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Evaluation of Present and Future Wastewater Impacts of Textile Dyeing Industries in Bangladesh

Laila Hossain†, Sumit Kanti Sarker†, Mohidus Samad Khan[1]

Department of Chemical Engineering, Bangladesh University of Engineering & Technology, Dhaka – 1000, Bangladesh
lailahossain77@gmail.com, sumitsarker1@gmail.com, mohid@che.buet.ac.bd

†Equally first author: both authors contributed equally

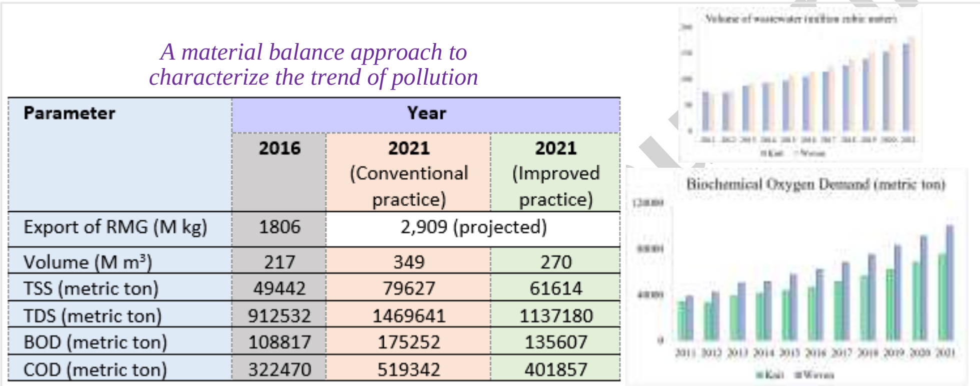
Abstract

The textile sector has been an important part of Bangladesh's (BD) economy over the past few decades. In Bangladesh, the textile sector currently has an export value of nearly 28 billion USD per year which contributes about 82% of the country's total export earnings. It is projected that the annual ready-made garment (RMG) export value will be about 50 billion USD per year by 2021. However, the growth of Bangladeshi RMG sector is associated with different environmental issues, mostly caused by wastewater generated by textile industries. Textile industries consume high volumes of water per unit fabric for processing, which cause depletion of ground water levels at a high rate. In addition, in many cases textile effluents are discharged into rivers or wetlands without proper treatment. Untreated textile effluent can contaminate groundwater and waterbodies, reduce dissolved oxygen in water and affect aquatic ecosystems which may indirectly cause climate change. Improving conventional technology, adopting cleaner production (CP) options, the reusing and recycling of treated water may reduce water consumption, effluent volume and water stresses, and may help preserving aquatic ecosystems. However, additional investments, lack of technological knowhow, and awareness are factors limiting the adoption of cleaner production options. In order to take effective measures for future improvement it is important to develop a nationwide wastewater impact tracking system. In this study, a material balance approach has been developed to characterize the trend of pollution impacts (2011-2021) associated with the textile dyeing industries of Bangladesh. It is estimated that in 2016 textile industries in Bangladesh produced about 1.80 million metric tons of fabric, which generated around 217

[1] Dr. Mohidus Samad Khan
Assistant Professor
Chemical Engineering Department, BUET
Dhaka-1000, Bangladesh
Email: mohid@che.buet.ac.bd

million m^3 of wastewater (2016) containing a wide range of pollutants. It is projected that wastewater production will reach 349 million m^3 by 2021 if the textile industries continue using conventional dyeing practices. Gradual adoption of improved technology and cleaner production options could reduce wastewater volume by around 23% by 2021. This projection will help policy makers to take necessary mitigation measures for treatment and pollution management. This analysis will also provide a baseline scenario and open new opportunities for textile engineers and environmentalists to develop innovative technologies for textile dyeing and effluent treatment.

Graphical abstract


A material balance approach to characterize the trend of pollution

Parameter	Year		
	2016	2021 (Conventional practice)	2021 (Improved practice)
Export of RMG (M kg)	1806	2,909 (projected)	
Volume (M m³)	217	349	270
TSS (metric ton)	49442	79627	61614
TDS (metric ton)	912532	1469641	1137180
BOD (metric ton)	108817	175252	135607
COD (metric ton)	322470	519342	401857

Keywords: textile; pollution load; wastewater impacts; untreated effluent

1. Introduction

The ready-made garment (RMG) industry occupies a unique position in Bangladesh's (BD) economy. It is the largest exporting industry in Bangladesh, having experienced phenomenal growth in last few decades (Hasan et al., 2016). The sector creates about 4.2 million employment opportunities and contributes significantly to national GDP (Gross Domestic Product) (Kiron, 2015) being the world's second largest exporter of clothing after China (Islam et al., 2013). Bangladesh textile industries currently have an annual export value of nearly 28 billion USD. It is expected that the annual RMG export value will be about 50 billion USD by 2021. Considering future projections, government, international brands, and policy makers are putting pressure on local industries to adopt cleaner production options to improve productivity and reduce pollution loads. Table 1 shows the RMG sector export statistics of Bangladesh over the last ten years (2006-2016).

Table 1: RMG sector export statistics of Bangladesh (Bangladesh Garment Manufacturers and Exporters Association, 2017a).

The textile manufacturing sector is the major industrial water user in Bangladesh. Despite significant economic contributions, Bangladesh textile industries cause a range of environmental problems, mostly the pollution of water resources (Ahmed and Tareq, 2008, Khan et al., 2011). Textile wastewater contains various chemicals such as oil, grease, caustic soda (NaOH), Glauber salt (Na_2SO_4), ammonia (NH_3), sulfide (S^{2-}), lead (Pb), heavy metals and other toxic substances (Islam et al., 2012). Typical characteristics of wastewater produced by the textile industry include high temperature, a wide range of pH values, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), heavy metals and strong pigment (Rott and Minke, 1999, Dey and Islam, 2015, Nergis et al., 2009, El-Gohary et al., 2010, Nabil et al., 2017). Key characteristics of wastewater produced from various stages during manufacturing process in textile industry are shown in Figure 1.

Figure 1: Components of major pollutants involved in various stages of a textile manufacturing industry (figure inspired from references (Arumai Dhas, 2008, Yusuff and Sonibare, 2004, Khan et al., 2006, Nabil et al., 2017).

High volumes of textile wastewater may cause alteration of physical, chemical, and biological properties of the aquatic environment, and could be harmful to public health, livestock, wildlife, fish and other biodiversity (Sultana et al., 2009, Islam et al., 2012). Under the 'Bangladesh Environment Conservation Act (ECA, 1995)' and 'Environmental Conservation Rules (ECR 1997)', textile dyeing industries are categorized as "Red industries", that must treat and monitor the wastewater quality conforming to national discharge quality standard (Sharif and Hannan, 1999, Huq, 2003, Environmental Conservation Rules, 1997). Despite having environmental regulations to control industrial pollution, lack of effective enforcement has jeopardized environmental quality (Haque, 2017). It is reported that in many cases, industrial effluents are discharged into nearby rivers or wetlands without proper treatment (Ali et al., 2010). High temperature wastewater discharged into rivers may increase the temperature of the water body, which in turn can affects flora and fauna (Joshi and Santani, 2012, Kanu and Achi, 2011). Untreated toxic efflluents have a severe deleterious effect on the quality of groundwater (Kasthuri et al., 2007). In addition, high volumes of untreated textile effluents cause a high 'grey water' footprint and increase water stress, which may instigate quick changes in aquatic ecosystems and influence the climate (Nevill et al., 2010, Franke and Mathews, 2013)potentially having high economic impacts on the fisheries sector (Brander, 2007, Vivekanandan et al., 2016).

Table 2 summarizes the typical values of major pollution loads of textile industries and DoE and BSR standards for wastewater discharge into inland surface water bodies (Khan et al., 2011, Department of Environment, 2008, Business for Social Responsibility, 2010).

Table 2: Typical values of major pollution loads of textile industries, DoE standards and BSR standards for wastewater discharge into inland surface water bodies (Business for Social Responsibility, 2010, Department of Environment, 2008, Khan et al., 2011).

Considering current and future environmental impacts, it is important to develop a database indicating wastewater impacts, growth rate and future projections of textile industries to plan effective measures to address environmental issues related to the Bangladeshi textile sector. In this study, a methodology based on material balance approach is developed to characterize present trends and future projections of pollution impacts associated with Bangladesh textile dyeing industries; future pollution load is calculated by considering existing dyeing practices as well as the possible adoption of cleaner production options. This database will help industries and policy makers to plan for environmental measures and regulations in coming years. This study will be also useful in water footprint calculation, and in the analysis of pollution loads resulting from other major industries.

