Characterization and Treatment of Textile Wastewater by Aquatic Plants (Macrophytes) and Algae

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ABSTRACT

Textile wastewater contains large quantities of organic and inorganic compounds, which cause toxic and hazardous pollutants in the environment. Efficacy, efficiency and feasibility of the biological treatment method using macrophytes and algae were investigated, and various physicochemical parameters (TSS, TDS, pH, color, EC, DO, BOD, COD and metal concentration) were also analyzed. In pre-treated sample, TSS, TDS, pH, temperature, DO, BOD, COD, EC and color were recorded as 913 mg/L, 2250 mg/L, 9.4, 41°C, 2.84 mg/L, 358 mg/L, 721 mg/L, 1555 µS/cm and 1347 TCU respectively. As, Cr, Pb and Cu (heavy metals) were observed exceeding the limit stipulated by WHO. COD and the pH reduction was effective in biological treatment with aquatic plants, algae and their combination, but not significant for color removal. *Eichhornia* treatment found most effective in reducing BOD, COD, TDS and TSS. Mixed treatment reduced the pH from 9.4 to 7.5. Both macrophytes and algae exhibited appreciable heavy metal uptake tendency, but *Eichhornia crassipes* was identified as the most effective in heavy metal removal because of its extensive root system. An *Eichhornia* based adsorbent was prepared for removal of color from the wastewater and found to be capable of removing 58% of the color. The investigation erected pathway towards phytoremediation of polluted surface water in lakes and rivers, too.

Keywords: textile effluents, phytoremediation, aquatic macrophytes, algae

INTRODUCTION

Textile is one of the largest and vital industrial sectors of Bangladesh with regard to earn foreign exchange and to engender employment. More than 78% of the total export earning comes from textile and textile-related goods. This sector provides 4.5 million jobs of which 80% are women and contributes 13% to national GDP (Bangladesh Textile Mills Association, 2007).

In Bangladesh, textile industries sector produces a huge amount of sewage which is highly noxious for the environment. In the finishing courses, a considerable amount of wastewater is generated. The industries consume large capacity of water and chemical for wet processes. The quantities of effluent discharged vary from plant to plant depending on the water consumption and the average daily products (Sultana et al., 2009). Textile discharge is disreputably known to contain strong color, a substantial number of suspended solids, an exceedingly fluctuating pH, a high temperature, COD, BOD and so on (Gurnham, 1965). As a result of these pernicious attributes, wastewater treatment is a basic necessity before disposing to natural water framework (Kabir et al., 2002). The process of changing raw fibers into completed apparel and non-apparel textile goods is exceptionally complex,

where most textile plants employ strategies which are not eco-friendly (Hashem et al., 2005). $ZnCl_2$ utilization is an option method leads to the fabric weight increment and in dye uptake and permits easy recovery of NaOH. In addition, the procedure is eco-friendly and does not require neutralization by acetic or formic acid (Karim et al., 2006). In recent years, hypochlorite is being supplanted by other bleaching operators. An ecologically safe alternative to hypochlorite is peracetic acid. It breaks downs to biodegradable oxygen and acetic acid. One of the upsides of peracetic acid is higher brightness value with less fiber loss (Rott and Minke, 1999). Recently, a one-step preliminary process for de-sizing, scouring, and bleaching has lessened the volume of water. The plausibility of a one-step process for de-sizing, scouring, bleaching, and mercerizing of cotton fabric followed by dyeing with direct dyes has been discussed (Slokar and Majcen, 1997). The color arises from chromophore and auxochrome groups in the dyes, which also cause pollution (Azymezyk et al., 2007). The first reported concept of total eco-friendly mordents or natural mordents during dyeing with natural dyes (Padma et al., 2008), were the first to point out that natural dye shades could be developed by a multiple dip method that renders natural dyeing more economical (Deo and Desai, 1999). Dyeing of natural and synthetic fibers with natural dyes has been the subject of numerous investigations. Extension of eco-friendly non-formaldehyde dye fixative agents for reactive dyes was recently reported (Bechtold et al., 2005; Sekar et al., 1995).

