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Industrialisation Scenario at Sreepur of Gazipur, Bangladesh and Physico-chemical Properties of Wastewater Discharged from Industries

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Authors' contributions

This work was carried out in collaboration among all authors. Author MBH designed the study, performed the analysis and wrote the manuscript. Authors MNI and MSA helped to design the study and supervised the work. Author MZH helped in manuscript preparation. All authors read and approved the final manuscript.

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ABSTRACT

This study was conducted to explore the present trend and pattern of industrial growth with spatial distribution of industries and seasonal extent of physicochemical characteristics of wastewater at Sreepur of Gazipur, Bangladesh. The wastewater samples were collected from 5 locations in three seasons viz. pre-monsoon, monsoon and dry season. A total of 120 medium to large industries were surveyed, among those 52 were in red category, 53 were in orange-B category, 13 were in orange-A and only 2 were in green category. In 1995, there were only three industries, which gradually increased to a total of 29 in 2005. Among them, 11 were in red category and 18 were in orange-B category. But from 2006-2010, a total 59 industries were developed and most of them were in red and orange-B categories. Similarly, during the period of 2011 to March 2013, a total 16

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industries were developed, among them 8 industries were in red and 3 were in orange-B category. Major types of wastewater discharging industries were textile, dyeing, washing and printing. Among the surveyed industries about 33% didn't have any effluent treatment plant (ETP). The mean value of pH, EC, DO, BOD, COD and TDS of wastewater were 7.28, 2.64, 1.62 mg L^{-1}, 82.0 mg L^{-1}, 217.31 mg L^{-1} and 1380 mg L^{-1}, respectively during pre-monsoon; 6.7, 1.15, trace, 8.0 mg L^{-1}, 152.4 mg L^{-1} and 539.58 mg L^{-1}, respectively during monsoon and 7.7, 1.82, 0.74 mg L^{-1}, 48.8 mg L^{-1}, 204.8 mg L^{-1} and 993.6 mg L^{-1}, respectively during dry season. Average DO concentrations in all seasons and sites were significantly low, while BOD and COD contents were higher in pre-monsoon and dry seasons than the DoE permissible limit. The study concluded that the area is now a hub of polluting industries which are mostly liable to pollute the surrounding environment.

Keywords: Industrialisation; spatial distribution; wastewater; Sreepur; Gazipur.

1. INTRODUCTION

During the last two decades, Bangladesh has experienced a dramatic expansion in small and medium level industries, particularly in garments and textile sector, which have boosted the economy of the country. Undoubtedly, industrialisation plays a significant role to accelerate economic growth and employment status, increase in incomes and standard of living of the people. On the contrary, with the rise in number of industries and expansion of urban areas, the agricultural and residential places are under tremendous pressure in Bangladesh. Therefore, the residents' peoples of such areas are now suffering from various forms of environmental and social hazards. Ironically, environmental degradation in such areas persistently continued despite multiple designated government agencies that are equipped with various conservation laws, codes and planning documents in hand during the past couple of years.

Once upon a time, Sreepur of Gazipur district has a unique topographical position with rich biodiversity and ecological habitats. But now-a-days farmlands are surrounded by boundary walls and used for different industrial purposes. Beautiful water bodies came the carrier of dark, filthy and foul smelled channel. Canals became narrowed down and the polluted water spreading over the farmlands during heavy rain in the rainy season. Furthermore, irrigation practices with these industrial wastewater adds significant quantities of different contaminants including toxic metals which is ultimately damaging the soil quality [1-6]. Consumption of agricultural commodities produced in such contaminated soil can cause serious health problems to the people [7-9].

However, there are scanty inclusive research for the Sreepur area in context of industrial pollution. Some of the researches are done sporadically along with areas of other Upazila's of same district, without providing inclusive result especially for this area [10]. Therefore, detailed systematic field researches on industrialisation scenario and their consequences on water pollution were inadequate or missing. Considering the fact stated above, this work was conducted to assess industrialisation scenario, their categorisation as environmental pollution sources and physico-chemical properties of wastewater discharged from different industries of Sreepur Upazila of Gazipur district.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

According to physiographic features Sreepur is an area which evolved during Pleistocene period having area of 465.25 km². The Upazila is located at the north-eastern part of Gazipur district, which lies between 24°01′ to 24°20′ N latitude and 90°18′ to 90°33′ E longitude [11]. Geologically, the Gazipur cluster lies on the southern corner of Madhupur tract with its average thickness of about 10 m, which consists of over consolidated clayey silt and is underlain by the Pleistocene Dupi Tila formation. The rocks encountered here are much younger in geologic age and ranges between Oligocene and Recent time. The basin has got the record of rapid subsidence and sedimentation [12]. Jamindari system was there like other parts of the then Bengal. "Bhawal Raja" estate was there for long time. By virtue of this, Jamindari system a number of people of this place historically owned handsome amount of land [13].

2.2 Data Collection about the Industries

Data of the industries in the study area were collected on the basis of the following prestructured format, viz. serial no., name of the industry, type of industry, category on the basis of ECR, installation of ETP (yes/no), location, GPS point, establishment year and area covered. In case of any query or clarification, industry personnel were asked to reply and sometimes it was discussed also with people living nearby industry. Some of the information collected on the basis of oral statement and some of the data collected black and white provided by the industry personnel. Distribution of different types of industries in the study area along with the sampling sites is shown in Fig. 1.

2.3 Water Sampling and Processing

A total of 5 wastewater samples were collected from the study area during three seasons viz. pre-monsoon, monsoon and dry from different points of the canal following the sampling techniques as outlined by APHA [14]. The collected water samples were stored in 500 mL preconditioned clean, high density plastic bottles and use for the analysis of physicochemical parameters. During collection of water samples, bottles were well rinsed using the same water. All the water samples were filtered through Whatman No.1 filter paper to remove unwanted solids and suspended material. After filtration, 3-4 drops of nitric acid were added to the samples to avoid any fungal and other microbial growth. In the laboratory, the samples were kept in a clean, cool and dry place. The locations of the sampling sites have been presented in Fig. 1.