2. Methodology

In this study, the production volume of textile product is calculated from export data and a projection of the production trend is made to calculate future wastewater impacts. Water Key Performance Indicator (KPI) was analyzed to determine annual textile effluents and project wastewater volume. Finally, pollution load associated with production is calculated for both conventional and improved technologies

2.1. Production Volume Calculation

Based on product price and weight, production volume was calculated from export data and a projection of a production trend was made. Export data for different types of RMG products were collected from the BGMEA database (Bangladesh Garment Manufacturers and Exporters Association, 2017b). It is assumed that local industries export 95% of their products to foreign countries, and the rest (5%) is consumed in the local market. To calculate production volume, the weight and export price of RMG products were analyzed (Table 3). Considering the high volume of shirt, T-shirt, trouser and sweater production in the Bangladeshi RMG industries, the average price and average weight considered for this study were 5 USD and 300 gram, respectively.

Table 3: Textile product price and weight analysis.

Export data from Bangladeshi textile industries from 2006 to 2016 were analyzed (Table 1), and a 10% annual growth was considered to project textile production from 2017 to 2021. Considering conventional dyeing practice, economic growth and RMG export projection by 2021, it was assumed that wastewater and pollution load caused by the textile dyeing industries would also increase by 10% per year starting from 2016.

2.2. Key Performance Indicator (KPI) Analysis

In this study, water consumption and production data were collected from nine textile industries situated in different zones of Bangladesh (Table 4). These industries have water flow meters installed in the production floors that track water consumption. Production data from six months from the factories were analyzed to calculate KPI (120 L/kg) (Table 4).

Table 4: Water KPI analysis of textile industries.

2.3. Material Balance Approach

The RMG manufactured in Bangladesh can be broadly classified into two categories: woven products and knitted products. Woven products include shirts, pants and trousers. Knitted products include T-shirts, polo shirts, undergarments, socks, stockings and sweaters (Murad Fabrication, 2016).

To calculate the wastewater impacts of textile industries, a material balance approach was applied, in which the production data of RMG industries, production growth rate, and water key performance indicator (KPI) were considered. Effluent characteristics presented in Table 5 were used to calculate present and future pollution load. Effluent characteristics were finalized by analyzing experimental studies and data from previous work (Department of Environment, 2008, Khan et al., 2011) (experimental results and techniques are included as supplementary information). Figure 2 shows flow charts of the methodology and material balance approach undertaken to calculate the textile wastewater volume and pollution load.

Table 5: Textile pollution load and considerations to calculate wastewater output.

Figure 2: Flow charts to calculate textile wastewater volume and pollution load. (a) Overall flow diagram of the methodology, (b) Material balance approach.

2.4 Cleaner Production (CP) options to reduce water KPI

In recent years, to conserve water and to reduce water consumption in RMG production, the government, funding agencies, international brands and industry managements have been considering cleaner production options for textile industries (Partnership for Cleaner Textile, 2017, International Textile Manufacturers Federation, 2014). These include installation of dyeing machines of low liquor ratio, reduction of process steps, reusing dye liquors, electrolytes and cooling water, counter current washing, good housekeeping, etc (Kar, 2012). Researchers have reported that adopting improved technologies and cleaner production options could reduce the KPI to 0.3-0.1 m^3/kg fabric (Ferdous, 2011). Local industries are slowly adopting cleaner production options. However, additional investments, and lack of technological knowhow and awareness are the key limiting factors in the adoption of cleaner production options. It is anticipated that existing and new textile dyeing industries will adopt cleaner production options in the upcoming years; therefore, it is expected that the overall KPI of textile dyeing industries will reduce every year. According to the report of the Bangladesh Partnership for Cleaner Textile (PaCT) program, 29 PaCT partner factories successfully managed to reduce their water KPI by around 27% in about five years by implementing best production practices (Bangladesh PaCT, 2017). Therefore, for projection considering more water efficient technologies, it is assumed that for 2017-2021, water KPI will reduce by 5% per year (in 2016, the baseline KPI is considered 0.12 m^3/kg fabric).

Implementation of cleaner production options reduce water consumption as well as pollution loads which in turn reduce the total cost associated with textile processes (Nhan, 2005). By improving chemical storage (annual cost saving: $81595) and reducing re-shading and re-dyeing (annual cost saving: $90946), a textile factory of 1000 ton per year capacity can save up to $172,500 USD per year (Ahmed et al., 2006), and will reduce chemical consumption and pollution load. In this study, it is considered that implementation of cleaner production will reduce effluent volume without increasing the pollution load.

3. Results

Figure 3 and Figure 4 present actual and projected textile production from 2011 to 2021, and corresponding wastewater volume generated by textile dyeing. For the textile production analysis from 2011 to 2016, available production data from textile industries from 2011-2016 were considered (Bangladesh Garment Manufacturers and Exporters Association, 2017b); 10% annual growth was considered to project textile production from 2017 to 2021. To calculate corresponding wastewater volume produced by textile dyeing industries, a KPI of 0.12 m^3/kg fabric was considered for conventional dyeing technology.

In a more optimistic scenario, it is anticipated that textile industries will gradually adopt developed and more water efficient dyeing technologies, which will reduce generation of wastewater volume and corresponding pollution loads; gradual adoption of improved technology and cleaner production options are assumed to reduce KPI by 5% per year from 2017.

Figure 3: Trend analysis of annual textile production in BD (2011-2021).

Figure 4: Yearly wastewater volume produced by textile industries using conventional dyeing technology.

Figure 5: Projected wastewater volume generated by textile dyeing industries for improved KPI (year 2017-2021); assuming textile dyeing industries will gradually adopt improved technologies and cleaner production options.

Figure 3 shows that by 2021 total production will be around 2.9 million metric tons of fabric, which is about 1.61 times the amount of fabric produced in 2016. Such a large increase in production will generate about 349 million m^3 of wastewater (2021) (Figure 4) for conventional KPI (0.12 m^3/kg fabric). From linear interpolation, it can be said that in 2021 effluent volume and pollution load generated by textile dyeing industries will be 1.61 times higher than those of the year 2016.

Adoption of improved technologies and cleaner production options will improve KPI and reduce wastewater generation (Figure 5). In 2021, the KPI is expected to reduce to 0.093 m^3/kg fabric; therefore, effluent production by textile dyeing industries will be reduced to 270 million m^3, which is 22.6% less than the effluent volume for conventional KPI. Considering the linear relationship, adoption of improved technologies is expected to reduce the pollution load by 22.6% by 2021.

Pollution loads of 2011-2021 corresponding to textile dyeing industries (Figures 6-7) were calculated considering wastewater characteristics presented in Table 5. Figures 6 and 7 present the annual pollution loads generated by textile dyeing industries following conventional dyeing practices and improved practices, respectively.

Figure 6: Annual pollution loads caused by textile industries following conventional practices; (a) TDS, (b) TSS, (c) BOD, (d) COD.

Figure 7: Annual pollution loads caused by textile industries after adopting improved practices; (a) TDS, (b) TSS, (c) BOD, (d) COD.

Total dissolved solids (TDS) in textile dyeing effluent include various salts like chloride, phosphates, carbonates, bicarbonates and nitrates of calcium, organic matter, sodium, potassium, magnesium and manganese, and other particles (Vaishali and Punita, 2013). Water with high TDS is unpalatable and potentially harmful for health and the environment (Hussain and Rao, 2013). In 2016, the calculated TDS produced by knit and woven dyeing effluents were 280,399 metric ton and 632,133 metric ton, respectively (Figure 6a). It is projected that in 2021, TDS for knit and woven dyeing effluent will be 451,585 metric ton and 1,018,056 metric ton (Figures 6a), respectively. It is expected that with improved KPI, TDS for knit and woven dyeing effluent will be reduced to 349,428 metric ton and 787,752 metric ton (Figure 7a), respectively.

Total suspended solids (TSS) of textile effluent include various types of materials suspended in the water. Suspended solids can lead to sludge deposits and anaerobic condition when untreated wastewater is discharged in the aquatic environment. In 2016, TSS produced by knit and woven dyeing effluent was 49,442 metric ton (Figure 6b), whereas, in 2021, the values will be 79,627 metric ton for existing KPI (Figure 6b), and 61,614 metric ton for improved KPI (Figure 7b), respectively.

Biochemical Oxygen Demand (BOD) is a measurement of the amount of dissolved oxygen (DO) that is used by aerobic microorganisms when decomposing organic matter is present in water. It is an important water quality parameter since it provides a biological index to assess the effect of discharge water on the environment. Higher BOD value causes depletion of dissolved oxygen in aquatic life. In 2016, BOD produced by knit and woven dyeing effluent was 108,817 metric tons (Figure 6c), whereas, in 2021, the values will be 175,252 metric tons for existing KPI (Figure 6c), and 135,607 metric tons for improved KPI (Figure 7c), respectively.