On the other hand, biological treatment could achieve greater efficiencies in the decolorization and detoxification of textile wastewater by using native aquatic plants. So, the objectives of the present study were to characterize the textile effluent and to find out an economically and environmental (eco) friendly solution for reducing the toxic effects of textile effluent using aquatic macrophytes and algae (Westhead et al., 2004).

MATERIALS AND METHODS

Collection and Analysis of Effluent Samples

The Abed Textiles Processing Mills Limited at Ghoradia in Narsingdi Sadar, is one of the pioneers of composite textile products in Bangladesh, which process fabrics for print, finish and package products to garments. Sample wastewater was collected from a common central drainage line of the industry where effluents were deposited from all the functional operations. Sampling protocol was followed carefully to inhibit the intrusion of any foreign particles that may affect the results. Sample color was measured by a colorimeter (Hanna: HI93727). The temperature was measured at the time of sample collection and total suspended solids (TSS), total dissolved solids (TDS), dissolved oxygen (DO), electrical conductivity (EC) and salinity was determined by standard equipment (Tufekci et al., 1998). Biological oxygen demand (BOD) and chemical oxygen demand (COD) were determined by 5-day BOD test and closed reflux, titrimetric method, respectively (APHA, 1998). Heavy metals were measured by atomic absorption spectroscopy (Shimadzu, Model-AA6401F AAS).

Collection of Aquatic Macrophytes and Algae

Aquatic macrophytes were collected from the Jahangirnagar University campus lakes and preserved in the artificial pond in Biological Research Division of Bangladesh Council of Scientific and Industrial Research (BCSIR) using tap water at normal temperature and without any nutrient. The inoculum of *Nostoc* was provided by the Biological Research Division.

Methods for Toxicity Testing

The collected effluent sample was taken in a big plastic bowl and settled for three days. After the settlement, the effluent was taken for toxicity testing. The experiments were designed in three sets. In 1st and 2nd sets, each earthen vessel with a dimension of 16" diameter × 10" depth containing four liters of effluent and 3rd set with 30" diameter × 20" depth vessel containing ten liters of effluent were used. Before starting experiment every vessel was washed properly followed by rinsing with effluent. Each treatment had 3 replicas and repeated twice.