2.4 Analytical Methods

The collected wastewater samples were analysed for various physicochemical parameters, which inclued: pH, electrical conductivity (EC) and total dissolved solids (TDS) were measured within a few hours by using a pH meter (Jenway 3505, UK) and a conductivity meter (SensIONTM+EC5, HACH, USA), respectively. Dissolve oxygen (DO) was determined by Azide modification method, where 2 ml of $MnSO_4$, 2 ml alkali iodide azide and 2 ml of conc. H_2SO_4 were added as outlined by APHA [14]. Biochemical oxygen demand (BOD) was

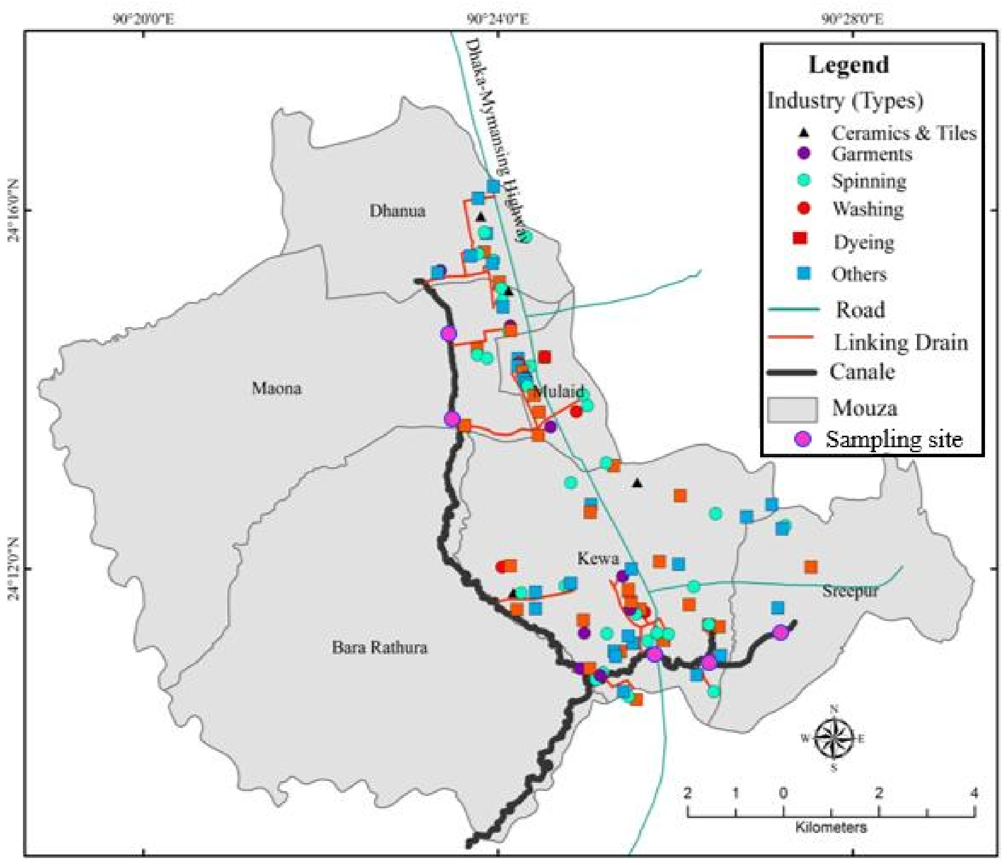

Fig. 1. Distribution of different types of industries and sampling sites in study area

also determined by Azide modification method, where the samples were kept in a BOD incubator at 20°C for 5 days. The differences between 5 days DO and initial DO was treated as BOD of the water sample. Chemical oxygen demand (COD) was measured by close reflux method using COD vials and measured the concentration by means of a photometer as outlined by APHA [14].

3. RESULTS AND DISCUSSION

3.1 Spatial Distribution of Industries

Over the recent years, Sreepur is experiencing immense pressure of new industrial and commercial establishments. But most of the development activities have done indiscriminately violating the extent environmental laws and ignoring overall public convenience. In the absence of any land zoning system or strict monitoring of land use policy both land developers and entrepreneurs are exploiting the farm lands and using those lands for industrial or commercial purposes.

In the study area, industrial densities are high in three unions of Sreepur upazila. Among these three unions, industries are mainly located in five mouzas namely- Sreepur, Kewa, Maona, Mulaid and Danua. Most of the industries were developed along the Dhaka-Mymensingh high way and *Gorgoria Masterbari*-Sreepur road. Major types of industries are textile, dyeing, washing and printing. There were also other types of readymade garments (RMG) industries such as, garments, spinning, sweaters, etc., but they don’t release any liquid waste to the surrounding environment or into the canal.

From Feb-March, 2013, a detailed survey of industries was carried out in the study area. A total of 120 medium to large industries was surveyed in the study area which are shown in Table 1. Among the industries surveyed, 52 were in red category and 53 were in orange-B category and 13 were in orange-A and only 2 were in green category industries (categorised on the basis of ECR [15]). Actual position and type of the major industries are depicted in Fig. 1.

3.2 Development Scenario and Density of Industries at the Study Area

Among the 120 industries surveyed, at least 20 textile dyeing and washing industries were close to the water sampling points. These industries and others also discharge their wastewater to the nearby canal through the pipeline or drain close to each of the sampling points. This pipeline or drain either constructed by the individual industry up to the canal or joined the individual pipeline/drain to a common pipeline/drain by which water ultimately goes to the canal. Different clusters of industries close to the sampling points are shown in Fig. 2. The pipeline or drain networking system so far identified in the field is also shown in Fig. 2 with arrow marks.

It can be seen from Table 1 that till 1995, there were only three industries in the study area. But, the number of industries gradually increased from 1996 and since then to 2005, a total of 29 industries developed, among them 11 was in red category and 18 were in orange - B categories. But, from 2006 to 2010 the number of industries massively increased in the study area. During this time, a total of 59 industries were developed in the study area, which were mostly in red and orange - B category. During this period 30 red category industries established against 23 orange - B category industries. As the survey was done till March 2013, therefore the number of industries from 2011 to March 2013 was not big enough compared to previous time due to the short period of time. This time, a total of 16 industries were developed and among them, 08 industries were in red and 03 industries were in orange - B categories. Therefore, it is a pity to say the study area is now a hub of polluting industries (Fig. 2) which are mostly liable to pollute the environment of the study area. It is to be noted here that out of 120 industries the year of establishment of 13 industries was not known. Most of the industries (49.17%) developed during the period 2006-2010. The majority of the red category and orange-B category industries discharge the liquid waste by their individual pipeline or a common pipeline involving other industries which finally connected to the nearby canal.