Chemical oxygen demand (COD) is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals, such as ammonia and nitrite. It is also a measure of water and wastewater quality. In 2016, the COD value for knit and woven dyeing industries was 405,254 metric tons (Figure 6d), whereas, for 2021, the predicted value will be 519,342 metric ton for existing KPI (Figure 6d) and 401,857 metric ton for improved KPI (Figure 7d).

4. Discussion

Rivers and water bodies near the textile industrial zones in Bangladesh (such as Dhaka, Narayanganj and Gazipur) are the major receivers of the untreated effluents discharged by textile industries. A large number of villages in Gazipur and D.N.D (Dhaka-Narayanganj-Demra) Embankment are now being threatened by environmental degradation caused by textile effluents (Bhuiyan et al., 2011). According to a recent study, textile industries near the Shitalakkhya River discharge their untreated dye with heavy metals into the river (Islam et al., 2015). By consuming and using this polluted water for bathing, washing and household work the marginal people who are living on the bank of the Shitalakkhya River, especially children, are prone to different types of pollution associated diseases, viz. nausea, skin sores, irritation of the respiratory tract (Sultana et al., 2009), typhoid, dysentery, cholera, viral hepatitis, etc. and in severe cases loss of life (Islam et al., 2015).

Textile industries consume high volumes of water per unit of fabric for production, which may cause depletion of ground water levels (Sagris and Abbott, 2015) (Anas, 2015). It has been reported that in Dhaka city, ground water levels have dropped by more than 200 ft over the last 50 years and these levels continue to decline at a high rate (Roberts, 2016). Groundwater helps supporting overlying rock and soil; once the water table drops, there might be a gradual settling of the land, a phenomenon known as land subsidence (Sah, 2001). Groundwater extraction by the textile industries threatens both the quality and quantity of drinking water available to the residents of Dhaka (Kar, 2012). Inconsistent rainfall caused by climate change, and excessive groundwater extraction may increase the salinity of ground water and soil (Qureshi et al., 2010), and further affect aquatic ecosystems and reduce the productivity of crops and aquatic life Moreover, any increase of salinity in water caused by excessive groundwater extraction may cause high blood pressure, heart disease, and heart failure in humans if the water is consumed (Strazzullo et al., 2009).

Effluents from textile industries with high nutrient concentration may result in eutrophication, which interferes with drinking and recreational water supplies (Panswad et al., 2016). The situation may worsen if pollution continues at its current rate. The current study shows that wastewater volume increased around 49% (Figure 6); as a consequence, TSS and TDS caused by textile effluents increased around 53%, and BOD and COD increased around 50% from 2011 to 2016 (Figure 6). From extrapolation of these trends, it can be predicted that by 2021 textile dyeing industries will produce 2.4 times more effluent than that produced in 2011 (Figures 4).

Adoption of improved technologies and cleaner production options will reduce water consumption and effluent volume for textile industries (Figures 5 and 7). Table 6 presents a comparison of present and future effluent loads of the textile dyeing industry. Table 6 shows that effluent water and pollution load decreases by around 22.6% if improved practices are considered by the textile industry. Reduction of water consumption will reduce the amount of water extracted for textile operations, which will consequently reduce the risk of groundwater depletion for textile operations in the country. Adoption of improved practices is also financially beneficial as pumping cost and chemical cost will be reduced for reduced amount of water and chemicals (Nhan, 2005, Ahmed et al., 2006).

Table 6: Comparison of present and future annual wastewater impacts of textile dyeing industries.

Researchers have reported that toxicity of TDS influenced by the ionic composition of water can affect fish and aquatic organisms. High TDS level (few hundred to few thousand ppm) in water caused by NaCl, Na_2CO_3, $NaHCO_3$, Na_2SO_4, and other ions (K, Li, Mg, Mo, etc) can affect fertilization, hatching, growth and longevity of Salmonidae fish populations (trout, char, salmon, grayling, whitefish, etc.) (Weber-Scannell and Duffy, 2007). Implementation of cleaner production will reduce TDS in textile effluent. However, further study will be required to understand the qualitative and quantitative effects of TDS concentrations in textile effluents on local freshwater fish species (e.g. sliver carp, rohu, katla, spiny eel, gangetic alia, catfish, carplet, climbing perch, goonch, reba, stripped loach, perchlet, etc.).

High concentrations of BOD and COD reduce the dissolved oxygen concentration in water bodies, which may result in fish mortality and changes in species composition, in the long run (Akpor and Muchie, 2011).

Untreated wastewater may also cause bioaccumulation of contaminants, which is the gradual accumulation of organic or inorganic contaminants into the living tissues of plant and animals from their environment. Bioaccumulation occurs when a contaminant is taken up by organisms faster than their bodies can break it down or eliminate it. Polluted water may also cause biomagnification of contaminants (Chambers and Mill, 1996).

The pH value of textile wastewater varies from 3.9 to 14 (Dey and Islam, 2015). High pH tends to facilitate the solubilization of ammonia, heavy metals and salts, whereas low pH tends to increase carbon dioxide and carbonic acid concentrations; pH values below 4.5 and above 8.5 can be lethal to aquatic life (Ministry of Environment, 1998).

Textile wastewater temperature can be as high as 65ºC. High temperature of effluents can increase the temperature of water bodies they are discharged into and reudce the level of dissolved oxygenthereforeleading to loss of biodiversity.

Inland water bodies affect climate at the regional scale through exchange of heat and water with the atmosphere (Krinner, 2003). In addition, they play a substantial role in the global carbon (C) cycle and thus potentially affect climate as well (Cole et al., 2007). Therefore, untreated textile effluent polluting inland water bodies may contribute to climate change and global warming. Groundwater pollution may cause low-yield of agricultural products and death of useful plants, which may in turn result in the import of food crops to meet the demand. Low-yield and high import will increase both the water and carbon footprint, and hence will affect the climate and ecosystems (Weber and Matthews, 2007).

To continue growth in the textile sector by addressing growing environmental issues it is important to ensure strict application of environmental regulations, and to introduce new technologies for textile processing and waste management, which are environmentally friendly and cost effective. One of the most successful inventions in recent years is waterless dyeing in the textile industries. In this technology, air or compressed CO_2 is used as dyeing medium instead of water (Dhanabalan, 2015). As a result, the amount of water use can reduce drastically, almost close to zero. However, these new technologies are expensive, cloth specific and can only be used for polyester. Therefore, further technological advancement is required to introduce less expensive techniques for a wide range of fabric. In addition, effective treatment of wastewater, followed by the reuse and recycling of treated effluent will reduce groundwater extraction and the associated water footprint, and will help to restore aquatic ecosystems (Hu and Cheng, 2013).

5. Conclusions

Textile production is the largest manufacturing sector in Bangladesh. The growth in this sector, and other small and medium scale enterprises, undoubtedly has a positive effect on national economic development; however, there are also environmental concerns. Effluent from textile industries is a major source of environmental pollution. In this study, the past trend (2011-2016) and future projection (2017-2021) of pollution impacts associated with the Bangladesh textile dyeing industry was developed by analyzing yearly RMG export data, RMG production growth rate, and pollution loads for textile dyeing industries. It is estimated that by 2021, BD textile industries will produce around 2.9 million metric tons of fabric, which will generate about 349 million m^3 of wastewater. Considering conventional key performance indicator (KPI), 349 million m^3 of wastewater will contain about 1,469,641 metric ton of TDS, 49,442 metric ton of TSS, 175,252 metric ton of BOD and 519,342 metric ton of COD. It is important to understand the effects of the TDS, BOD, and COD on the biological diversity of local rivers and wetlands; and this requires systematic research. To reduce water extraction, water footprint and water stress, it is vital to treat textile effluents, implement cleaner production options, introduce waterless dyeing technologies, and reuse the treated water. This study will serve as a baseline to help the Government, funding agencies, industry management and technologists to analyze the wastewater impact of increased textile production, and to develop environment friendly dyeing practices and technologies.