Treatment with Macrophytes

The 1st set of experiment was conducted with three types of aquatic macrophytes, *Spirodela polyrhiza*, *Pistia stratiotes*, *Eichhornia crassipes* and one algae (*Nostoc*), taken individually in a separate vessel. The body and root part of the plants were washed to remove sediments and other impurities. Six fresh plants of weight 200-250 gm *Pistia stratiotes* and 50 gm of *Spirodela polyrhiza* (Tiwari et al., 2007), and three fresh *Eichhornia crassipes* plants of weight 400-450 gm were separately used for toxicity test. To evaluate the toxic effect of tannery effluents, 50 gm of fresh algae (*Nostoc*) were taken into a separate earthen vessel. The effluent was shaken by a stick at two to three hours' interval to maintain the equal distribution of algae. In this investigation, 4 cycles of plants were used. The first and second cycle lasted for a day, the third cycle for two days and the last cycle had been continued for three days.
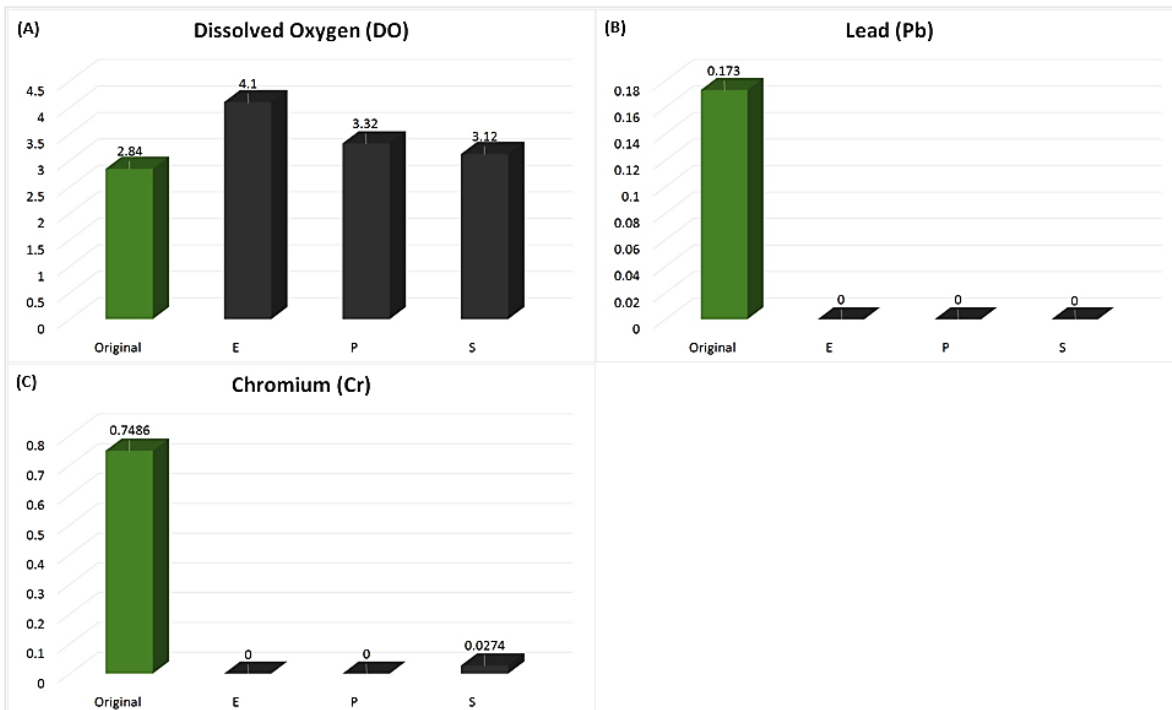
Figure 1. Effect of *Eichhornia, Pistia* and *Spirodela* on three important parameters, (A) DO increase, (B) Pb and (C) Cr reduction, on wastewater

After every cycle, the plants were replaced with fresh plants. Thus, the effluent was kept in exposure to the plants for a total period of seven days.

Combined Treatment with Aquatic Macrophytes and Algae

In the 2nd set of experiment, 3 types of aquatic macrophytes were used separately in combination with algae. Two fresh *Eichhornia crassipes* + 25 gm of *Nostoc*, 3 fresh *Pistia stratiotes* + 25 gm of *Nostoc* and 50 gm of *Spirodela polyrhiza* + 25 gm of *Nostoc* were taken to the treatment vessels.

Mixed Treatment

In the 3rd set of experiment, 3 types of aquatic macrophytes, 2 fresh *Eichhornia crassipes* plants, 3 fresh *Pistia stratiotes* plants, 50gm of fresh *Spirodela polyrhiza* plants were taken along with 25 gm of *Nostoc*, algae in the same treatment vessel. 4 cycles of plants were used.

RESULTS

In the present study, attempts were made to treat the effluent in a biological way which was more environment-friendly, cheap and easy.

Analysis of the Textile Wastewater Characteristics

Physicochemical data of the textile wastewater and permissible limits for parameters in the wastewater from an industrial establishment by World Health Organization (WHO) (WHO, 2002) were presented in **Table 2**. Among the parameters, TDS and TSS were found 2250 mg/L and 913 mg/L respectively, pH and temperature of the wastewater were recorded to be 9.4 and 41°C. DO was found 2.84 mg/L. COD, BOD and EC were found as 721 mg/L, 358 mg/L and 1555 µS/cm respectively. Water anions as phosphate, sulfate and chloride were found as 1.21 mg/L, 207.6 mg/L and 0.006 mg/L respectively, which were within the permissible limit. Metals as Na and K were tested in the sample and were detected within the permissible limit. However, heavy metals as Cr, Cu, Pb and As were observed way beyond the permissible limit. Effects of different macrophytes and algae on different parameters of effluents were presented in **Table 2**.