3.3 Status of Effluent Treatment Plant (ETP) of the Existing Industries

Among the surveyed industries, 68 needed effluent treatment plant (ETP), but during the survey it was found 45 installed ETP of different capacity and 23 didn’t install ETP. Therefore, about 33% of surveyed industries didn’t have ETP. Installation of ETP has been made mandatory in liquid waste generating industries by the Department of Environment (DoE) and DoE is not supposed to issue any environmental

Table 1. Detailed information about the industrial establishment in the study area (up to 2013)

SL no.	Name of the Industry	Type	Category (according to ECR [15])	Presence of ETP (Yes/No)	Mouza	GPS point	Establishment year	Area in Acre
1	Unilliance Group	Composite	Red	Yes	Sreepur	$24^0$11′39″$90^0$21′59.3″	2008	20
2	Hams Garments Ltd.	Knit composite	Red	Yes	Sreepur	$24^0$11′33.8″ $90^0$27′09.1″	2010	2
3	Aman Textile Ltd.	Composite	Red	Yes	Sreepur	$24^0$11′21.3″ $90^0$26′29.5″	2008	13.2
4	AnwaraMannan Textile Mills Ltd.	Spinning	Red	No	Kewa	$24^0$11′02.1″ $90^0$26′30.4″	2012	11.22
5	Ishraque Spinning Mills Ltd.	spinning	Orange-B	No	Sreepur	$24^0$10′49.1″ $90^0$26′14.3″	2006	36.3
6	Chittagong Denim Mills Ltd.	Denim/ Fabrics	Red	Yes	Kewa	$24^0$11′22.6″ $90^0$26′22.4″	2007	7.26
7	Fakruddin Textile Mills Ltd.	Textile composite	Red	Yes	Kewa	$24^0$11′22.8″ $90^0$26′22.5″	2007	13.53
8	Power Mann Limited	Transformer	Red	No	Kewa	$24^0$11′36.0″ $90^0$26′09.0″	2001	1
9	Fashion Makers Ltd.	Fashion	Green	-	Kewa	$24^0$11′44.1″ $90^0$24′10.3″	2010	1.65
10	Skynet Power Company Ltd.	Textile division	Red	No	Kewa	$24^0$11′48.1″ $90^0$26′12.1″	2008	1.81
11	Denimach Washing Ltd.	Washing	Red	Yes	Kewa	$24^0$11′12.1″ $90^0$25′52.1″	2006	17.82
12	Denimach Ltd.	Oven bottom	Orange-B	No	Kewa	$24^0$11′16.2″ $90^0$25.5′51″	2006	3.96
13	Crystal Industries Pri-vate Bangladesh Ltd.	Sweater, Jumper	Orange A	No	Sreepur	$24^0$11′17.0″ $90^0$25′47.2″	2010	4.68
14	Mita Textiles Ltd.	Spinning/ Yarn	Orange-B	-	Kewa	$24^0$11′17.0″ $90^0$25′47.3″	1992	19.18
15	How Are You Textile Industries Ltd.	Textile	Red	Yes	Kewa	$24^0$11′11.7″ $90^0$25′40.9″	2006	2.8
16	Meghna Knit Composite Ltd.	Knit composite	Red	Yes	Kewa	$24^0$11′10.2″ $90^0$25′31.2″	2006	3
17	Onetex Ltd.	Yarn/ Dyeing	Red	Yes	Kewa	$24^0$11′04.7″ $90^0$25′22.6″	2003	55
18	Eco-Cotton Mills Ltd.	Cotton	Orange-B	-	Kewa	$24^0$11′04.9″ $90^0$25′18.2″	1996	39.6
19	Sabnam Textile Mills Ltd.	Textile	Orange-B	-	Kewa	2401101.5 9002519.3	1996	2
20	Pandora Sweaters Ltd.	Sweater	Orange-B	Yes	Kewa	2401115.0 9002527.9	2005	1
21	Your Fashion Sweater Ltd.	Sweater	Green	-	Kewa	$24^0$11′16.7″ $90^0$25′13.4″	2008	1
22	Welldone Apparel Ltd.	Sweater	Orange- A	-	Kewa	$24^0$11′17.0″ $90^0$24′58.0″	2011	11
23	Perfetti Van Melle Bangladesh Pvt. Ltd.	Candy, Gum	Orange-B	Yes	Kewa	$24^0$10′53.4″ $90^0$24′55.2″	2009	11.38
24	Westeria Textiles Ltd.	Textile	Red	Yes	Kewa	$24^0$10′53.4″ $90^0$25′01.9″	2007	1.23
25	Synergey Textile Ltd.	Textile	Red	No	Kewa	$24^0$10′45.9″ $90^0$25′06.0″	2012	1
26	Integrated Textile Resources Ltd.	Printing	Orange- A	Yes	Kewa	$24^0$10′50.6″ $90^0$25′10.6″	2012	15
27	Dignity Textile Mills Ltd.	Textile	Red	Yes	Kewa	$24^0$10′48.7″ $90^0$25′09.0″	2011	4
28	Argon Denims Ltd.	Denim/ Fabrics	Red	No	Kewa	$24^0$11′25.7″ $90^0$24′57.5″	2008	8
29	Colour and Fashion Industries Ltd.	Sweater	Red	No	Sreepur	$24^0$10′37.9″ $90^0$26′25.7″	2010	2.86
30	Uniglory Cycle Components Ltd.	By-cycle	Red	Yes	Maona	$24^0$10′32.5″ $90^0$25′33.5″	2003	5.61
31	SM Knit Wears Ltd.	Knit composite	Red	Yes	Maona	$24^0$35′35.4″ $90^0$25′27.5″	2000	21.12
32	SM Knitting Industries Ltd.	dyeing	Red	-	Maona	$24^0$10′34.4″ $90^0$25′28.1″	2000	11.68
33	Meghna Cycles Ltd.	By-cycle	Red	Yes	Maona	$24^0$10′37.9″ $90^0$25′24.7″	2010	9.24
34	Aswad Composite Mills Ltd.	Composite	Red	-	Kewa	$24^0$11′48.7″ $90^0$24′45.0″	2008	16.5
35	Shekhor Sweaters	Sweater	Orange-A	-	Kewa	$24^0$11′50.1″ $90^0$24′48.4″	2010	8.25
36	Phoenix Home Textiles Ltd.	Bed sheet	Red	Yes	Kewa	$24^0$11′50.3″ $90^0$24′49.1″	2013	6.6
37	Taqwa Fabrics Ltd.	Knit composite	Red	Yes	Kewa	$24^0$11′44.5″ $90^0$24′25.2″	2009	24.42
38	X Ceramics Ltd.	Tiles	Orange-B	Yes	Kewa	$24^0$11′32.7″ $90^0$24′12.6″	2010	4.95
39	Abcott Industries Ltd.	Cotton (medical)	Orange-B	-	Kewa	$24^0$11′33.3″ $90^0$24′25.2″	2013	13.86
40	Shaharish Composite Towel Ltd.	Home textile	Red	No	Kewa	$24^0$11′43.8″ $90^0$24′15.6″	2012	2.92
41	Knit Horizon Ltd.	Knitting & dyeing	Red	No	Kewa	$24^0$12′01.3″ $90^0$24′02.4″	2011	4.12
42	KSS Knit Composite Ltd.	Knit composite	Red	Yes	Sreepur	$24^0$12′02.1″ $90^0$24′08.1″	2010	4