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List of Figures

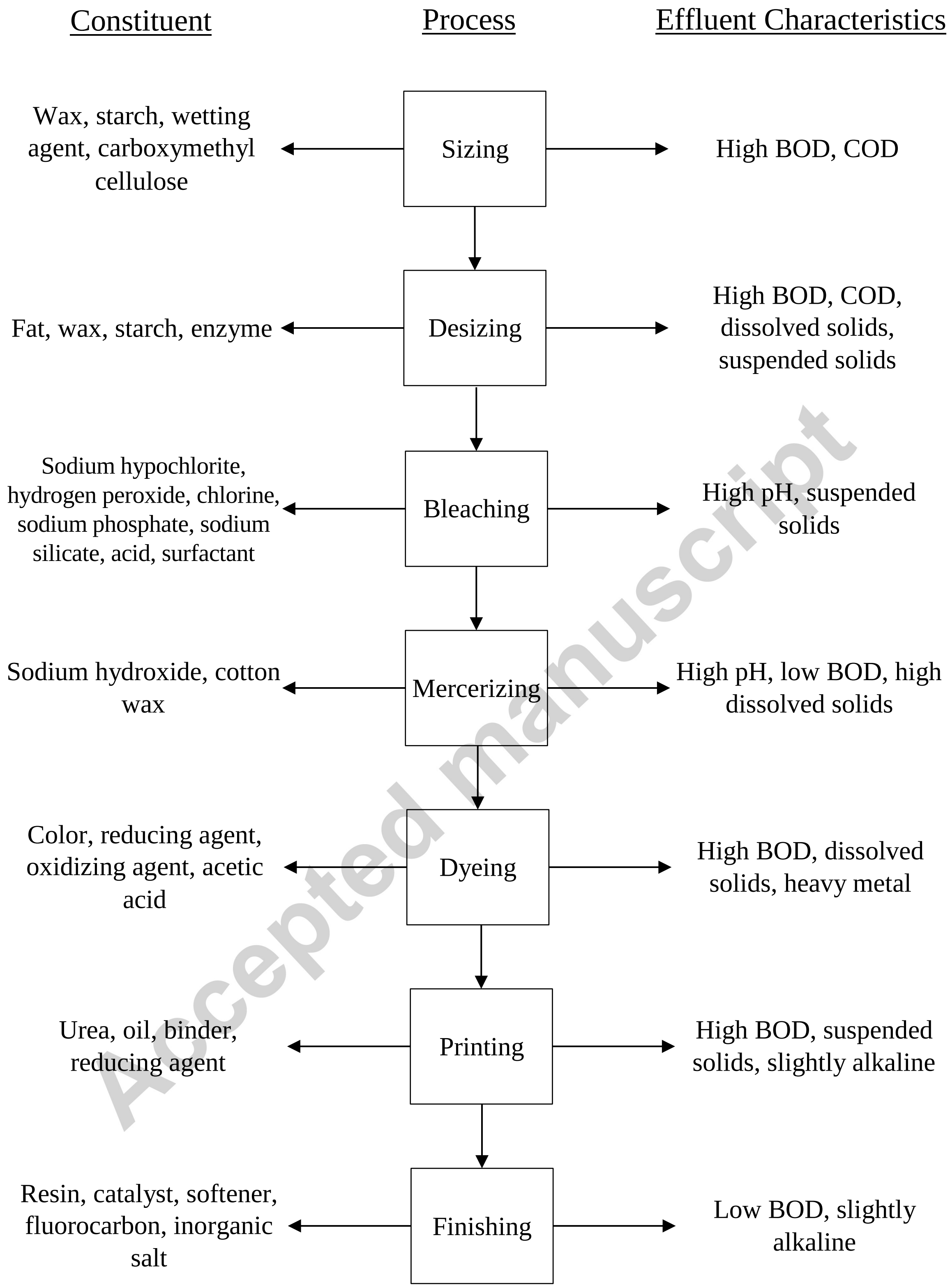
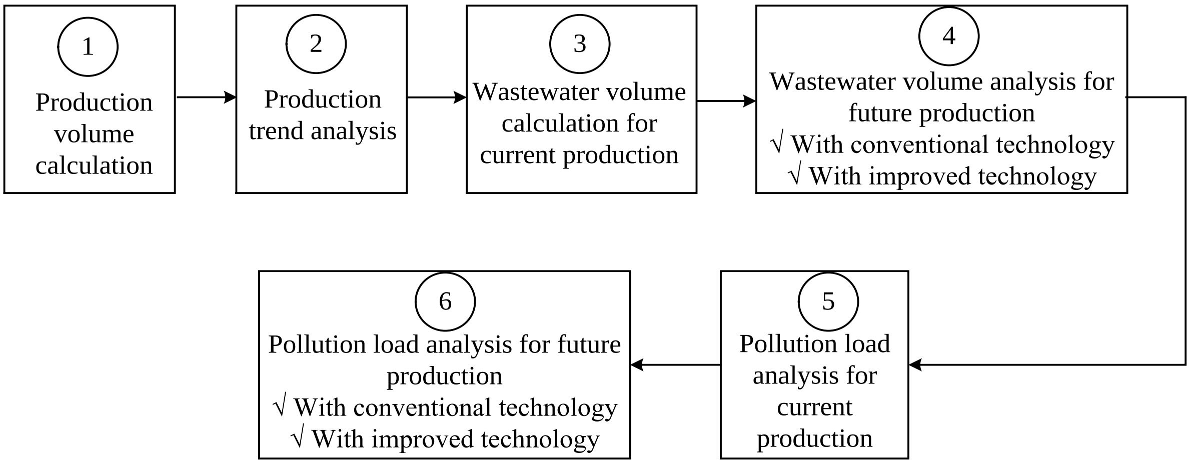
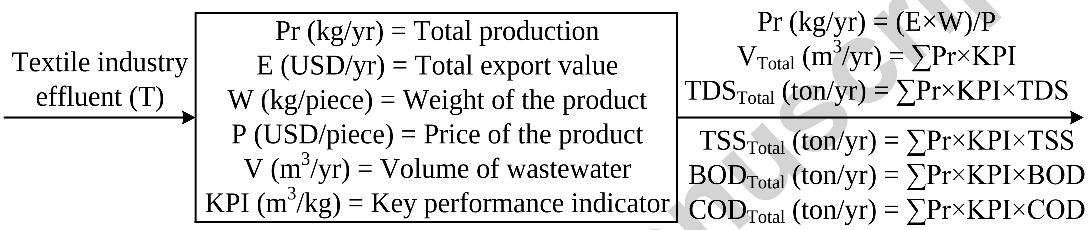


Figure 1: Components of major pollutants involved in various stages of a textile manufacturing industry (figure inspired from references (Arumai Dhas, 2008, Yusuff and Sonibare, 2004, Khan et al., 2006, Nabil et al., 2017)).



(a)



(b)

Figure 2: Flow charts to calculate textile wastewater volume and pollution load. (a) Overall flow diagram of the methodology, (b) Material balance approach.

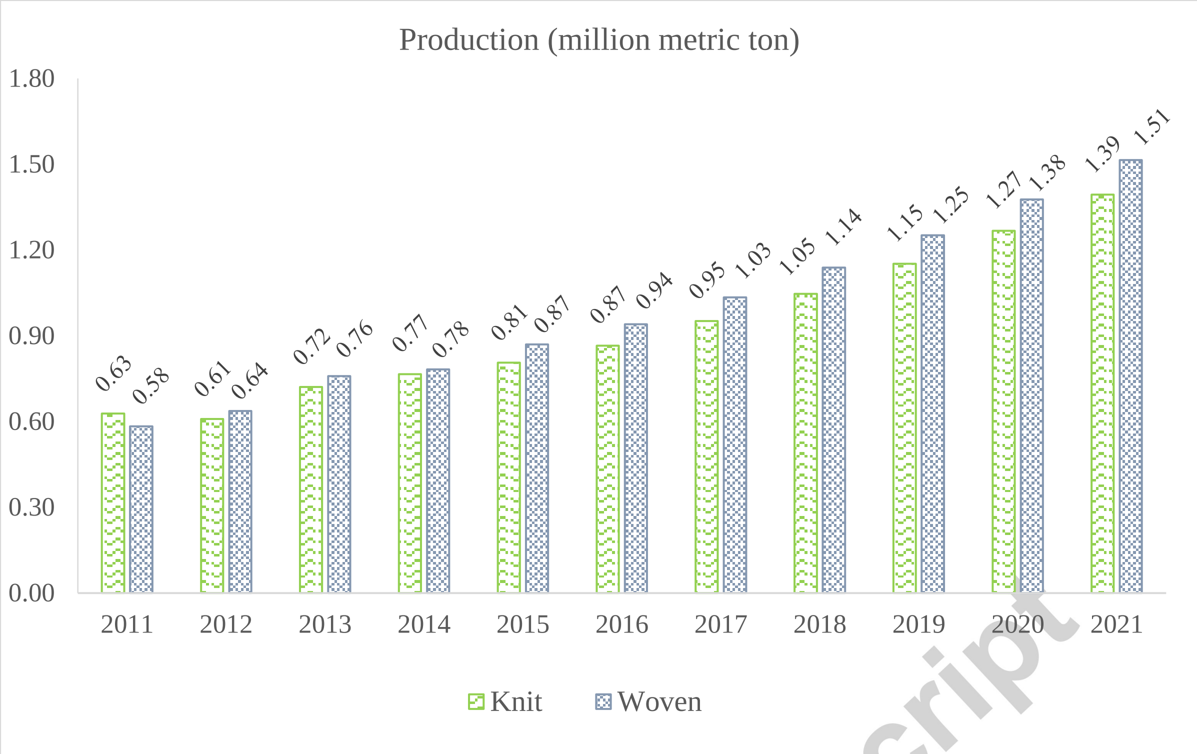


Figure 3: Trend analysis of annual textile production in Bangladesh (2011-2021).