Effect on Effluent's DO Level

After P, E, N and S treatments, DO levels in the effluent were changed to 3.32, 4.1, 1.38 and 3.12 mg/L respectively. DO levels in the effluent after the combined treatment of EN, PN and SN were 3.08, 2.75 and 2.34 mg/L respectively. In the mixed treatment DO level of effluent was 1.7 mg/L. Maximum 44% increase in DO

Table 1. Comparison of the concentrations of heavy metals in fresh and spent plants

Heavy metal (ppm)	*Eichhornia*		*Pistia*		*Spirodela*	
	Fresh	Spent	Fresh	Spent	Fresh	Spent
Cr	0	1.9087	0	1.2268	0.0314	0.8504
Pb	0.3106	0.3478	0.0628	0.1908	0.0297	0.2569
Fe	15.2776	16.7189	12.2450	15.2992	4.6713	6.6274
Cu	0.2980	0.4486	0.1531	0.9546	0.1684	0.4037
Zn	1.6559	1.6865	1.6215	1.8184	1.579	1.6702
As	0	0.0912	0	0.0736	0	0.0484

Table 2. Effect of different biological treatments on wastewater

	DO (mg/L)	TDS (mg/L)	TSS (mg/L)	EC (µS/cm)	COD (mg/L)	BOD (mg/L)	PO_4^{3-} (mg/L)	SO_4^{2-} (mg/L)	pH	Na (mg/L)	K (mg/I)	Pb (mg/L)	Cu (mg/L)	Fe (mg/L)	Zn (mg/L)	As (mg/L)	Cr (mg/L)	Color (TCU)
Pre-treatmen	2.84	2250	913	1555	721	358	1.21	207.6	9.4	70	4.3	0.173	0.133	0.8419	0.2298	116.4	0.7486	1347
Standard	4.5	2000	500	1200	400	250	5	500	8	200	-	0.1	0.1	10	5	100	0.1	300
P	3.32	1087	779	1531	652	277	1.49	48.8	7.9	60	12.7	0	0.0653	0.3793	0.0019	46.1	0	1340
E	4.1	766	652	1497	519	193	1.93	58	7.6	60	17.3	0	0.1029	0.6157	0.0424	44.6	0	1338
N	1.38	1767	1072	1534	757	394	1.71	98.5	8.4	80	10.1	0	0.114	0.5496	0.0625	25.4	0.1058	1345
S	3.12	1174	829	1629	697	308	0.77	63	7.8	70	17.3	0	0.1076	0.4962	0.0338	33.8	0.0274	1339
EN	3.08	1256	897	2300	638	305	1.54	93.3	7.7	77	18.8	0	0.1055	0.3996	0.0631	63.1	0	1223
PN	2.75	1310	922	2800	653	350	1.49	64.6	8.3	73	10.7	0	0.087	0.3157	0.0118	11.8	0	1248
SN	2.34	1186	927	2370	689	344	1.045	64.5	8.3	80	11.3	0	0.0992	0.2712	0.0201	20.3	0	1230
Mixed	1.7	1185	903	1773	572	339	2.86	94.8	7.5	71	19	0	0.0886	0.3716	0.0526	52.6	0	1216

P: Pistia, E: Eichhornia, N: Nostoc, S: Spirodela, EN: Eichhornia and Nostoc, PN: Pistia and Nostoc, SN: Spirodela and Nostoc and Mixed: mixed treatment

level was affected by *Eichhornia* (4.1 mg/L) on the seventh day (**Table 2**; **Figure 1**) which is slightly incorporated with previous findings (Gidhamaari et al., 2012).