SL no.	Name of the Industry	Type	Category (according to ECR [15])	Presence of ETP (Yes/No)	Mouza	GPS point	Establishment year	Area in Acre
43	Crown Wool Wear Ltd.	Yarn/ Dyeing	Red	Yes	Maona	24^{0}13′36.1″ 90^{0}23′37.5″	2007	12
44	Yasmin Spinning Mills Ltd.	Spinning	Orange-B	-	Maona	24^{0}12′43.1″ 90^{0}25′02.6″	2001	15
45	SQ Celsius Ltd.	Sweater	Orange-B	Yes	Kewa	24^{0}12′38″ 90^{0}25′02.2″	2002	20
46	Noman Weaving Mills Ltd.	Weaving	Orange-B	-	Maona	24^{0}12′57.7″ 90^{0}24′49.1″	2006	22.37
47	Reedisha Knitex Ltd.	Knit & dyeing	Red	Yes	Dhanua	24^{0}15′32.1″ 90^{0}23′50.5″	2004	33
48	Hongkong Shanghai Manjela	Spinning	Orange-A	-	Dhanua	24^{0}15′31.1″ 90^{0}23′46.4″	1990	14.08
49	Nayanpur Hatchery (Kazi Farms Group)	Hatching	Orange-B	-	Dhanua	24^{0}15′29.6″ 90^{0}23′41.2″	*NK	1.81
50	Confidence Knit Wear Ltd.	Knitting	Orange-A	-	Dhanua	24^{0}15′19.7″ 90^{0}23′20.8″	2011	5.28
51	Salvo Alkali Chemi- cal Industry Ltd.	Chemical	Red	Yes	Dhanua	24^{0}15′18.4″ 90^{0}23′18.9″	2004	7.5
52	Brac Seeds/Feeds	Seed, feed meal	Orange-B	-	Dhanua	24^{0}16′16.0″ 90^{0}23′56.7″	2000	4
53	ML Steel Mills Ltd.	Tubes, Furniture	Orange-B	-	Dhanua	24^{0}16′08.1″ 90^{0}23′46.5″	2010	42
54	RAK Ceramics (Bangladesh)	Tiles	Orange-B	Yes	Dhanua	24^{0}15′56.2″ 90^{0}23′48.1″	2002	7.1
55	RAK Pharmaceu- ticals Private Ltd.	Medicine	Orange-B	Yes	Faridpur	24^{0}15′46.2″ 90^{0}23′51.5″	2008	*NA
56	KEA Printing and Packaging Ltd.	Packaging	Orange-A	-	Faridpur	24^{0}15′44.6″ 90^{0}23′52.1″	2007	2.3
57	Roshawa Spinning Mills Ltd.	Spinning	Orange-B	-	Dhanua	24^{0}15′45.4″ 90^{0}23′50.4″	*NK	8.25
58	Otto Spinning Ltd.	Spinning	Orange-B	-	Faridpur	24^{0}15′26.6″ 90^{0}23′56.9″	1998	2.3
59	M and U Cycles Ltd.	By- cycle	Red	No	Dhanua	24^{0}15′24.5″ 90^{0}23′55.9″	*NK	85.8
60	HA-MEEM Denim	Denim	Red	Yes	Maona	24^{0}15′12.0″ 90^{0}24′00.8″	2007	0.99
61	Century Spinning Mills Ltd.	Spinning	Orange-B	-	Uttarpara	24^{0}15′07.8″ 90^{0}24′02.0″	*NK	6.5
62	MIR Ceramics Ltd.	Tiles	Orange-B	Yes	Uttarpara	24^{0}15′06.3″ 90^{0}24′06.9″	2003	14.85
63	Jaber Spinning Mills Ltd.	Spinning	Orange-B	-	Uttarpara	24^{0}14′58.3″ 90^{0}24′02.2″	2006	0.34
64	Shamsuddin Knitwear Ltd.	Knitting	Orange-A	-	Uttarpara	24^{0}14′59.8″ 90^{0}24′02.9″	2013	*NA
65	Summit Uttaranchal Power Company Ltd.	33 MW Power generation plant	Red	No	Uttarpara	24^{0}14′55.3″ 90^{0}24′03.1″	*NK	*NA
66	Monica Fashion Ltd.	Garments	Orange-A	-	Mulaid	24^{0}14′42.6″ 90^{0}24′08.0″	*NK	9
67	Sufia Cotton Mills Ltd.	Cotton	Orange-B	-	Mulaid	24^{0}14′39.5″ 90^{0}24′07.0″	2000	33
68	Nice Denim Mills Ltd.	Denim	Red	No	Uttarpara	24^{0}14′39.6″ 90^{0}24′08.5″	2013	6.6
69	Zarba Textile Mills Ltd.	Cotton	Orange-B	-	Uttarpara	24^{0}14′26.9″ 90^{0}23′45.7″	2007	13.2
70	Asia Composite Mills Ltd.	Composite	Red	-	Uttarpara	24^{0}14′23.3″ 90^{0}23′45.7″	2006	2.64
71	Ashfaq Textiles Ltd.	Textile	Orange-B	No	Uttarpara	24^{0}14′21.1″ 90^{0}23′52.3″	2002	5
72	Premiaflex Plastics Ltd.	Plastic materials	Orange-B	--	Uttarpara	24^{0}13′29.5″ 90^{0}24′27.1″	2008	6.6
73	Uniglory Cycles Industries Ltd.	By-cycle	Red	No	Mulaid	24^{0}14′20.9″ 90^{0}24′13.4″	2009	1.74
74	Meghna Associates Ltd.	Steel Rim	Red	-	Mulaid	24^{0}14′18.0″ 90^{0}24′14.1″	2012	5.61
75	Ismail Textile Mills Ltd.	Cotton	Orange-B	No	Mulaid	24^{0}14′21.8″ 90^{0}24′31.4″	2008	3
76	Ekota Composite Mills Ltd.	Composite	Red	No	Mulaid	24^{0}14′21.6″ 90^{0}24′31.3″	2000	5
77	Haseen Apparels and Knit Composite	Yarn/ Dyeing	Red	Yes	Mulaid	24^{0}14′15.8″ 90^{0}24′13.1″	2008	2.51
78	Blue Seal Composite Textile	Composite	Red	Yes	Mulaid	24^{0}14′15.6″ 90^{0}24′21.8″	2006	*NA
79	Talha Spinning Mills and Saad-Saan Textile Mills	Spinning	Orange-B	-	Mulaid	24^{0}14′12.3″ 90^{0}24′16.5″	*NK	5.135
80	Siraj Cycles Industries Ltd.	Tire, tube etc.	Red	No	Mulaid	24^{0}14′08.4″ 90^{0}24′18.5″	2010	0.7342
81	Adib Dyeing Ltd.	Knitting/ Dyeing	Red	Yes	Mulaid	24^{0}14′07.0″ 90^{0}24′17.5″	2004	3
82	The Welltex Ltd.	Sweater	Orange-A	-	Mulaid	24^{0}14′04.5″ 90^{0}24′19.2″	2005	9.9
83	Super Meat Ltd.	Meat processing	Orange-B	-	Mulaid	24^{0}14′02.5″ 90^{0}24′19.7″	*NK	1.326
84	Paradise Spinning Mills Ltd.	Spinning	Orange-B	-	Mulaid	24^{0}13′56.2″ 90^{0}24′24.3″	*NK	3.63
85	Anwara Knit Composite Ltd.	Composite	Red	Yes	Mulaid	24^{0}13′45.0″ 90^{0}24′27.7″	2006	0.41

