 3b) at the Bosila Bridge (South point), which receives organic or partially treated effluents from various industries like tannery, garments, dairy etc. along with city sewage brought by flash points. Relatively the minimum BOD was found 0.30 mg/L in the B1 station at Buriganga Bridge 2, near the Babu Bazar Point (Figure 3b). In study areas water slightly polluted (BOD = Over 3.0 mg/L) during winter season and lightly polluted (3.0-4.9 mg/L) during rainy season, accordance to river pollution Index (RPI), by the (UNEP, 2008) guideline water and effluent quality guidelines (standards) of selected parameters for different uses as set by DoE in Bangladesh

(BOD = >2 mg/L). Compliance with DoE standard for BOD (>2 mg/L), the investigated water BOD level was not meet for drinking purposes and to maintain the aquatic ecosystem. The optimal value of BOD for good water quality is 6 mg/L. Higher BOD and COD values indicate water pollution (Islam *et al*. 2011).

Chemical Oxygen Demand: In the present study COD value recorded ranged from 216 mg/L to 336 mg/L (Table 3) during winter season (January, 2013). The lowest COD value was recorded 216 mg/L in the B3 station and highest COD value was recorded 336 mg/L in the station respectively A3 and B2 (Figure 3c) at Near kamragirchar poin and other sampling point located at the point of the Buriganga bridge-2, the Kathuria point in the Buriganga river. Mean COD value was recorded 265.33±36.12 mg/L in the Buriganga river during winter (January, 2013) season. Behavior of COD was opposite to DO. Comparatively the COD value was recorded moderately low during rainy (August, 2012) season (47.85 mg/L to 413.34 mg/L) in the Buriganga river (Table 6). Mean COD was recorded 188.60 ± 99.23 mg/L. The highest COD value was found 413.34 mg/L at the B3 station (Figure 3c) at Buriganga Bridge 2, Kathuria point in the river. Relatively maximum COD value may cause oxygen depletion on reason of decomposition by microbes to a level detrimental to aquatic life (Ravindra and Kaushik 2003). The standard value for COD is 4 mg/L (DoE 1997; Islam *et al*. 2011).Therefore the water of the Buriganga river wasn't relatively safe for using drinking and maintaining aquatic ecosystem during study session, since of the DoE COD standards is 4 mg/L, but in study area COD value were found more than greater the DoE indicate level (Table 4). Showed high COD of water due to massive municipal and industrial activities around the river.

Chloride (Cl^-) Ion: In the present study Chloride (Cl^-) ion was recorded as ranged from 0.0-0.3 mg/L in the Buriganga river during winter(January,2013) season. The mean Chloride (Cl^-) ion was recorded 0.13 ± 0.12 mg/L and the maximum Chloride (Cl^-) was recorded 0.30 mg/L respectively sample station in A2, B1, C2 and D3 (Figure 3d). Else, to found variation of Chloride (Cl^-) value one to another season in the Buriganga river. The Chloride (Cl^-) ion measured extended 0.00-0.04 mg/L in rainy(Ausgust,2012) season. The mean Chloride (Cl^-) ion was recorded 0.11 ± 0.11mg/L and the highest Chloride (Cl^-) ion was recorded 0.40 mg/L at the sample point F3 (Figure 3d) near the Amin Bazar Bridge, East point. The lowest Chloride (Cl^-) ion was found many more sample points in study area, which could be attributed to dilution effect of heavy rains as suggested by Dwivedi and Odi (2003). But all these Chloride values at different times of year were within the permissible limit (Table 3).

Recommendation: Buriganga river highly polluted by industrial waste and effluents, human waste and sewage. Buriganga river bed is filled with sediment specially polythene layer and silt. Water quality maintenance is the continuous processes, therefore the water qualities various parameters should be monitoring regularly. Particular recommendation mentions below for protecting the Buriganga River pollution and kept standards water quality. These are

- All the industries especially Hazaribagh tanneries should be shifted into specific industrial location.
- Municipal and domestic refuse and waste to threw directly in the Buriganga River without any treatment. So to set up waste water treatment plant.
- Pollution source data banks are not available by the categorizations, use list of chemicals and other toxicants which industries to play their role in the market.
- Government should force all the industries to installed and use ETPs (Effluent Treatment Plant).
- Shipbuilding industries one of the major causes for the polluting Buriganga river, many Shipbuilding industries to established by unplanned on the southern bank of the river. So the Shipbuilding industries to formulate by as planned.
- Public awareness is the very important gears for pollution control, it is must be positive attempt for prevention against pollution. The media (printed and electronic media) can play a vital role to save the Buriganga river. They should do the following things to create awareness among the people and draw the attention of the government to save the Buriganga river Special programme should be telecast on TV and the Radio.
- Therefore it was recommended that a Buriganga River Management Authority will be established, to work under the administration of the Ministry of Environment and Forests (MOEF). This agency could be allocated with legislative power and would hold individual responsibility to manage and coordinate all activities related to pollution control and conservation of the Buriganga River.

CONCLUSION

The outputs of this study provide appreciated information to water resource managers, environmentalists and investigators to implementation of appropriate strategies for the improvement of water quality management efforts. The investigated study results and finding to compliance water quality parameters with DoE guidelines, Compliance with standards. From above discussion it was observed that, the physiochemical properties such as Temperature, pH, TDS, TSS and Cl^-ion were within the safe limit throughout the year (Table 3). Nevertheless Dissolved Oxygen concentration in winter (January) season was very low due to various microbial activities and it creates an unfavorable environment for aquatic lives. Hence, the DO was relatively high during rainy (August) season to followed DoE standards (Table 3). In contrast, the BOD was relatively low during both (winter and rainy) season from DoE guideline (Table 2), same characteristics to represent COD as like BOD. Chemical parameters concentration (DO, BOD, COD) of Buriganga river water was relatively by low during winter (January) season due to dilution effect and concentration was high in rainy (August) season due to diverse industrial and urban activities in low water level condition.

Therefore, the Buriganga River water was moderately polluted during study period. River water quality was poorer in winter season than rainy season (Table 2). All Physico-chemical water quality parameters are interrelated one to other parameters. Investigated maximum water quality Physico-chemical parameters high level positive correlated (according to Pearson correlation, Table 4). But a few parameters to represent negative mid-level correlation, like as COD and TDS or TSS, another negative correlation between BOD and TDS or DO and TDS. Also, water quality parameters between pH and DO to represent negative correlation, that means when to raise pH orderly DO level to fall. On the other indicator, when the pH value to fall systematically DO level to raise (Table 4).

Although, few water qualities parameters to maintain DoE and WHO standards, but these value were very poor for permanent water qualities. Water quality was better in rainy season than the winter season. In winter (January) season the level of pollution was much higher than in rainy (August) season. The present study to show that quality of water is not now safe limit. The comparison of water quality parameters in terms of national and international standards, it could be deduced that water quality at rainy season is "Good" and fit for maintain aquatic ecosystem after disinfection; water at winter season is "Poor" whereas is "Unfit for human consumption" and could only be used for aquaculture, irrigation and for industrial purposes.

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