Effect on Effluent's TDS Level

After P, E, N and S treatments, TDS levels in the effluent were changed to 1087, 766, 1767 and 1174 mg/L respectively. TDS levels in the effluent after the combined treatment of EN, PN and SN were 1256, 1310 and 1186 mg/L respectively. TDS level of mixed treatment effluent was 1185 mg/L. The maximum decrease in TDS level was affected by *Eichhornia* treatment (**Table 2**).

Effects on Effluent's TSS Level

After P, E, N and S treatments, TSS levels in the effluent were found as 779, 652, 1072 and 829 mg/L respectively. TSS levels in the effluent after the combined treatment of EN, PN and SN were 897, 922, and 927 mg/L respectively. In the mixed treatment, TSS level of effluent was 903 mg/L. The maximum decrease in the TSS level was affected by *Eichhornia* treatment (**Table 2**).

Effects on Effluent's EC

High EC indicated that a large number of ionic substances like sodium, potassium, iron etc. were present in textile effluent (Kabir et al., 2002). After P, E, N and S treatments, EC in the effluent were detected in 1531, 1497, 1534 and 1629 µS/cm respectively. EC in the effluent after the combined treatment of EN, PN and SN were 2300, 2800, 2370 µS/cm and mixed treatment was 1773 µS/cm respectively. The maximum decrease in the EC level was affected by *Eichhornia* treatment (**Table 2**).

Effects on Effluent's COD

After P, E, N and S treatments, COD in the effluent were found 652, 519, 757 and 697 mg/L respectively. COD in the combined treatment of EN, PN and SN were 638, 653, 689 mg/L and mixed treatment was 572 mg/L respectively. Maximum 28% decrease in the COD was affected by *Eichhornia* treatment (**Table 2**). The COD improvement rate with microflora (biological method) was 69% (Rajvaiday and Markendey, 1998).

Effects on Effluent's BOD

P, E, N and S treatments changed the BOD in the effluent to 277, 193, 394 and 308 mg/L respectively. BOD in the effluent after the combined treatment of EN, PN and SN were 305, 350 and 344 mg/L respectively. Mixed treatment changed the BOD to 339 mg/L. Maximum 46% decrease in the BOD was affected by *Eichhornia* treatment (**Table 2**) whereas (Gidhamaari et al., 2012) the previous report was the bacterial culture improved BOD almost 75% within two weeks from the date of inoculation.

Effects on Effluent's PO_4^{3-}, SO_4^{2-} and Cl^- Level

Phosphate level was within the standard limit in the wastewater sample (1.21 mg/L). After P, E, N and S treatments, the levels in the effluent were recorded as 1.49, 1.93, 1.71 and 0.77 mg/L respectively. And after the

combined treatment of EN, PN, SN and after mixed treatment were 1.54, 1.49, 1.045 and 2.86 mg/L respectively. The maximum decrease in the PO_4^{3-} level was caused by *Spirodela* treatment in the present study (**Table 2**) where others (Sekaran and Mariappan, 1994) reported the efficiency of removal of phosphates was greater in the immobilized condition than free cells of bacteria. Sulfate level was within the standard limit in the wastewater sample (207.6 mg/L) (**Table 2**). After P, E, N and S treatments, levels observed as 48.8, 58, 98.5 and 63 mg/L respectively. After the combined treatment of EN, PN and SN the levels were 93.3, 64.6 and 64.5 mg/L respectively. Mixed treatment changed the sulfate level to 94.8 mg/L. Maximum decrease was observed by *Pistia* treatment. After P, E, N and S treatments, chloride levels in the effluent were found 0.006, 0.02, 0.01 and 0.006 mg/L respectively. After the combined treatment of EN, PN and SN the levels were 0.018, 0.01 and 0.008 mg/L respectively. Mixed treatment changed the level to 0.02 mg/L. Data were not included in the table because chloride level was within the standard limit in the wastewater sample (0.006 mg/L).