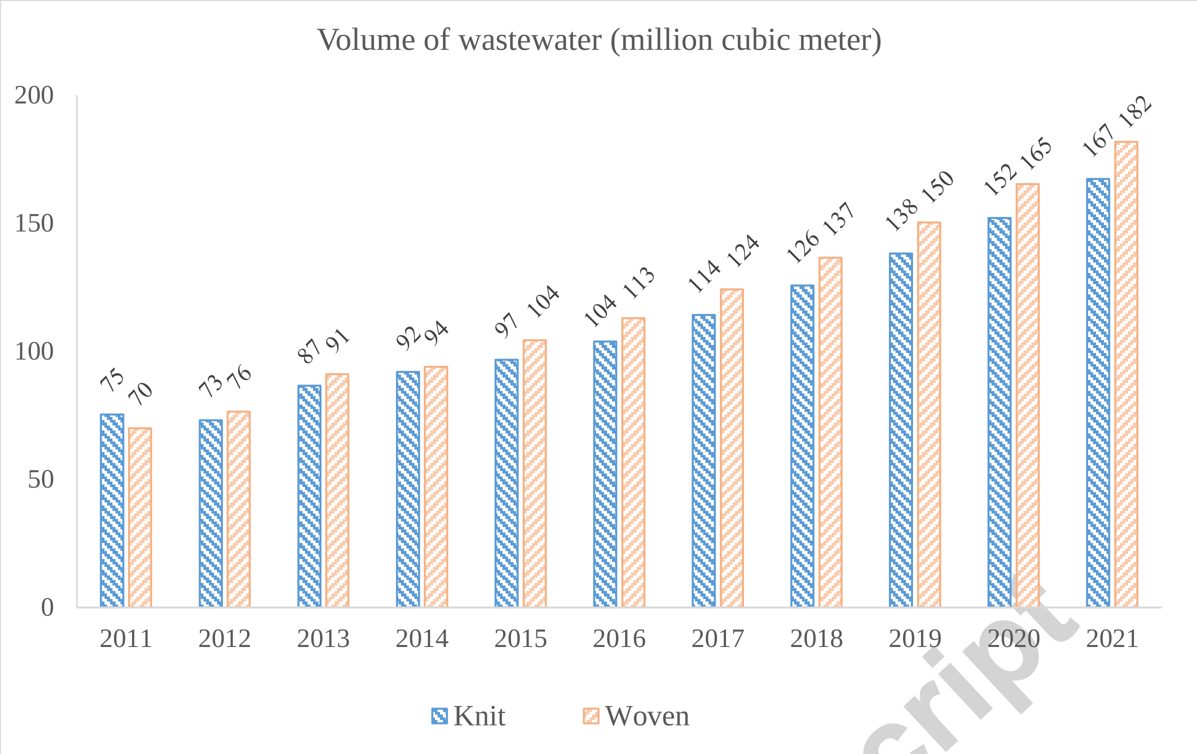


Figure 4: Yearly wastewater volume produced by textile industries using conventional dyeing technology.

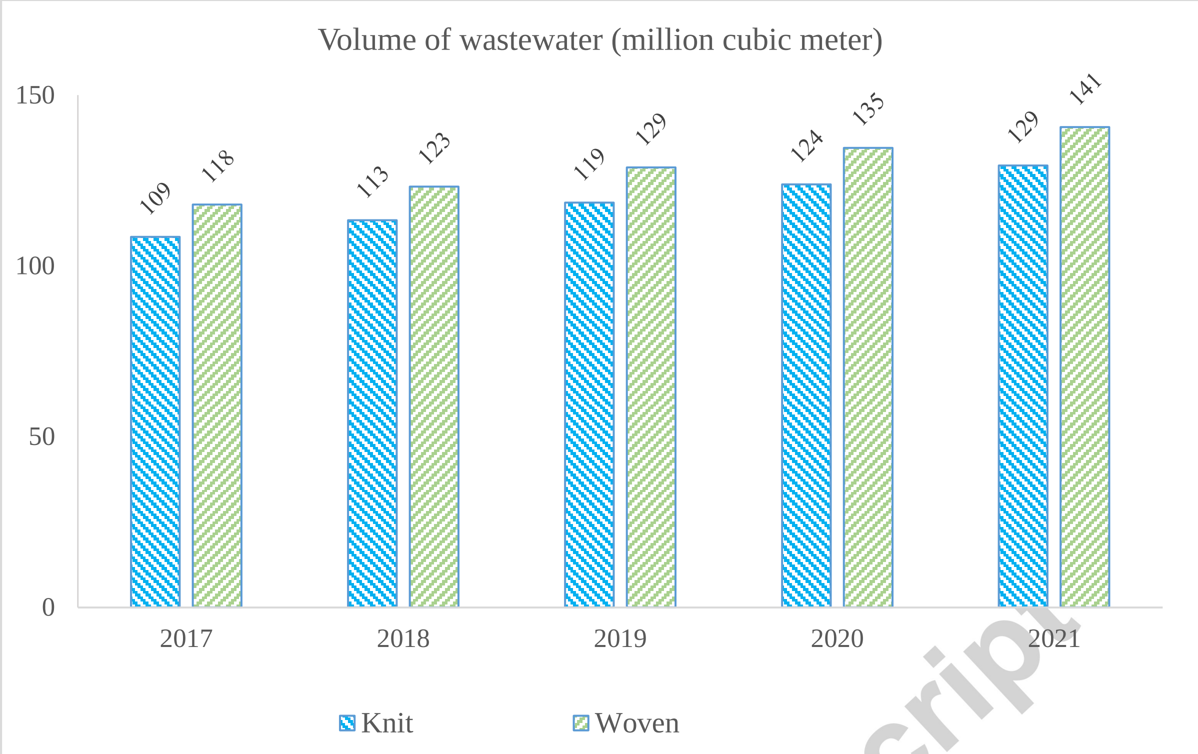
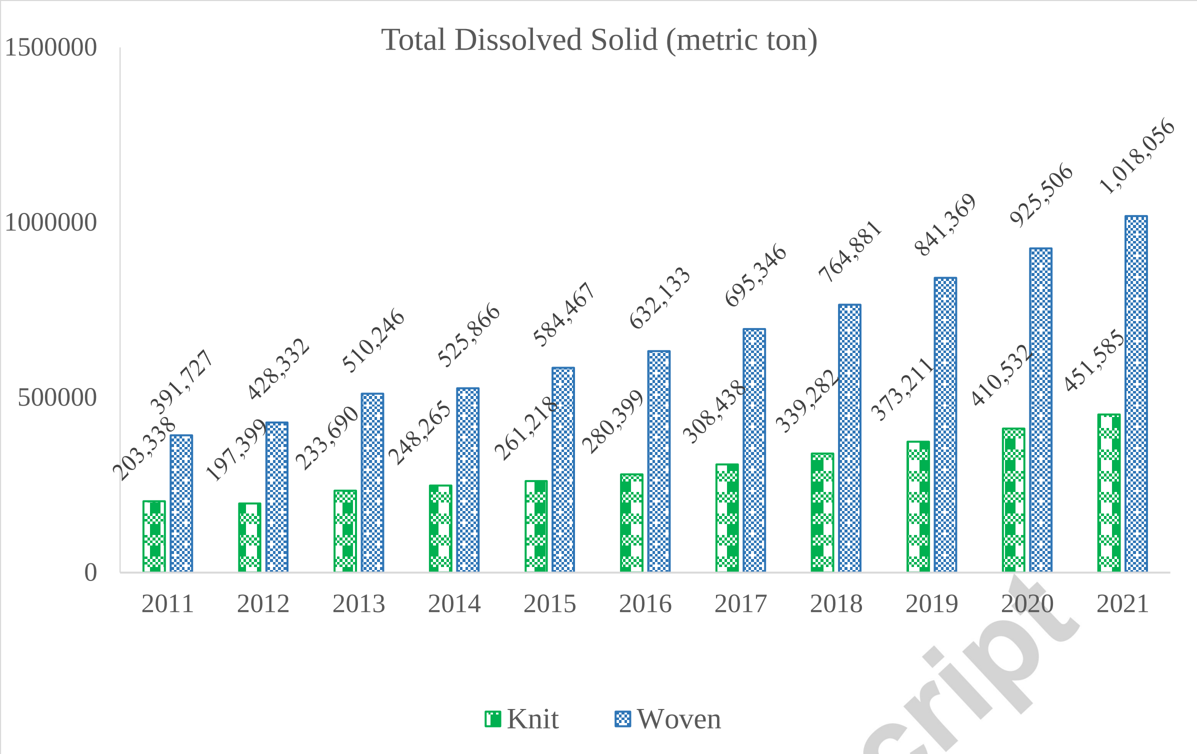
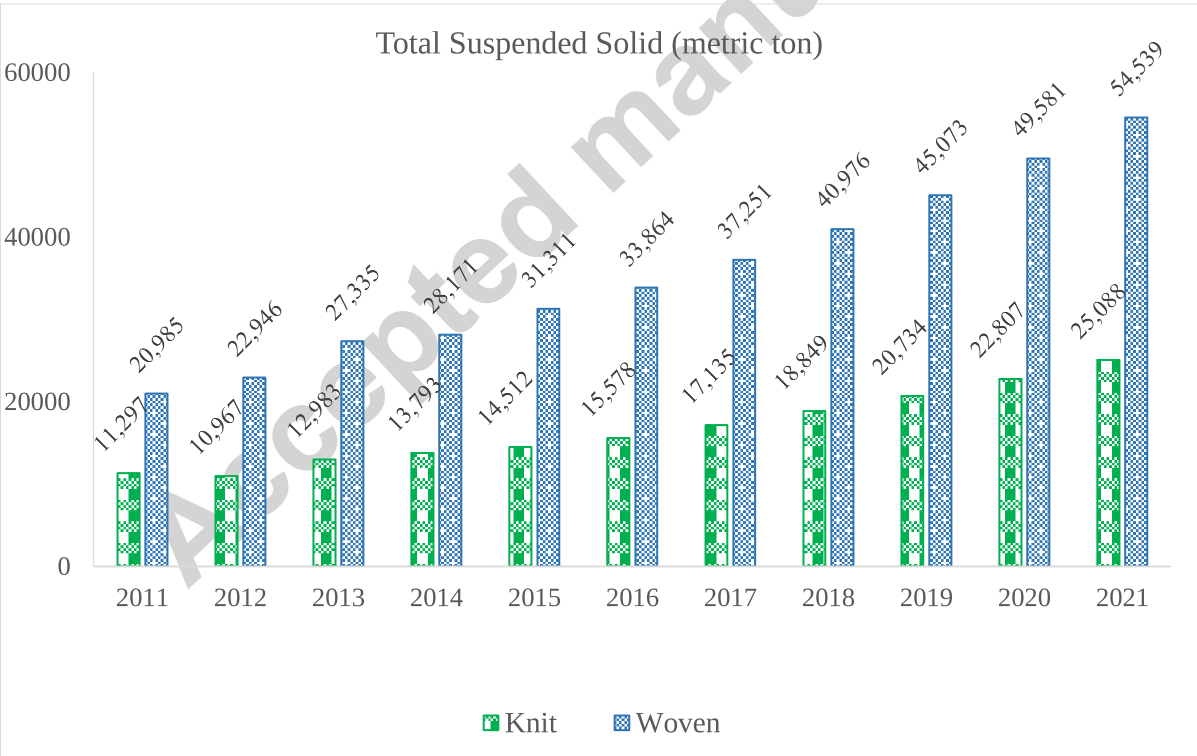