SL no.	Name of the Industry	Type	Category (according to ECR [15])	Presence of ETP (Yes/No)	Mouza	GPS point	Establishment year	Area in Acre
86	Golden Times Swe-ater & Dyeing Ltd.	Sweater and dyeing	Orange-B	No	Mulaid	2401335.2 9002435.4	2009	8
87	Viyellatex Spinning Ltd.	Spinning	Orange-B	-	Mulaid	24^{0}13′56.5″ 90^{0}24′57.4″	2005	4.62
88	Badar Spinning Mills Ltd.	Spinning	Orange-B	-	Mulaid	24^{0}13′49.3″ 90^{0}25′00.3″	*NK	6.6
89	Noman Textile Mills Ltd.	Cotton	orange-B	-	Mulaid	24^{0}13′45.4″ 90^{0}24′52.8″	*NK	1.62
90	ABL Design and Fashions	Knit	Orange-B	Yes	Kewa	*RNT	2006	2.8
91	Greenfield Composite Ltd.	Composite	Red	Yes	Kewa	*RNT	*NK	21.5
92	Great Wall Ceramic Ind. Ltd.	Tiles	Orange-B	Yes	Kewa	24^{0}11′31″ 90^{0}25′39″	2006	15+5.85
93	DIRD Composite Textile	Composite	Red	Yes	Doladia	*RNT	2007	35
94	ACI Formulation Ltd.	Agro- chemicals	Red	Yes	Gojaria	*RNT	1998	10.125
95	Alpha Agro Ltd.	Agro- chemicals	Red	Yes	Atlora	*RNT	2000	4.62
96	FS Sweater Ltd.	Sweater	Orange-B	Yes	Kewa	*RNT	2002	22
97	Nestle Bangladesh Ltd.	Food item	Orange-B	Yes	Baroipara	*RNT	1998	33
98	Paramount Textiles Ltd.	Dyeing	Red	Yes	Gilarchala	24^{0}11′33″ 90^{0}25′36″	2009	*NA
99	Health Care Pharmeceuticals Ltd.	Medicine	Orange-B	Yes	Kewa	*RNT	2000	*NA
100	DaDa Zipper	Dyeing	Red	Yes	Dhanua	*RNT	2008	13.2
101	Padma Paper Mills Ltd.	Dyeing	Red	Yes	Satiabari	*RNT	2008	0.75
102	Organic Health Care Ltd.	Medicine	Orange-B	No	Kewa	24^{0}11′30″ 90^{0}25′33″	2007	4.29
103	Vintage Denim Ltd.	Denim/ Fabrics	Orange-A	No	Gilarchala	24^{0}11′33″ 90^{0}25′29″	2008	26.4
104	Zubair Spinning Mills Ltd	Spinning	Orange-B	-	Gilarchala	24^{0}11′38″ 90^{0}25′30″	2008	2.64
105	Miracle Industries Ltd.	Plastic bag	Orange-B	No	Gilarchala	24^{0}11′45″ 90^{0}25′28″	1993	2.3
106	Bangladesh Master Pack Ltd.	Plastic bag	Orange-B	-	Gilarchala	24^{0}11′46″ 90^{0}25′28″	2007	2.64
107	Package stone Ltd.	Lebel medicine	Orange-B	-	Kewa	24^{0}11′55″ 90^{0}25′24″	2003	2.38
108	Sk Sweaters Ltd	Sweater	Orange-A	-	Sreepur	24^{0}12′00″ 90^{0}25′30″	2012	14
109	Spring Knit Wears Ltd	Sweater	Orange-A	-	Ansar rd.	24^{0}12′05″ 90^{0}25′49″	*NK	3.63
110	Noman Home Textile Mills Ltd.	Fabrics	Red	-	Ansarrd	24^{0}12′03″ 90^{0}26′02″	2009	9.5
111	New Hope Feed Mill Bangladesh Ltd.	Cattle/poultry Feed	Orange-B	-	Bhangnahati	24^{0}12′29″ 90^{0}27′14″	2008	23
112	Nourish Poultry and Hatchery Ltd.	Poultry	Orange-B	-	Patka	24^{0}11′38″ 90^{0}29′28″	2001	2
113	Gentry Pharmaceuticals Ltd.	Medicine	Orange-B	-	Bhangnahati	24^{0}12′27″ 90^{0}27′12″	2013	6.6
114	CRC Textile Mills Ltd.	Yarn	Orange-B	-	Bhangnahati	24^{0}12′35″ 90^{0}26′48″	2008	*NA
115	Markup Cotton (Square Group)	Cotton	Orange-B	-	Ujilabo	24^{0}12′43″ 90^{0}27′05″	2006	13.2
116	Sarah Composite Mills Ltd.	Jute goods	Orange-B	-	Kewa	24^{0}12′37″ 90^{0}26′27″	2012	3.63
117	Nikki Thai Aluminium Industries Ltd.	Alumnium	Red	-	Kewa	24^{0}12′49″ 90^{0}26′03″	2009	5
118	Nakib Spinning Mills Ltd.	Spinning	Orange-B	-	Kewa	24^{0}12′58″ 90^{0}25′34″	2007	8.58
119	MM Spinning Mills Ltd.	Spinning	Orange-B	-	Kewa	24^{0}13′09″ 90^{0}25′18″	2006	40
120	Out Pace Spinning Mills Ltd.	Spinning	Orange-B	-	Kewa	24^{0}13′11″ 90^{0}25′13″	2009	*NA
Total land								**1223.75**