Effects on Effluent's pH

Initial pH was found above the standard (6.5 - 8) (**Table 2**). Na_2CO_3, $NaHCO_3$ and $NaOH$ used in the dye and printing process may be responsible for the high pH of the effluent (Ahmed, 2007). After P, E, N and S treatments, pH values of the effluent were detected as 7.9, 7.6, 8.4 and 7.8 respectively. After the combined treatment of EN, PN and SN the values were 7.7, 8.3 and 8.3 respectively. Mixed treatment changed to a maximum decrease of 7.5.

Effects on Effluent's Na and K Level

After P, E, N and S treatments, Na levels of the effluent were found 60, 60, 80 and 70 mg/L respectively. Na levels in the effluent after the combined treatment of EN, PN and SN were 77, 73, 80 mg/L and mixed treatment was 71 mg/L respectively. The maximum decrease in the Na level was affected by *Pistia* and *Eichhornia* treatment. From **Table 2**, it was found that the wastewater sample contained 4.3 mg/L of potassium. After P, E, N and S treatments, K levels of the effluent were found as 12.7, 17.3, 10.1 and 17.3 mg/L respectively. K levels in the effluent after the combined treatment of EN, PN and SN were 18.8, 10.7 and 11.3 mg/L respectively. K level of effluent was 19 mg/L in mixed treatment. The maximum decrease in the K level was affected by *Nostoc* treatment.

Effects on Effluent's Cd Level

No Cd was found in the original sample. After all treatments, Cd levels of the effluent were also found nil, data was not shown.

Effects on Effluent's Pb Conc.

Pb level was beyond the standard limit in the wastewater sample (0.173 mg/L). All treatments showed 0 mg/L Pb level of effluent. So, all the treatments were very effective in removal of Pb (**Table 2; Figure 1**).

Effects on Effluent's Cu Conc.

Table 2, indicated the Cu level which was beyond the standard limit in the wastewater sample (0.133 mg/L). After P, E, N and S treatments, Cu levels of the effluent were 0.0653, 0.1029, 0.114 and 0.1076 mg/L respectively. The Cu levels in the effluent after the combined treatment of EN, PN and SN were also 0.1055, 0.087 and 0.0992 mg/L respectively. Mixed treatment also changed the Cu level of effluent to 0.0886 mg/L. The maximum decrease in the Cu level was affected by *Pistia* treatment.

Effects on Effluent's Fe Conc.

Fe level was within the standard limit in the wastewater sample **Table 2** (0.8419 mg/L). After P, E, N and S treatments, Fe levels of the effluent were found 0.3793, 0.6157, 0.5496 and 0.4962 mg/L respectively. After combined treatment, Fe levels of EN, PN and SN were 0.3996, 0.3157 and 0.2712 mg/L respectively. Mixed treatment showed 0.3716 mg/L of Fe level. The maximum decrease in the Fe level was found in the combined treatment of (*Spirodela + Nostoc*).

Effects on Effluent's Zn Conc.

The Zn level was within the standard limit in the wastewater sample **Table 2** (0.2298 mg/L). Treatment of P, E, N and S showed that the Zn levels of the effluent were 0.0019, 0.0424, 0.0625 and 0.0338 mg/L respectively. Zn levels in the effluent after the combined treatment of EN, PN and SN were 0.0631, 0.0118 and 0.0201 mg/L respectively. Mixed treatment changed the Zn level of effluent to 0.0526 mg/L. The maximum decrease in the Zn level was affected by *Pistia* treatment.

Effects on Effluent's As Conc.

It was observed from **Table 2** that the As level was beyond the standard limit in the wastewater sample (116.4 mg/L). After P, E, N and S treatments, As levels of the effluent were found 46.1, 44.6, 25.4 and 62.2 mg/L

respectively. As levels in the effluent after the combined treatment of EN, PN and SN were 72.5, 56.7 and 75.6 mg/L and mixed treatment was 43.3 mg/L respectively. All treatment decreased the As level but the maximum decrease was observed in the combined treatment of (*Pistia + Nostoc*).