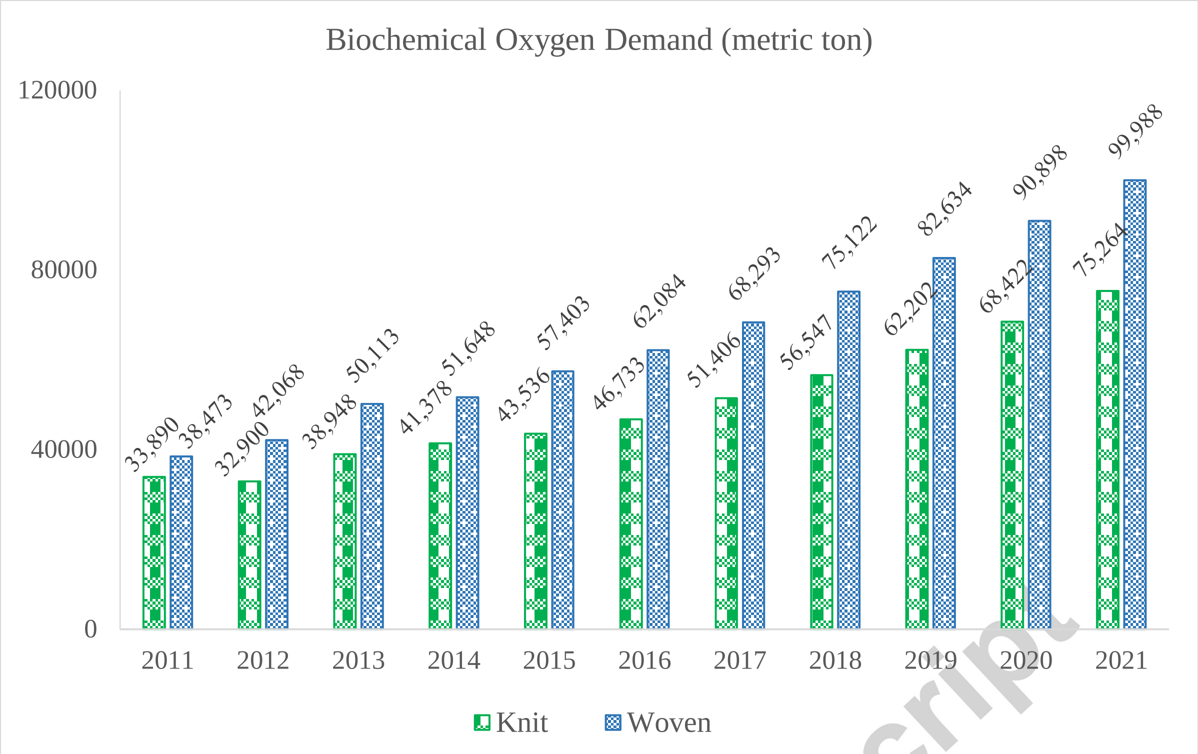
Figure 5: Projected wastewater volume generated by textile dyeing industries for improved KPI (year 2017-2021); assuming textile dyeing industries will gradually adopt improved technologies and cleaner production options.


Total Dissolved Solid (metric ton)
1500000
1000000
500000
0
203,338
391,727
197,399
428,332
233,690
510,246
248,265
525,866
261,218
584,467
280,399
632,133
308,438
695,346
339,282
764,881
373,211
841,369
410,532
925,506
451,585
1,018,056
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Knit
Woven

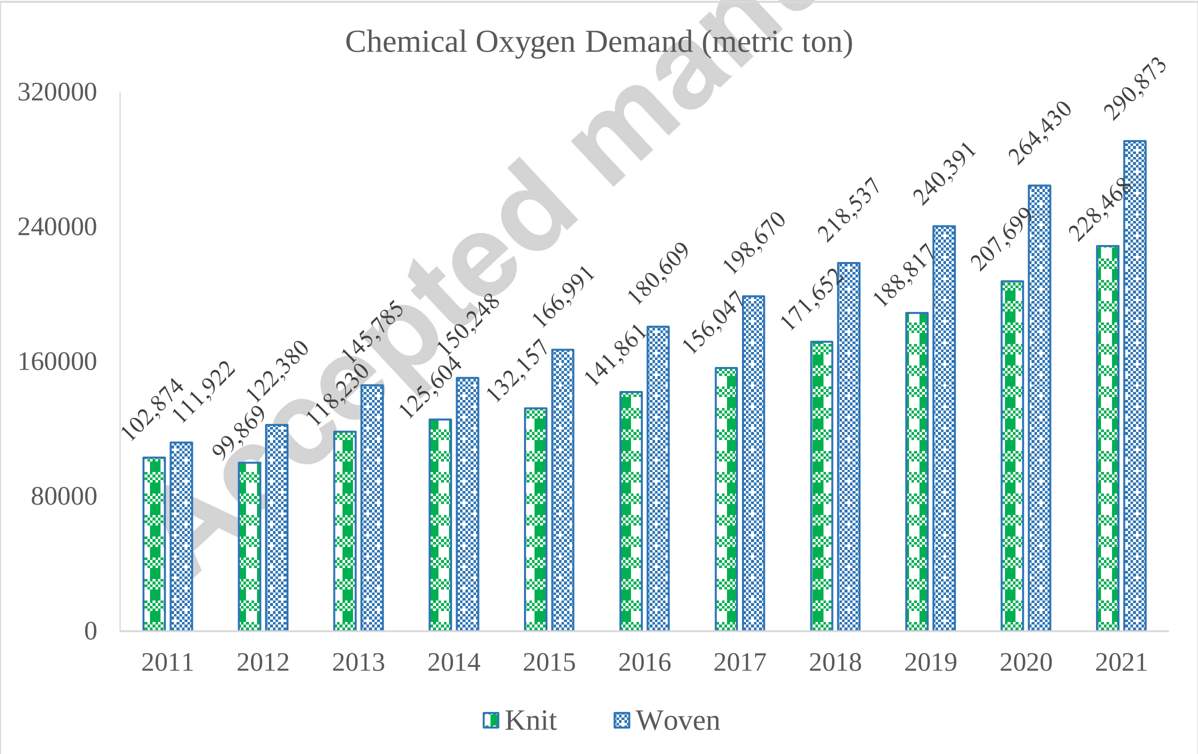
(a)