**RNT = Reading Not Taken; *NA = Not Available and *NK = Not Known*

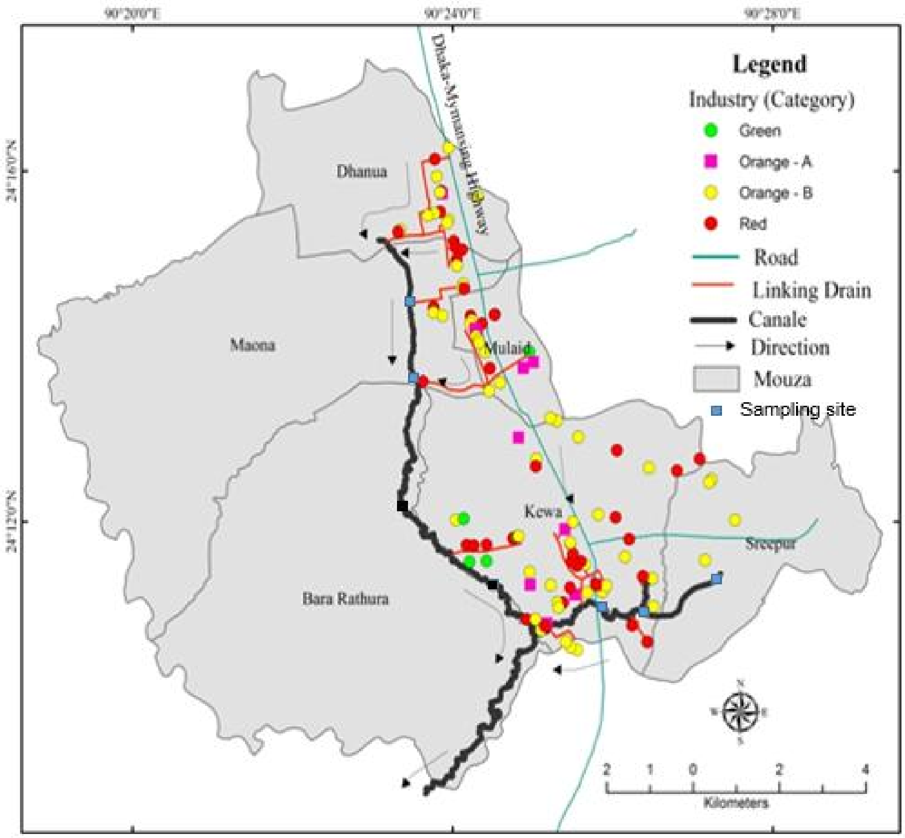

Fig. 2. Cluster of some industries nearby sampling points along with the direction of linking drain/ pipeline

clearances to industries running without ETP. The monitoring team of DoE penalizes the violator following the "polluter pay principle" and DoE also has made a big change in the law through amending the Environmental Conservation Act, 1995 in the year 2010 and also enacted the Environment Court Act, 2010 repealing the Environment Court Act, 2000. Amid these manifold stringent measures there were still many industries without ETP. Although some of the industries have ETP, but either that was not fully functioning or not up to the proper capacity. But there was also a limitation during the survey, it was not possible to see how many industries ETP was fully functional or had optimum capacity.

During the period 13 July 2010 to 29 January 2013 through enforcement drive of DoE some industries of Sreepur area were penalized for non-compliance of environmental rules and regulations. Twelve (12) effluent releasing industries were visited and it was found that four (4) had no ETP and five (5) either had ineffective or closed ETPs. Among the rest of the industries, two were dumping solid wastes on the nearby agricultural lands and the other industry was discharging liquid wastes to the environment without mentioning status of ETP [16]. From the above instances, it can be assumed that in the long run, a good result from the concept of ETP installation can only be ensured by proper monitoring and environmental audit by the government. But, the reality is that the success of this initiative could not be made possible alone by the government, the integrity and sincerity of the industrial owner or the management is most important.

3.4 Physicochemical Characteristics of Wastewater Samples

3.4.1 pH of water sample

Average pH of canal waters for the sites was comparatively high in both pre-monsoon (7.28 ± 0.29) and dry (7.70 ± 0.35) seasons than monsoon season (6.70 ± 0.58) (Table 2). The range of pH was 6.78-7.52 in pre-monsoon season, 6.40-7.30 in monsoon season and 7.30-8.70 in dry season. The higher pH value in pre-monsoon and dry season was because of high base saturation with low volume of water during this period. On the other hand, the pH was slightly low during monsoon season in all sites due to dilution effect. During bleaching and mercerizing processes in textile production processes wastewater produce high pH [17]. The seasonal variation of pH values obtained in this study supports with some other studies. Haque [18] reported that the maximum pH has observed in the winter and minimum in the rainy season.

The pH variation is primarily caused by different kinds of dye stuff used in the dyeing process in different industries. In textile dyeing industries H_2O_2 and NaOH is used as bleaching and kier agents. Higher pH approaches in effluents owing to the waste composition of textile mills such as: NaOCl, NaOH, Na_2SiO_3, surfactants, sodium phosphate [19]. A study conducted by Moniruzzaman et al. [20] on the water of Buriganga river found that the pH of water was slightly alkaline from December to April (7.4 to 7.6) and the highest average pH value found during the month of April (pH = 7.6). This is due to high base saturations with low volume of water during dry season. On the other hand, the pH of water was slightly lower in wet season from June to October (7.3 to 7.4) than dry season due to dilution effect and the lowest average pH value found during the month of August (pH = 7.3). But all these pH values at different times of year were within the permissible limit. Although there was minor seasonal variation in pH, but all the values were within permissible limit of DoE standard for inland surface water (6.0-9.0) and irrigation water (6.5-8.5).

3.4.2 Electrical conductivity (EC)

Electrical conductivity (EC) is an estimate of the total amount of dissolved ions in water. The EC of water is an indicator of salinity and hazard gives the total salt concentration in water [21]. The mean EC value was comparatively high in pre-monsoon (2.64 ± 0.53 ds/m) and dry (1.82 ± 0.66 ds/m) seasons than monsoon season (1.15 ± 0.43 ds/m) (Table 2). The range was 2.16-3.30 ds/m in pre-monsoon season, 0.25-1.8 ds/m in monsoon season and 1.14-2.27 ds/m in dry season. In pre-monsoon and dry seasons EC values in all sites and in monsoon season EC values in two sites were beyond DoE permissible limit (1.2 ds/m). Such a high value of EC is not suitable for aquatic life and irrigation purposes. On the other hand, the EC value was relatively low during monsoon season due to dilution effect, although at three points (1, 2 and 3) EC values were within permissible limit during monsoon season (0.25, 0.77 and 1.2 mg L^{-1}) but in another two points EC (4 and 5) values were beyond permissible limit (1.8 and 1.74 mg L^{-1}). The lower value of EC of three points might be because of upstream site where accumulation of ions was less than downstream points. The sites 4 and 5 were just adjacent to the industrial effluent releasing point. Therefore, the effluent got less time for effect of dilution and it might be another reason of higher value of EC in these two sites. Another reason might be addition of urban or construction wastes as these two sites were located just adjacent to the roadside where some construction activities also occurred. Furthermore, at site 4 there was an end point of municipal drainage line. Through this line, many pollutants also come out which add to the canal water. Apart from the above reasons these two sites were located downstream level. Therefore, accumulation of substances from different upstream flows to the downstream could be the reason of higher values recorded. The higher values of EC recorded indicates that a large amount of ionic substances were released from the different industries in the study area. A difference in the conductivity in effluent, wastewater or surface water is mainly as a result of difference in the concentration of charged solutes [22]. Haque [18] reported that high tide and winter season have shown the maximum values of EC, and low tide and rainy season have shown the minimum value in the Sundarban area.