Effects on Effluent's Cr Conc.

Table 2 and **Figure 1**, indicated the Cr level which was beyond the standard limit in the wastewater sample (0.7486 mg/L). Cr levels of the effluent after treatment of P, E, N and S, were found 0, 0, 0.1058 and 0.0274 mg/L and treatment of EN, PN and SN changed to 0, 0 and 0 mg/L respectively. Mixed treatment changed the Cr level to nil. So, except *Nostoc* and *Spirodela* treatment, all the other methods were highly effective in reducing Cr level of the wastewater.

Effects on Effluent's Color

The color level was beyond the standard limit in the wastewater sample (1347 TCU) (**Table 2**). After P, E, N and S treatments, color levels of the effluent were found 1340, 1338, 1345 and 1339 TCU respectively. Color levels in the effluent after the combined treatment of EN, PN and SN were 1223, 1248 and 1230 TCU and mixed treatment was 1216 TCU respectively. So, none of the treatment was able to reduce color effectively from the wastewater.

Heavy Metal Accumulation by Plant

All the plants used in the present study showed a good affinity towards heavy metals.

From **Table 1**, it can be inferred, the plants had no or very small amount of heavy metals as fresh and not exposed to the textile wastewater. But, after the exposure, the concentration increased drastically. In fact, *Eichhornia*, *Spirodela* and *Pistia* were biomagnifying the heavy metals by accumulating those in their body and root systems. This tendency makes these aquatic macrophytes suitable for heavy metal removal from the industrial effluents. However, efficiency and tolerance to a particular type of metal is essential for such application. Nevertheless, *Eichhornia* was found effective in removing most of the heavy metals and showed excellent tolerance against the toxic metals even at high levels. Biological treatment of wastewater is more favorable and cost-effective as compared to other physiochemical methods reported (Metcalf and Eddy, 2003; Haque, 2003).

DISCUSSIONS

For a sustainable economy, industrial growth is mandatory. In Bangladesh, textile sector is one of the largest industrial sectors fetching majority of the foreign currency and generating bulk of the employment opportunities. So, the socio-economic contribution of the textile industries is undeniable. However, it also produces huge amount of effluent which are very toxic for environment. But, due to the environmental concerns, we cannot step back from the process of industrialization. In this study, attempts were made to characterize the textile wastewater and to treat the effluent with biological means.

The major findings of the study were: i) Physicochemical parameters as TSS, TDS, pH, EC, BOD, COD and color were found to be present higher than the limit, stipulated by WHO, ii) Pb, Cu, As, and Cr was found to be present in much higher concentration than the permissible limit, iii) Water anions (phosphate, sulfate and chloride) were found to be present within the permissible limit, iv) Although *Nostoc* decreased Pb, Cu and Fe level in effluent significantly, yet it has been identified unsuitable for application for textile wastewater treatment as it aggrandized COD, BOD and TSS in the wastewater sample, v) *Eichhornia crassipes* was found most efficient in reducing TDS, TSS, EC, and COD & BOD, vi) Mixed treatment was most effective in reducing pH and among the macrophytes and algae; *E. crassipes* was most effective in reducing pH, vii) *Pistia*, *Spirodela*, *Nostoc* and *Eichhornia*, all showed efficacy in removing heavy metals, however, *Eichhornia* was most effective due to its ability to store higher amount of heavy metals than other macrophytes and algae, viii) None of the macrophytes and algae was able to remove color appreciably from the wastewater, ix) *Eichhornia* based adsorbent was found to be capable of removing 58% of color and x) Among the marcophytes (*Eichhornia crassipes*, *Pistia stratiotes* and *Spirodela polyrhiza*) and algae (*Nostoc*) investigated, *Eichhornia crassipes* has been identified most expeditious in the treatment of wastewaters from the textile industries.