Total Suspended Solid (metric ton)
60000
40000
20000
0
11,297
20,985
10,967
22,946
12,983
27,335
13,793
28,171
14,512
31,311
15,578
33,864
17,135
37,251
18,849
40,976
20,734
45,073
22,807
49,581
25,088
54,539
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Knit
Woven

(b)

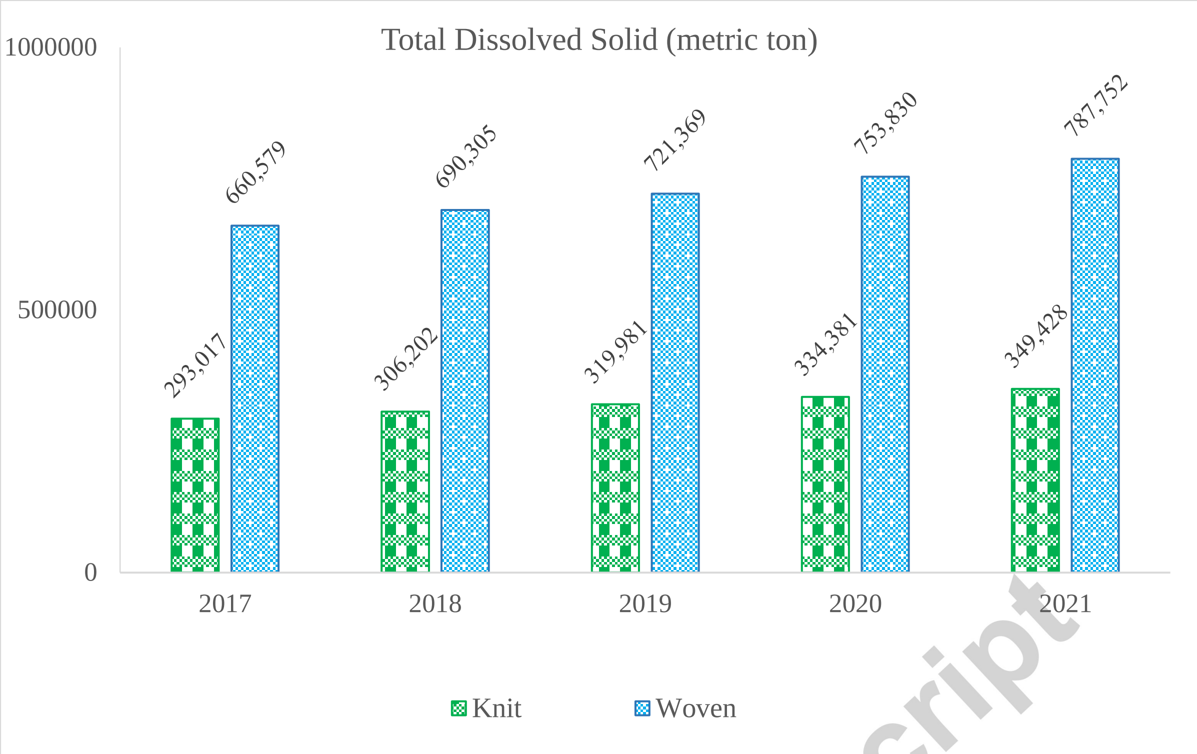


(c)

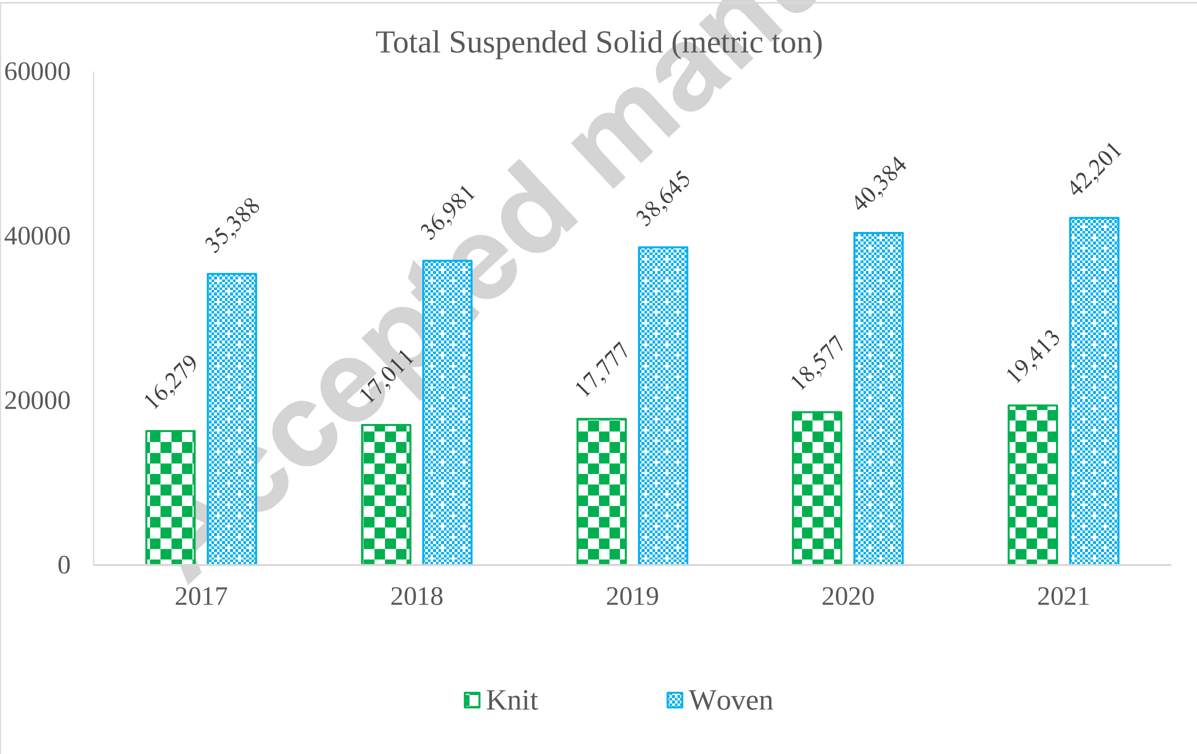


(d)

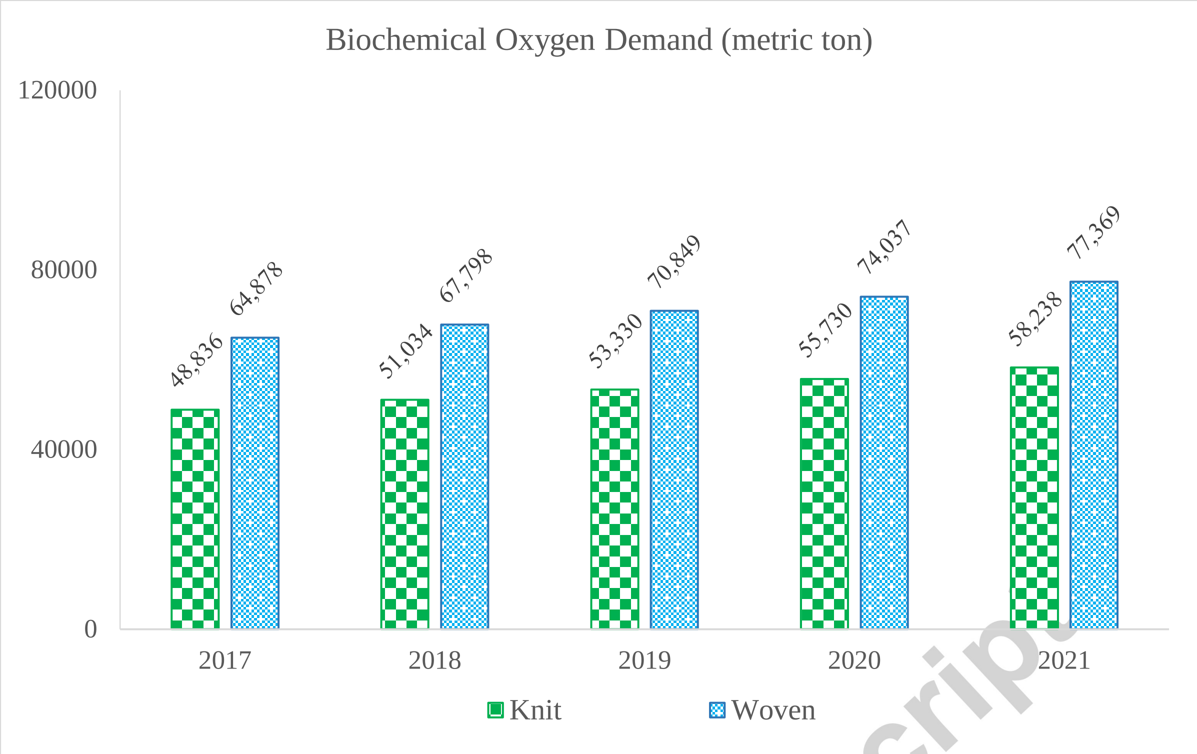
Figure 6: Annual pollution loads caused by textile industries following conventional practice; (a) TDS, (b) TSS, (c) BOD, (d) COD.