3.4.3 Total dissolved solids (TDS)

The TDS values were also comparatively higher in pre-monsoon (1380 ± 273.32 mg L^{-1}) and dry season (993.6 ± 253.13 mg L^{-1}). Similar to EC, it was relatively lower during monsoon season (539.58 ± 313.97 mg L^{-1}). The range was 1118-1763 mg L^{-1} in pre-monsoon season, 114.9-809 mg L^{-1} in monsoon season and 601-1286 mg L^{-1} in dry season (Table 2). The higher TDS value in pre-monsoon and dry season was because of high base saturation with low volume of water during dry and pre-monsoon time. On the other hand, the TDS was lower during monsoon season in all sites due to dilution effect. But, TDS during monsoon season in two sites (4 and 5) was comparatively higher than other three sites as the sites were just adjacent to the industrial effluent releasing point. Therefore, the effluent got less time for effect of dilution. Another reason might be the addition of urban or construction wastes as mentioned earlier. Furthermore, at site 4 there was an end point of municipal drainage line. Through this line many pollutants also came out which adds to the canal water. Apart from above reasons, these two sites were located downstream level. Therefore, accumulation of substances from different upstream flows to the downstream, this could be the reason for higher values of TDS. The result supports the studies done by Haque [18], he found that TDS value increased in the order: rainy season < summer < winter. High TDS elevates the density of water, influences osmo-regulation of fresh water organisms and utility of water for drinking and irrigation purposes. Primary sources for elevated TDS level water pollution discharge from industrial and sewage line, particularly during dry and pre-monsoon season with low water level. Textile, dyeing and printing processes release huge amount of suspended solids and dissolved solid which are mixed in the wastewater during desizing, dyeing and printing stages [17,23]. Although there was seasonal variation of TDS, all the values were within permissible limit of DoE standard (2100 mg L^{-1}) of Bangladesh.

3.4.4 Dissolve oxygen (DO)

The average DO values of wastewater samples were 1.61 ± 0.76; 0.74 ± 0.54 mg L^{-1} and trace in pre-monsoon, dry and monsoon season, respectively. The range was 1.11-2.81 mg L^{-1} in pre-monsoon season, 0.14-1.59 mg L^{-1} in dry season (Table 3). Adequate DO is necessary for good quality water. As DO levels in water drops below 5.0 mg L^{-1}, aquatic life is put under stress. The lower the concentration, the greater the stress [24]. DO concentrations in all sampling sites were significantly lower than the DoE permissible limit (4.5-8.0 for inland surface water and ≥ 5 for irrigation water) and unsuitable for drinking, fisheries and irrigation purposes. This may be due to high organic and microbial activities with low volume of water. High amount of organic wastes are discharged from textile and dyeing industries into the canal. The dye effluent disposed into the canal water reduces the depth of penetration of sunlight into the water environment, which in turn decreases photosynthetic activity and dissolved oxygen (DO). From the above DO values, it is clear that the water is completely unsuitable for drinking, fishing and irrigation purposes in all seasons in all sampling sites. This result is at par with the findings reported by Zakir et al. [25] for the Mayur river water of Khulna, Bangladesh. Textiles and dyeing mills of the study area release a huge amount of BOD and COD wastes, which consume the DO of water. In natural waters, DO concentration is greatest at 0^0C and decreases with increasing temperature. Again, solubility of oxygen decreases with increasing salinity of water [26].

3.4.5 Biological oxygen demand (BOD)

BOD is a direct measure of the oxygen uptake in the microbiologically mediated oxidation of organic matter. In other words, it measures the amount of oxygen consumed by an organic compound undergoing decomposition [27]. The BOD average in the study area is relatively higher in pre-monsoon (82 ± 36.93 mg L^{-1}) and dry season (48.8 ± 21.04 mg L^{-1}) than monsoon season (8 ± 5.66 mg L^{-1}). The range was 50-144; 23-71 and 4-12 mg L^{-1} in pre-monsoon, dry and monsoon season, respectively (Table 3). Different steps are followed in the textile processing before the cloth is taken for bleaching- it is subjected to kier boiling to remove natural impurities, such as grease, wax, fats, etc. Chemicals used are caustic soda, soda ash, sodium silicate and sodium peroxide. The effluent water from this process is brown in colour and highly alkaline and high in both BOD and COD [28]. Freeman et al. [23] reported that the major pollution indicator parameters for textile wet finishing effluents were the COD, BOD, TDS, suspended solids (SS), colour and heavy metals levels. Wynne et al. [29] stated that textile effluents are highly coloured and saline, contain non-biodegradable compounds, and are high in BOD and COD. Ahmed et al. [30] reported that tannery and textile industries use organic substances as raw materials and high levels of dissolved organic matter consume large amounts of oxygen and increase BOD level, which undergoes anaerobic fermentation processes leading to formation of ammonia and organic acids. High base saturation with low volume of water during dry and pre-monsoon time was the reason behind to increase the BOD in the study area. On the other hand, the BOD is slightly low during monsoon season due to dilution effect. Overall, the BOD value is higher in all sites in all 3 seasons and beyond DoE permissible limit (4.5-8.0 for Inland surface water, ≤ 10 for irrigation and ≤ 6 for fishing). The determined values were not suitable for irrigation, fishing and drinking purposes, although some farmers of the area use the canal water in their lands for irrigation purposes.

Table 2. pH, EC and TDS of wastewater discharged from industries of Sreepur, Gazipur at different seasons

Site	pH of water					EC of water (dS m^{-1})					TDS of water (mg L^{-1})				
	Pre-monsoon	**Monsoon**	**Dry**	**Mean ±SD**	**Range**	**Pre-monsoon**	**Monsoon**	**Dry**	**Mean ±SD**	**Range**	**Pre-monsoon**	**Monsoon**	**Dry**	**Mean ±SD**	**Range**
1	7.52	7.30	8.70	7.84 ±0.75	7.30 – 8.70	2.96	0.25	2.27	1.83 ±1.40	0.25 – 2.96	1512	115	1286	970.96 ±749.9	115 - 1512
2	6.78	6.60	7.60	6.99 ±0.53	6.60 – 7.60	2.74	0.77	1.95	1.82 ±0.99	0.77 – 2.74	1384	339	1068	930.33 ±535.9	339 - 1384
3	7.31	6.40	7.60	7.11 ±0.62	6.40 – 7.60	2.04	1.20	2.01	1.75 ±0.47	1.20 – 2.04	1123	580	1080	927.67 ±301.9	580 - 1123
4	7.36	6.50	7.30	7.05 ±0.48	6.50 – 7.36	3.30	1.80	1.74	2.28 ±0.88	1.74 – 3.30	1763	855	933	1183.67 ±503.2	855 - 1763
5	7.42	6.70	7.30	7.14 ±0.38	6.70 – 7.42	2.16	1.74	1.14	1.68 ±0.51	1.14 – 2.16	1118	809	601	842.67 ±260.1	601 - 1118
Average	**7.28**	**6.70**	**7.70**	-	-	**2.64**	**1.15**	**1.82**	**-**	-	**1380**	**539**	**993**	-	-
SD	**0.29**	**0.35**	**0.58**		-	**0.53**	**0.66**	**0.43**	**-**	-	**273.32**	**313.97**	**253.13**	-	-
Range	**6.78-7.52**	**6.40-7.30**	**7.30-8.70**	-	-	**2.16-3.30**	**0.25-1.80**	**1.14-2.27**	**-**	-	**1118-1763**	**115-809**	**601-1286**	-	-
Standard (DoE)	**6.0 – 9.0 (Inland surface water) 6.5 – 8.5 (irrigation water)**					**1.2 dS m^{-1}**					**2100 mg L^{-1}**				