In previous studies *Eichhornia crassipes* (Shah et al., 2010; Schneider et al., 1995; Dar et al., 2011), *Pistia stratiotes* (Rodrigues et al., 2017; Lu et al., 2011) and *Spirodela polyrhiza* (Ansal et al., 2010; Li et al., 2017) showed their potentials in phytoremediation of wastewater. In a 2017 review article Mishra and Maiti elaborately discussed the previous findings on the pollutant removal characteristics of *Eichhornia crassipes* (Mishra and Maiti, 2017). *E. crassipes* previously demonstrated the ability to remove silver from industrial wastewater for subsequent recovery with high efficiency in a short time (Pinto et al., 1987). And also, its rapid growth in polluted wastewater and the capacity to absorb heavy metals (Wolverton and McDonald, 1976). Others observed that *E. crassipes* have been used

successfully in wastewater treatment system to improve the water quality by reducing the levels of organic and inorganic nutrients (Brix, 1993; Wolverton and McDonald, 1975). The studied efficacy of *Spirodela polyrhiza* to remove boron from the contaminated water was reported (Davis, 2007; Davis et al., 2002). COD reduced 69% from the textile effluent with the combined treatment of *Nostoc*, *Eichhornia crassipes* and *Pistia stratiotes*. With combined treatment of only *Nostoc* and *Eichhornia crassipes*, COD reduced 65% in glass containers (Roy, 2008; Roy et al., 2010). pH reduction from 11.2 to 8.6, showed the algae can reduce textile wastewater metallic contaminants (Shrivastava and Praksh, 1991). And also, can uptake Al, Cu, Ca, Fe, Mg, Mn, and Zn from dairy manure.

CONCLUSION

The economy of Bangladesh is galloping due to the rapid progress in the textile industries. Industrial pollution is also a by-product of this achievement. The study showed the potential of macrophytes (*Eichhornia crassipes*, *Pistia stratiotes* and *Spirodela polyrhiza*) and algae (*Nostoc*) in the treatment of wastewater collected from textile mills. This was a very cheap, convenient process and may be helpful in phytoremediation of industrial wastewater in different sectors and polluted rivers and lakes of Bangladesh.

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ABBREVIATIONS

BCSIR: Bangladesh Council of Scientific and Industrial Research; TSS: Total suspended solids; TDS: Total dissolved solids; pH: Negative logarithm of hydrogen ion concentration; EC: Electrical conductivity; DO: Dissolved oxygen; BOD: Biochemical oxygen demand; COD: Chemical oxygen demand; mg/L: Milligram per Liter; °C: Degree centigrade; μS/cm: Microsiemens per meter; TCU: True color unit; As: Arsenic; Cr: Chromium; Pb: Lead; Cu: Copper; WHO: World Health Organization; GDP: Gross domestic product; $ZnCl_2$: Zinc chloride; NaOH: Sodium hydroxide; Al: Aluminum; Ca: Calcium; Fe: Iron; Mg: Magnesium; Mn: Manganese; Zn: zinc; gm: Gram; Na: Sodium; K: Potassium; PO_4^{3-}: Phosphate; SO_4^{2-}: Sulfate; Cl^-: Chloride; Na_2CO_3: Sodium carbonate; $NaHCO_3$: Sodium bicarbonate; Cd: Cadmium; ppm- Parts per million.

Ethics Approval and Consent to Participate: Not applicable.

Consent for publication: Not applicable.

Data availability: All relevant data are within the paper.

Competing Interests: The authors have declared that no competing interest exists.

Authors' Contribution: CKR designed the study and carried out all the experiments, analysis, data interpretations. SSR drafted, edited, finalized, revised the article and coordinated to the publisher. MAAJ participated in designing, supervising and coordinating the study. All authors read and approved the final article.

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