Total Dissolved Solid (metric ton)
1000000
500000
0
293,017
660,579
306,202
690,305
319,981
721,369
334,381
753,830
349,428
787,752
2017
2018
2019
2020
2021
Knit
Woven

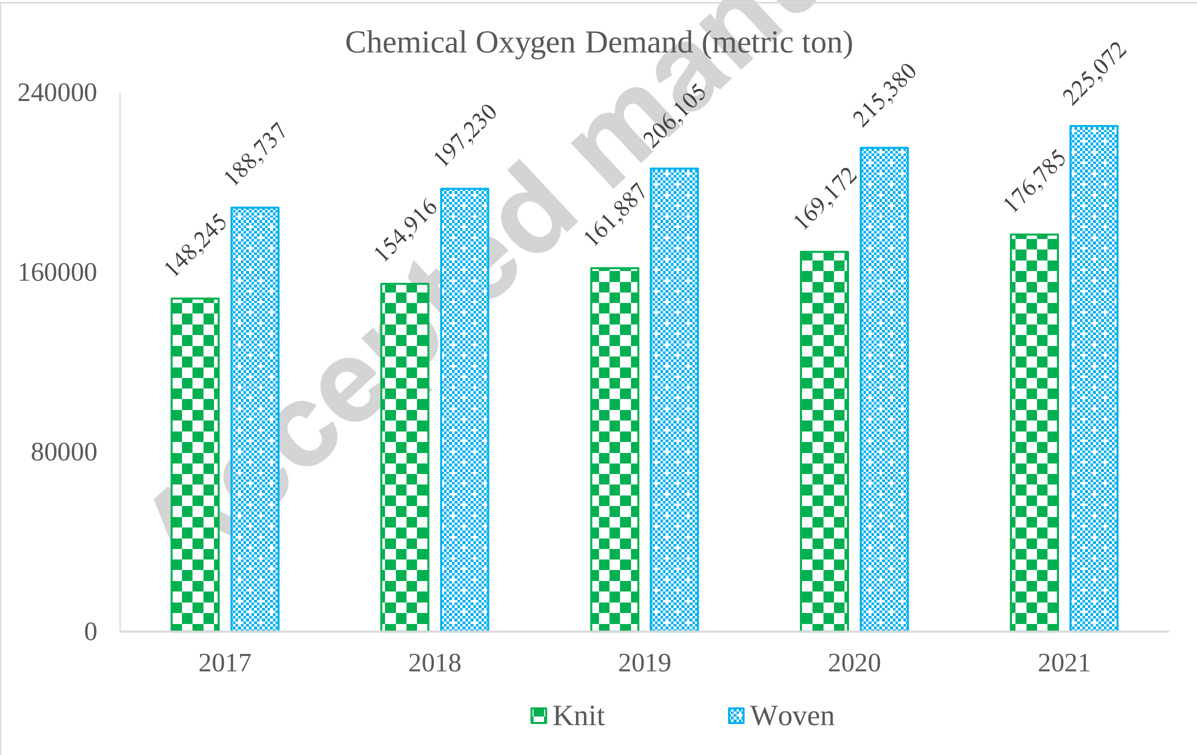
(a)


Total Suspended Solid (metric ton)
60000
40000
20000
0
16,279
35,388
17,011
36,981
17,777
38,645
18,577
40,384
19,413
42,201
2017
2018
2019
2020
2021
Knit
Woven

(b)



(c)



(d)

Figure 7: Annual pollution loads caused by textile industries after adopting improved practices; (a) TDS, (b) TSS, (c) BOD, (d) COD.

List of Tables

Table 1: RMG sector export statistics of Bangladesh (Bangladesh Garment Manufacturers and Exporters Association, 2017a).

Year	Export of RMG (million USD)	Percentage increase in export of RMG	Total export of BD (million USD)	Percentage of RMG's to total export
2006-07	9211.23	-	12177.86	75.64
2007-08	10699.80	16.16	14110.80	75.83
2008-09	12347.77	15.40	15565.19	79.33
2009-10	12496.72	1.20	16204.65	77.12
2010-11	17914.46	43.35	22924.38	78.15
2011-12	19089.73	6.56	24301.90	78.55
2012-13	21515.73	12.71	27027.36	79.61
2013-14	24491.88	13.83	30186.62	81.13
2014-15	25491.40	4.08	31208.94	81.68
2015-16	28094.16	10.21	34257.18	82.01

Table 2: Typical values of major pollution load of textile industries, DoE standards and BSR standards for wastewater discharge into inland surface water bodies (Business for Social Responsibility, 2010, Department of Environment, 2008, Khan et al., 2011).

Parameter	Knit dyeing industries	Woven dyeing industries	DoE standards (maximum allowable limit)	BSR standards (maximum allowable limit)
pH	6-11	8-10	6-9	6-9
Total dissolved solid (TDS)	2000-3000 ppm	5000-6000 ppm	≤ 2100 ppm	-
Total suspended solid (TSS)	50-166 ppm	200-300 ppm	≤ 150 ppm	≤ 30 ppm
Biochemical oxygen demand (BOD)	350-550 ppm	500-600 ppm	≤ 50 ppm	≤ 30 ppm
Chemical oxygen demand (COD)	1200-1400 ppm	1500-1750 ppm	≤ 200 ppm	≤ 200 ppm

Table 3: Textile product price and weight analysis.

Product Type	Price per piece (USD)	Weight per piece (gm)
Shirt	3.5 – 5	200 – 300
T-shirt	3 – 5	200 – 300
Hoodies & Sweatshirt	6 – 8	400 – 500
Sweater	4 – 5	350 – 500
Denim	6 – 8	400 – 500
Trouser	5 – 8	250 – 300
Blouses and other basic women wear	5 - 6	200 - 400

Table 4: Water KPI analysis for textile industries.

Factory (Location)	Average production (ton/month)	Average production water consumption (m^3/month)	KPI (L/kg)
Factory A (BSCIC, Narayanganj)	425	29,325	69
Factory B (Ashulia, Dhaka)	190	20,800	110
Factory C (Fatullah, Narayanganj)	510	63,750	125
Factory D (Sonargaon, Narayanganj)	320	42,880	134
Factory E (BSCIC,Tongi)	270	36,450	135
Factory F (Maona, Gazipur)	335	45,895	137
Factory G (Bhulta, Narayanganj)	265	37,100	140
Factory H (Kashimpur, Gazipur)	750	106,500	142
Factory I (Kashimpur, Gazipur)	240	35,280	147

Table 5: Textile pollution load and considerations to calculate wastewater output.

Type of industry	TSS (ppm)	TDS (ppm)	BOD (ppm)	COD (ppm)
Knit dyeing	150	2700	450	1366
Woven dyeing	300	5600	550	1600
Price per piece of product			5 USD	
Weight per piece of product			300 g	
Percentage of internal consumption and rejection			5	

Table 6: Comparison of present and future annual wastewater impacts of textile dyeing industries of Bangladesh.

Parameter	Year		
	2016	2021 (Conventional practice)	2021 (Improved practice)
Production of RMG (million metric ton)	1.8	2.9 (projected)	
Volume (million cubic meter)	217	349	270
TSS (metric ton)	49442	79627	61614
TDS (metric ton)	912532	1469641	1137180
BOD (metric ton)	108817	175252	135607
COD (metric ton)	322470	519342	401857

Highlights

- A material balance approach is developed to characterize pollution impacts associated with BD textile dyeing industries.
- In 2016, textile industries in Bangladesh produced about 1.80 million metric tons of fabrics.
- In 2016, textile industries in Bangladesh generated around 217 million m^3 of wastewater.
- In 2021, textile industries in Bangladesh will produce about 2.91 million metric tons of fabrics.
- In 2021, around 349 million m^3 of wastewater will be produced using conventional dyeing practices.