Table 3. DO, COD and BOD of wastewater discharged from industries of Sreepur, Gazipur at different seasons

Site	DO of water (mg L^{-1})					COD of water (mg L^{-1})					BOD of water (mg L^{-1})				
	Pre-monsoon	**Monsoon**	**Dry**	**Mean ±SD**	**Range**	**Pre-monsoon**	**Monsoon**	**Dry**	**Mean ±SD**	**Range**	**Pre-monsoon**	**Monsoon**	**Dry**	**Mean ±SD**	**Range**
1	2.81	trace	0.65	1.73 ±1.53	trace - 2.81	469.1	51.0	288.0	269.38 ±209.7	51.0 - 469.1	50.0	trace	42.0	46.0 ±5.7	trace - 50.0
2	1.11	trace	0.47	0.79 ±0.45	trace - 1.11	74.1	56.0	152.0	94.02 ±51.0	56.0 - 152.0	72.0	trace	38.0	55.0 ±24.0	trace - 72.0
3	1.12	trace	0.14	0.63 ±0.69	trace - 1.12	74.1	362.0	271.0	235.69 ±147.2	74.1 - 362.0	60.0	12.0	70.0	47.3 ±31.0	12.0 - 70.0
4	1.08	trace	0.85	0.96 ±0.16	trace - 1.08	98.9	184.0	119.0	133.92 ±44.5	98.8 - 184.0	144.0	4.0	23.0	57.0 ±76.0	4.0 - 144.0
5	1.96	trace	1.59	1.78 ±0.26	trace - 1.96	370.4	109.0	194.0	224.45 ±133.3	109.0 - 370.4	84.0	trace	71.0	77.5± 9.2	trace - 84.0
Average	**1.61**	**trace**	**0.74**	**-**	**-**	**217**	**152.4**	**204.8**	**-**	**-**	**82**	**8**	**48.8**	**-**	**-**
SD	**0.76**	**-**	**0.54**		**-**	**188.35**	**128.83**	**73.44**	**-**	**-**	**36.93**	**5.66**	**21.04**	**-**	**-**
Range	**1.11-2.81**	**trace**	**0.14-1.59**	**-**	**-**	**74.1-469.1**	**51-362**	**119-288**	**-**	**-**	**50-144**	**trace-12**	**23-71**	**-**	**-**
Standard (DoE)	**4.5 – 8.0; ≥ 5 (for irrigation purposes)**					**200**					**≤ 10 for irrigation; ≤ 6 for fishing; ≤ 2 for drinking**				

3.4.6 Chemical oxygen demand (COD)

Average COD value was higher in pre-monsoon season (217 ± 188.35 mg L^{-1}) and dry (204.8 ± 73.44 mg L^{-1}) season than monsoon season (152.4 ± 128.83 mg L^{-1}). The range was 74.0-469.14 mg L^{-1} in pre-monsoon season, 119.0-288.0 mg L^{-1} in dry season and 51.0-362.0 mg L^{-1} in monsoon season (Table 3). COD and BOD are often used to estimate the total quantity of organic matter present in water. Textile industries release a lot of chemical oxygen demanding wastes. The COD levels obtained from garment washing show that detergents, softeners and impurities on the fabrics contributes a significant portion of the COD. The highest COD levels were obtained on dyeing indicating that in addition to fabric impurities removed during scouring or desizing and the contribution of detergents and softeners. Dyes contain high concentrations of salts, and exhibit high BOD/COD values [17]. Among the sampling sites, 1 and 5 sites during pre-monsoon season and 3 site during monsoon season had COD values excessively higher than other. At each of these sites, heavy construction activities were going on during sampling and such activities could contribute different types of pollutants into the canal water which might be the reason of increasing COD. Increase in organic loadings due to construction activities would increase COD and reduce DO levels [31]. According to Firdissa et al. [32], the mean COD value of effluent from selected industries was significantly above the maximum permissible limit value and effluent with high COD load are released from beverage followed by paint, food, soap, tannery, textile and pharmaceutical industry. Sivakumar et al. [33], calculated a ratio of COD:BOD for effluent samples collected from 3 different textile dyeing and bleaching industries, resulting in 1.87, 1.90 and 1.84, respectively. This indicates that these effluents are high in recalcitrant and hardly degradable compounds and may not undergo more than 50% substrate biodegradation, as it is known that organic matter with 50-90% substrate biodegradation has a COD:BOD ratio between 2 and 3.5 [33]. However, on the basis of COD value, the canal water in the study area was not suitable for any domestic uses and also not fit for irrigation purposes.

4. CONCLUSION

This study has explored trend and pattern of industrial growth with spatial distribution of industries and seasonal variations in physicochemical properties of wastewater. A total of 120 medium to large industries was surveyed in the study area of which 52 were in red category and 53 were in orange-B category and 13 were in orange-A and only 2 were in green category. The study revealed that these industries discharge their wastewater into the nearby canal through the pipeline or drain. Number of industries massively increased in the study area during the period 2006-2010 and most of them were in red and orange-B categories. Although installations of effluent treatment plants (ETP) has been made mandatory in liquid waste generating industries by the Department of Environment (DoE), Bangladesh, about 33% of the industries were found to be without ETP. The pH of wastewater collected from the study area was slightly alkaline in pre-monsoon and dry season and near neutral during monsoon season. Average EC values were much higher than DoE standard in pre-monsoon and dry season. TDS value was higher in pre-monsoon and dry season, but comparatively lower in monsoon season although the values were within permissible limit of DoE standard. DO level in wastewater in all seasons was much lower than the DoE standard. BOD and COD values were comparatively higher in pre-monsoon and dry season, and in both seasons average values were much higher than the DoE standard of Bangladesh. Finally, the study results inferred that the area is now a hub of polluting industries which are mostly liable to pollute the surrounding environment. Therefore, to overcome the present situation integrated action plan is necessary. Enforcement and monitoring from the government side alone will not give a concrete solution although political commitment of the ruling government is very important. Thus, action together by the government agencies, non-government organisations and community people will give a fruitful result to make the situation tolerable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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